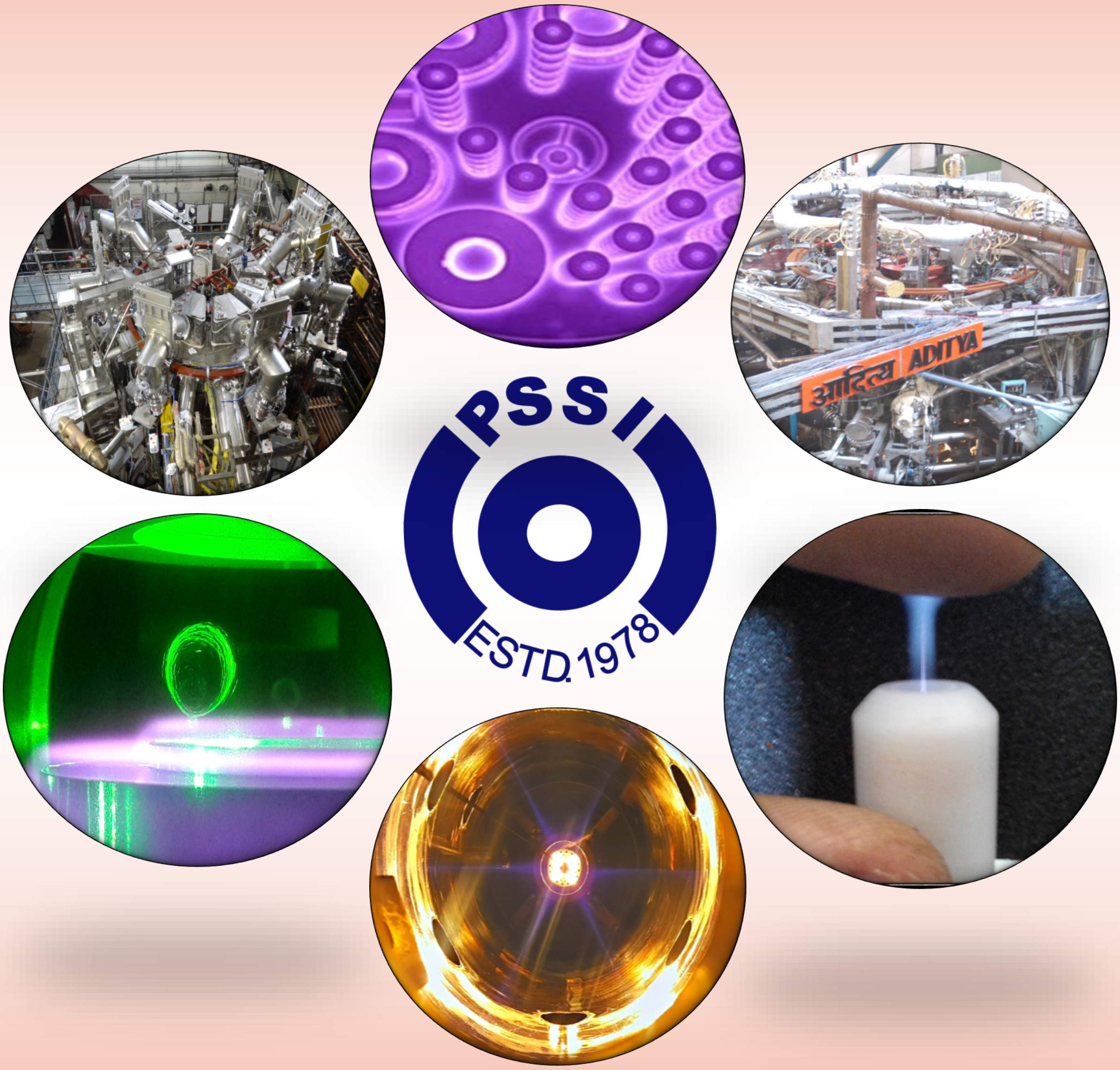
PLASMA-2017

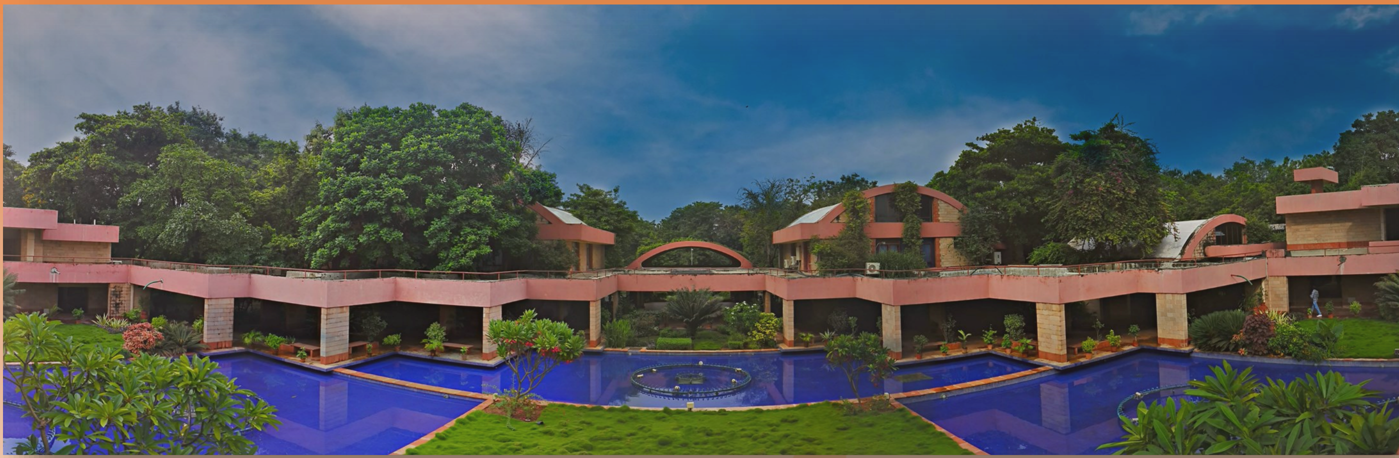
32nd National Symposium on Plasma Science & Technology

7-10 November, 2017

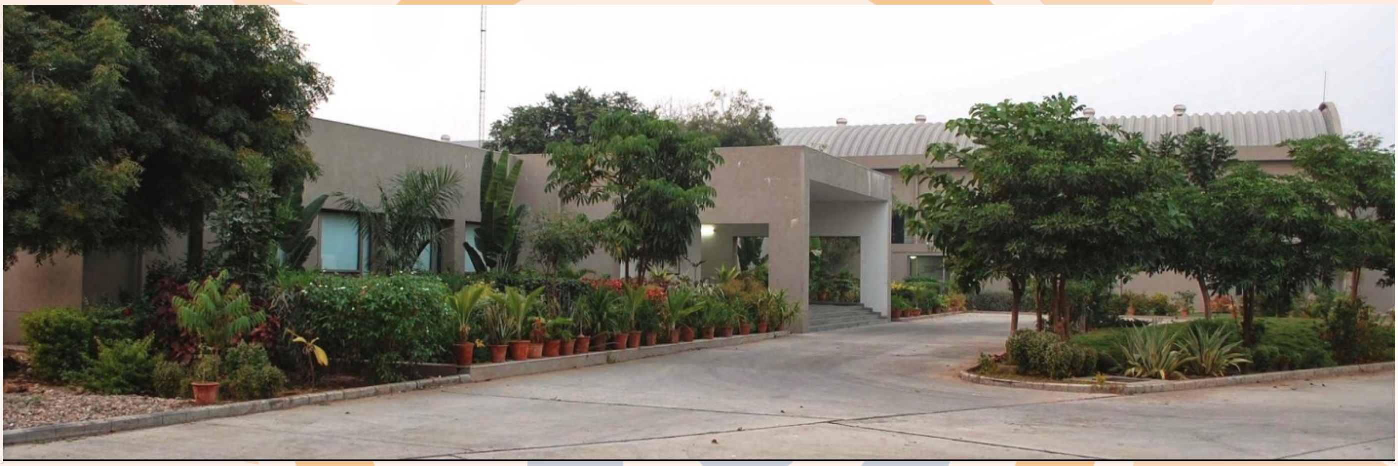


Book Of Abstracts

Institute for Plasma Research, Gandhinagar (Gujarat)



Institute for Plasma Research, Gandhinagar



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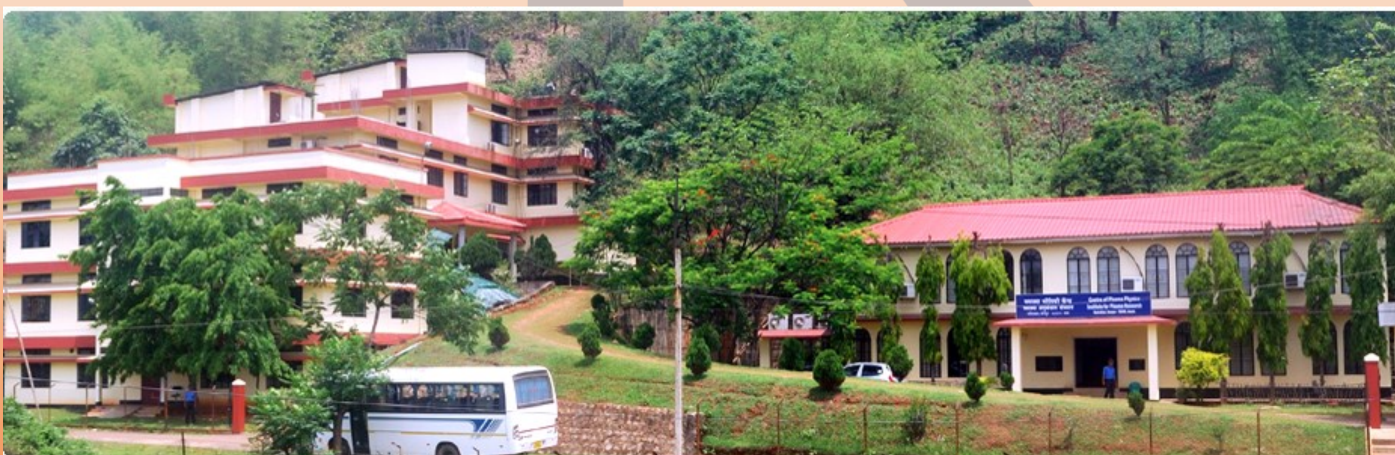

Center of Plasma Physics (CPP-IPR) Guwahati

Plasma-2017

32nd National Symposium on Plasma Science & Technology
(Plasma for Societal Benefits)

07-10 November 2017

Book of Abstracts

Compiled & Edited by

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Organized by

Plasma Science Society of India
Board of Research in Nuclear Sciences
&
Institute for Plasma Research, Gandhinagar, Gujarat, India

32nd National Symposium on Plasma Science & Technology on Plasma for Societal Benefits

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From The Editors Desk

Dear Friends,

On behalf of the Editorial Board, Local Organizing Committee, PLASMA 2017, we are glad to inform that 32nd National Conference on Plasma Science and Technology is being organized by Plasma Science Society of India (PSSI) and Institute for Plasma Research (IPR) from November 7-10, 2017 at IPR, Gandhinagar. It gives us immense pleasure in writing this message on this occasion.

The theme of this year's conference is "*Plasma for Societal Benefits*". The main objective is to improve the knowledge base and skills through interactive sessions, for addressing issues of concern to our society at this forum over immediate time scales and over times scales of future energy requirements. The scientific content of this conference focuses on how to incorporate the knowledge, expertise and skills developed over diversified spread of plasma science and technology viz., Industrial Applications, Agriculture, Medical Science, Material Development, Space and Defense Applications and in Energy Domains, especially of Fusion Energy. This is an opportunity for young researchers from the field of science and technology to have a good overview of the issues related to this subject.

Delegates attending this year conference will definitely feel the absence of Prof P. K. Kaw, founder director of IPR. His sudden demise is a great loss, not only to the plasma community in India but also to the community worldwide. Young researchers can take a leaf out of his contributions and focus on realizing his dreams for the country.

This year conference will see lectures delivered by the esteemed faculties on variety of fields where plasma science has ventured, covering almost all aspects of plasma science and technology. Besides this, large time is allocated for the poster session, which we believe offers a better platform for enthusiastic students, young research scientists and academicians for serious interactions. We extend our warmest thanks to all authors for their keen interest, enthusiasm and timely submission of abstracts. This year conference will have more than 450 abstracts and probably equal number of delegates.

As editors of abstract book for Plasma 2017, we anticipate that this conference will prove to be of immense value and will be extremely useful to expand the scope of application domain of plasma science and technology. This forum of collection of thoughts will also offer a window for new perspectives and directions in the area of societal benefits of plasma science and technology.

Lastly, we would like to wish all delegates an interactive, knowledge sharing and harmonious PLASMA - 2017.

Foreword

Welcome to the 32nd National Symposium on Plasma Science & Technology which is to be hosted by Institute for Plasma Research, during 07-10 November 2017 at Gandhinagar, Gujarat. The theme for this symposium is *"Plasma for Societal Benefits"*, a topic that is quickly gaining traction in both academic and industrial discussions because of the relevant plasma based solutions to societal issues such as energy, agriculture, healthcare, waste management as well as industry along with nano-technology. This annual event will provide a forum in which the whole plasma community will learn, interact and discuss about their works which should lead to potential research collaborations at various laboratories.

Plasma based technologies have lot of potential to give to the society and thus helping the development of the country. The time has come for PSSI to lead from the front in taking the plasma science to all fronts of country's education from schools to colleges and beyond. We believe that the added advantage of IPR, with exclusive facilities, hosting the symposium will help many young students and researchers to take up the challenge to every part of the country.

The success of this symposium depends completely on the effort, talent, and energy of researchers in the field of Plasma Science and Technology who have written and submitted abstracts for both oral and poster presentations on a variety of topics. The program will be enlightened by Invited Talks also. I thank all those participants sincerely. Praise is also deserved for the Scientific Program Committee members and many others who have invested significant time in putting a commendable program for this symposium.

I would like to encourage each of our members to increase your involvement in PSSI to share your knowledge, skills, and expertise with our community, so that we can all benefit personally and professionally.

My best wishes for the grand success of Plasma 2017.

Prof. Prabal Kumar Chattopadhyay
President, Plasma Science Society of India.

Institute for Plasma Research,
Gandhinagar-382 428, India

Message

I am happy to know that the Plasma Science Society of India is organizing its 32^{nd} National Symposium on Plasma Science and Technology in collaboration with the Institute for Plasma Research during 7- 10 November, 2017 at IPR. This year's conference has special significance since it focuses on applications of Plasma Technology for the benefit of society.

It is well known that plasma science & technology has made major advances over the past few decades. The worldwide effort towards Controlled Thermonuclear Fusion, which has found a focus in the International Thermonuclear Experimental Reactor (ITER) project, is making good progress. There are major technological contributions being made by ITER-India in this project, with Indian deliverables being amongst the first to reach the project Site.

In parallel with the fusion programme is the ever-growing list of plasma applications in industry, agriculture, textile processing, waste disposal, aerospace technologies, plasma stealth systems, plasma thrusters, plasma antennas and so on. These are major challenges for the plasma science community in India. Rapid development & deployment of these technologies in India over the next few years requires a focused and broad-based effort similar to that for the fusion programme.

I would hope that participation in this Symposium would motivate young researchers from different branches of science and engineering to enter these challenging fields.

Lastly, on behalf of IPR, I thank the organizers for their sincere efforts for organizing this symposium and BRNS for its financial support. I extend my best wishes to all the participants and hope that the Symposium will achieve its desired objectives.

Shashank Chaturvedi

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PLASMA – 2017

Conference Schedule (07-10 November, 2017)

	Time	Time	Hrs	Time	Time	Hrs	Time	Time	Hrs	Time	Time	Hrs	Time
	8:00-9:00	9:00-10:15	1h 15m	10:15-10:45	10:45-13:00	2hr 15m	13:00-14:00	14:00-17:00	3 hrs	16:30-17:00	17:00-19:00	2 Hrs	19:30-21:00
DAY-01 07-Nov-2017	registration	**Inaugural Function**	Min	High Tea	**Session - 1 (BP)**	Min	Lunch	**Poster Session – 1 (BP +PU+PP)**		Tea	**Buti Award Presentations**		**Dinner**
		Inauguration	30		S1-I-01 - Invited	30					BYSA-01	20	
		Keynote address	45		S1-I-02 - Invited	30					BYSA-02	20	
					S1-O-01 - Oral	12					BYSA-03	20	
					S1-O-02 - Oral	12					BYSA-04	20	
					S1-O-03 - Oral	12					BYSA-05	20	
					S1-O-04 - Oral	12					BYSA-06	20	
					S1-O-05 - Oral	12							
					D1/S1-Basic Plasma			**D1 / P1 (BP + PU + PP)**					

	09:00-11:15	2h 15m	11:15-11:30	11:30-13:45		13:40-14:45	14:45-17:45	16:30-17:00	17:45-18:30	18:30-19:30	20:00-21:00
DAY-02 08-Nov-2017	**Session - 2 (NF)**	Min	Tea	**Session - 3 (PP + IP)**	Min	Lunch	**Poster Session – 2 (NF)**	Tea	**Guzdar Award Presentation**	**PSSI-GBM**	**Dinner**
	S2-I-01 - Invited	30		S3-I-01 - Invited	30						
	S2-I-02 - Invited	30		S3-I-02 - Invited	30						
	S2-O-01 - Oral	12		S3-I-03 - Invited	30						
	S2-O-02 - Oral	12		S3-O-01 - Oral	12						
	S2-O-03 - Oral	12		S3-O-02 - Oral	12						
	S2-O-04 - Oral	12		S3-O-03 - Oral	12						
	S2-O-05 - Oral	12			12						
	D2 / S2- Nuclear Fusion						**D2 / P2 (NF)**				

DAY-03 09-Nov-2017	09:00-11:15	2h 15m	11:15-11:30	11:30-13:45		13:40-14:45	14:45-17:45	16:30-17:00	17:45-19:30	1h 30m	19:30-21:30
	Session - 4 (SA)	Min	Tea	**Session - 5 (LP + CM)**	Min	Lunch	**Poster Session – 3 (SA + CM + EP)**	Tea	**Session - 6 (EP + PU)**	Min	
	S4-I-01 - Invited	30		S5-I-01 - Invited	30				S6-I-01 - Invited	30	Cultural programme & Director's Dinner
	S4-I-02 - Invited	30		S5-I-02 - Invited	30				S6-I-02 - Invited	30	
	S4-O-01 - Oral	12		S5-O-01 - Oral	12				S6-O-01 - Oral	30	
	S4-O-02 - Oral	12		S5-O-02 - Oral	12				S6-O-02 - Oral	12	
	S4-O-03 - Oral	12		S5-O-03 - Oral	12				S6-O-03 - Oral	12	
	S4-O-04 - Oral	12		S5-O-04 - Oral	12				S6-O-04 - Oral	12	
	S4-O-05 - Oral	12		S5-O-05 - Oral	12						
	D3 / S4- Space Plasma			**D3 / S5 – Laser Plasma + Computer Modeling**			**D3 / P3 (SA+CM+EP)**		**D3 / S6- Exotic Plasma + Pulsed Power**		

DAY-04 10-Nov-2017	09:00-12:00	11:15-11:30	12:00-13:30	1 Hr 30 min	13:30-14:30	14:30-15:30
	Poster Session – 4 (IP + LP + PD)	TEA	**Session - 7 (PD)**		LUNCH	**Concluding Session & Award Presentation**
			S7-I-01 - Invited	30		
			S7-I-02 - Invited	30		
			S7-O-01 - Oral	12		
			S7-O-01 - Oral	12		
			S7-O-03 - Oral	12		
			S7-O-04 - Oral	12		
	D4 / P4 – Industrial Plasma + Laser Plasma + Plasma Diagnostics		**D4 / S 7 – Plasma Diagnostics**			

DAY 1 : 07-Nov-2017							
REG	08:00	09:00	Registration				
INAUG	09:00	09:30	Inaugural Function				
KN	09:30	10:15	KN-01	Address by PSSI President			
TEA	10:15	10:45	High Tea				
D1/S-01	**10:45**	**13:00**	**SESSION – 1 : BASIC PLASMA (BP)**			Email	Abs#
S1-I-01	10:45	11:15	Invited - 1	25+5	Dr. Shantanu Karkari, IPR Gandhinagar	skarkari@ipr.res.in	
S1-I-02	11:15	11:45	Invited - 2	25+5	Dr. Kushal Shah, IISER, Bophal	kushals@iiserb.ac.in	
S1-O-01	11:45	12:00	Oral – 1	10+2	Roshan Chalise, Tribhuvan University Nepal	[BP-08; Pg. #10]	40
S1-O-02	12:00	12:15	Oral – 2	10+2	Tania Ghosh, IISER Kolkata	[BP-48; Pg. #56]	91
S1-O-03	12:15	12:30	Oral – 3	10+2	Pallavi Trivedi, IPR Gandhinagar	[BP-22; Pg. #26]	154
S1-O-04	12:30	12:45	Oral – 4	10+2	Sanghamitro Chatterjee, IIT Kanpur	[BP-75; Pg. #86]	424
S1-O-05	12:45	13:00	Oral – 5	10+2	Sarvesh Kumar, IUAC New Delhi	[BP-86; Pg. #99]	480
LUN	13:00	14:00	LUNCH				
D1 / P-01	14:00	17:00	**POSTER – 1 (BP +PU+PP)**				
BYSA	**17:00**	**19:00**	**Buti Young Scientist Award Presentations**				
BYSA-01	17:00	17:20	Buti Award	15+5	Ajay Lotekar, IIG [72/CM-06/BUTI]	Pg. # 117	72
BYSA-02	17:20	17:40	Buti Award	15+5	Niraj Kumar, CEERI [365/PU-04/BUTI]	Pg. # 486	365
BYSA-03	17:40	18:00	Buti Award	15+5	A. Mukherjee, IPR [207/BP-27/BUTI]	Pg. # 32	207
BYSA-04	18:00	18:20	Buti Award	15+5	Harish Charan, IPR [351/EP-12/BUTI]	Pg. # 155	351
BYSA-05	18:20	18:40	Buti Award	15+5	Bivash Dolai, GGCU [26/BP-05/BUTI]	Pg. # 7	26
BYSA-06	18:40	19:00	Buti Award	15+5	Deep Kumar Kuri, Tezpur University [89/LP-10/BUTI]	Pg. # 422	89

DIN	19:30	20:30	DINNER				
DAY 2 : 08-Nov-2017							
D2 / S-02	**09:00**	**11:15**	**SESSION – 2 : NUCLEAR FUSION (NF)**				
S2-I-01	09:00	09:30	Invited - 3	25+5	Dr. S. R. Mohanty, CPP-IPR, Guwahati	smruti@cppipr.res.in	
S2-I-02	09:30	10:00	Invited - 4	25+5	Dr. Joydeep Ghosh, IPR Gandhinagar	jghosh@ipr.res.in	
S2-O-01	10:00	10:15	Oral – 6	10+2	Aroh Srivastava, IPR Gandhinagar	[NF-29; Pg. #229]	62
S2-O-02	10:15	10:30	Oral – 7	10+2	P. V. Subhash, ITER-India	[NF-03; Pg. #197]	136
S2-O-03	10:30	10:45	Oral – 8	10+2	Bibhu Prasad Sahoo, IPR, Gandhinagar	[NF-11; Pg. #208]	318
S2-O-04	10:45	11:00	Oral – 9	10+2	Raghuraj Singh, ITER-India	[NF-67; Pg. #278]	330
S2-O-05	11:00	11:15	Oral – 10	10+2	Harshita Raj, IPR Gandhinagar	[NF-73; Pg. #287]	342
TEA	11:15	11:30	TEA				
D2 / S-03	**11:30**	**13:45**	**SESSION – 3 : INDUSTRIAL PLASMA/ PLASMA PROCESSING (IP+PP)**				
S3-I-01	11:30	12:00	Invited - 5	25+5	Dr. Priyabrata Banerjee, CMERI, Durgapur	priyabratabanerjee16@gmail.com	
S3-I-02	12:00	12:30	Invited - 6	25+5	Dr. T.K. Thiyagarajan, BARC Mumbai	tktrajan@gmail.com	
S3-O-01	12:30	13:00	Invited - 7	25+5	Dr. V. L. Mathe. University of Pune	vlmathe@physics.unipune.ac.in	
S3-O-03	13:00	13:15	Oral – 11	10+2	Divya Deepak G, Mody University of S&T	[PP-01; Pg. #465]	08
S3-O-04	13:15	13:30	Oral – 12	10+2	Nisha Chandwani, IPR Gandhinagar	[IP-04; Pg. #179]	160
S3-O-05	13:30	13:45	Oral – 13	10+2	Krishna Enni, IISU, Trivandrum	[PP-10; Pg. #475]	348
LUN	13:45	14:45	LUNCH				

D2 / PS-02	14:45	17:45	**POSTER SESSION – 02** (NF)
GUZDAR	17:45	18:30	GUZDAR AWARD presentation

GBM	18:30	19:30	**PSSI GBM**
DIN	20:00		DINNER

DAY 3 : 09-Nov-2017							
D3 / S-04	**09:00**	**11:15**	**SESSION – 4 : SPACE PLASMA (SA)**				
S4-I-01	09:00	09:30	Invited - 8	25+5	Dr. Kowsik Bodi, IIT Bombay	kbodi@aero.iitb.ac.in	
S4-I-02	09:30	10:00	Invited - 9	25+5	Dr. Durgesh Tripathi, IUCAA, Pune	durgesh@iucaa.in	
S4-O-01	10:00	10:15	Oral - 14	10+2	Ajeet Kumar Maurya, BHU Varanasi	[SA-07; Pg. #507]	39
S4-O-02	10:15	10:30	Oral - 15	10+2	Suktisama Ghosh, IIGM Mumbai	[SA-39; Pg. #543]	180
S4-O-03	10:30	10:45	Oral - 16	10+2	Pralay Karmakar, Tezpur University	[SA-51; Pg. #555]	268
S4-O-04	10:45	11:00	Oral - 17	10+2	Govind Nampoothiri, ISRO, Trivandrum	[SA-14; Pg. #514]	333
S4-O-05	10:45	11:00	Oral - 18	10+2	Ramit Bhattaacharyya, PRL, Ahmedabad	[SA-54; Pg. #558]	370
TEA	11:15	11:30	TEA				
D3 / S-05	**11:30**	**13:45**	**SESSION – 5 : LASER PLASMA + COMPUTER MODELING (LP + CM)**				
S5-I-01	11:30	12:00	Invited - 10	25+5	Dr. A. P. Mishra, V B U, Shantiniketan	apmisra@visva-bharati.ac.in	
S5-I-02	12:00	12:30	Invited - 11	25+5	Dr. Shreekant Barnwal, RRCAT, Indore	sbarnwal@rrcat.gov.in	
S5-O-01	12:30	12:45	Oral - 19	10+2	Raghwendra Kumar, BARC Mumbai	[CM-08; Pg. #119]	108
S5-O-02	12:45	13:00	Oral - 20	10+2	Sowmiya K, Bharathiyar University	[CM-12; Pg. #123]	173
S5-O-03	13:00	13:15	Oral - 21	10+2	Parvathy Nancy, M G University, Kottayam	[LP-39; Pg. #453]	179
S5-O-04	13:15	13:30	Oral - 22	10+2	Ratan Kumar Bera, IPR Gandhinagar	[LP-21; Pg. #434]	217
S5-O-05	13:30	13:45	Oral - 23	10+2	Abdul Kalam S, University of Hyderabad	[LP-42; Pg. #458]	375
LUN	13:45	14:45	LUNCH				

D3 / PS-03	14:45	17:45	**POSTER SESSION – 03** (SA + CM + EP)				
D3 / S-06	**17:45**	**19:30**	**SESSION – 6 : EXOTIC PLASMA + PULSED POWER (EP+ PU)**				
S6-I-01	17:30	18:00	Invited - 12	25+5	Dr. Surendra Prasad, BHU Varanasi	prasads@bhu.ac.in	
S6-I-01	18:00	18:30	Invited - 13	25+5	Dr. Rohit Shukla, BARC Vishakapatanam	rshukla@gmail.com	
S6-O-01	18:30	18:45	Oral - 24	10+2	Manish Kumar Shukla, University of Delhi	[EP-15; Pg. #158]	83
S6-O-02	18:45	19:00	Oral - 25	10+2	Sandeep Kumar, IPR Gandhinagar	[EP-04; Pg. #146]	122
S6-O-03	19:00	19:15	Oral - 26	10+2	Jyotirmoy Pramanik, Kharagpur College	[EP-26; Pg. #173]	265
S6-O-03	19:15	19:30	Oral - 27	10+2	Udit Narayan Pal, CEERI Pilani	[PU-07; Pg. #491]	486
DIN	19:30	21:00	**CULTURAL PROGRAMME + DIRECTOR'S DINNER**				

DAY 4 : 10-Nov-2017							
D4 / PS-04	09:00	12:00	**POSTER SESSION – 04 (IP + LP + PD)**				
D4/S-07	12:00	13:30	**SESSION – 7 : PLASMA DIAGNOSTICS (PD)**				
S7-I-01	12:00	12:30	Invited - 14	25+5	Dr. Divya Oberoi, NCRA-TIFR, Pune	div@ncra.tifr.res.in	
S7-I-02	12:30	13:00	Invited - 15	25+5	Dr. Rajesh Srivastava, IIT Roorkie	rajsrfph@iitr.ac.in	
S7-O-01	13:00	13:15	Oral – 28	10+2	Bajra Mishra, KIIT Bhubaneswar	[PD-32; Pg. #388]	319
S7-O-01	13:15	13:30	Oral – 29	10+2	Suvendu Kumar Dash, Trident Academy, Bhubaneswar	[PD-37; Pg. #393]	328
S7-O-01	13:30	13:45	Oral – 30	10+2	Anuj Ram Baitha, IIT Kanpur	[BP-67; Pg. #77]	367
S7-O-01	13:45	14:00	Oral - 31	10+2	Suman Danani, ITER-India	[PD-46; Pg. #402]	439
LUN	13:30	14:30	LUNCH				
D4 / S-08	14:30	16:00	SESSION – 8 : CONCLUDING SESSION				
AWARDS	15:00	16:00	Distribution OF AWARDS and Concluding remarks				

KEYNOTE ADDRESS

Dr. Anil Bhardwaj, Director PRL

INVITED SPEAKERS

SL	SESSION	SPEAKER	AFFILIATION	E-MAIL	TITLE OF TALK
1	S1-BP	Shantanu Karkari	IPR	skarkari@ipr.res.in	Experiments To Investigate Plasma Sheaths
2	S1-BP	Kushal Shah	IISER, Bhopal	kushals@iiserb.ac.in	Rf Heating And Fermi Accelerators
3	S2-NF	S R Mohanty	CPP-IPR	smruti@cppipr.res.in	Compact Fusion Neutron Sources Based On Inertial Electrostatic Confinement Concept
4	S2-NF	Joydeep Ghosh	IPR	jghosh@ipr.res.in	Recent Results From Aditya Upgrade
5	S3-IP/PP	Priyabrata Banerjee	CMERI, Durgapur	priyabratabanerjee16@gmail.com	Plasma: An Ultimate Solution In Waste Management
6	S3-IP/PP	Kowsik Bodi	IIT Bombay	kbodi@aero.iitb.ac.in	Numerical Simulation Of Electrically Conducting Fluids
7	S3-IP/PP	V. L. Mathe	Univ. Of Pune	vlmathe@physics.unipune.ac.in	Atmospheric Pressure Dielectric Barrier Discharge Plasma For Effective Degradation Of Organic Water Pollutants
8	S4-SA	Tarun Kumar Pant	VSSC	tarun_kumar@vssc.gov.in	Plasma Processes In Near Earth Space : An Emerging Perspective
9	S4-SA	Durgesh Tripathi	IUCAA	durgesh@iucaa.in	Heating And Maintaining The Solar Coronal Plasma To Million Degrees
10	S5-LP/CM	A. P. Mishra	VBU, Shantiniketan	apmisra@visva-bharati.ac.in	Non-Linear Interaction Of Waves In Plasmas : A Simulation Approach
11	S5-LP/CM	Shreekant Barnwal	RRCAT	sbarnwal@rrcat.gov.in	Capillary Discharge Soft X-Ray Laser
12	S6-EP/PU	Surendra Prasad	BHU	prasads@bhu.ac.in	Numerical Modelling Of Surface Modes At The Interface Of Air And Semi-Infinite One Dimensional Plasma Photonic Crystals
13	S6-EP/PU	Rohit Shukla	BARC Vizag	rshukla@gmail.com	Applied Compact Pulsed Power & Diagnostics Development Activities At Barc Visakhapatnam, Atchyutapuram Main Campus
14	S7-PD	Divya Oberoi	NCRA-TIFR	div@ncra.tifr.res.in	Solar Plasma Diagnostics Using Low Radio Frequency Oscillations
15	S7-PD	Rajesh Srivastava	IITR, Roorkie	rajsrfph@iitr.ac.in	Spectroscopic Diagnostic Of Argon And Krypton Plasma Using A C-R Model With Fully Relativistic Electron Impact Cross-Sections

BASIC PLASMA (BP)

COMPUTER MODELING FOR PLASMA (CM)

EXOTIC PLASMA (EP)

INDUSTRIAL PLASMA (IP)

NUCLEAR FUSION (NF)

PLASMA DIAGNOSTICS (PD)

LASER PLASMA (LP)

PLASMA PROCESSING (PP)

PULSED POWER (PU)

SPACE AND ATMOSPHERIC PLASMA (SA)

02/BP-01/P

QUANTUM DOTS FOR MICROWAVE PROPAGATION FOR FUTURE QUANTUM INTERNET PROTOCOL: A NOVEL THEORY

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Abstract

As Quantum dots made of ZnS are trending in displays as TV panels and laser will be used to study the faster microwave propagation in space and on earth which will be difficult to bypass as quantum key encryption decryption is difficult to decode. Quantum internet protocol is much faster, safer and secure in microwave propagation than the present Internet Protocol v6, which forms the aspect of our study. Assimilation of hardware, Quantum dots with Quantum protocol theory beautifies the aspect of study.

Earlier Internet protocol version 12 (IPv12) was studied by Hazarika [1].Cryptographic Key Management in Delay Tolerant Network was studied by Menesidou et al [2].Cryptographic key management in deploying IPv6 was studied by Zamani et al [3],Quantum information theory, From classical to quantum Shannon theory was given by Wilde [4]

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05/BP-02/P

TRANSIENT EVOLUTION AND RELAXATION OF PARTICLE ENERGY DISTRIBUTION FUNCTIONS IN PULSED MICROWAVE PLASMA BREAKDOWN

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Abstract

The pulsed plasmas are known for its extensive contribution in material processing [1], etching [2], deposition [3] as well as in electron-cyclotron-resonance ion sources (ECRIS) for extracting higher charge-state ion current [4]. It helps in reducing film stresses while depositing thin film [5] and controls damage due to energetic ions and charge build-up by controlling the ion and neutral fluxes to the surface [6]. Clearly, a control of plasma energetic particles is desirable, leading to the investigation of basic plasma studies such as time-evolution of plasma parameters [7, 8]. However, the excitation and ionization rate coefficients of the medium are governed by the electron energy distribution function (EEDF) while the surface modification in material processing applications further depends on the ion energy distribution function (IEDF).

A monte-carlo simulation code is employed to study evolution and subsequent probable relaxation of energy distribution function of charged particles during and post-breakdown of plasma using pulsed microwaves (2.45 GHz). A comparative analysis of the transient evolution of EEDF and IEDF of plasmas generated over a wide pressure range (10^{-3} - 760 torr) of noble gases (helium, neon and argon) in the presence of multicusp magnetic field is carried out. At low pressure, mean free path is less and hence magnetic field plays an important role in plasma generation, while at high pressure electron-neutral collisions increases, diminishing the effect of magnetic field. This consequently affects the EEDF profile which will be demonstrated in detail.

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24/BP-03/P

NON-IDEAL EFFECTS IN THE GRAVITATIONAL INSTABILITY OF ROTATING QUANTUM PLASMA WITH PRESSURE ANISOTROPY

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Abstract

The influence of various non-ideal effects have been studied in isotropic quantum plasma [1,2] using the quantum magnetohydrodynamic (QMHD) model. Recent study shows that electron temperature anisotropy play significant role in the waves and instabilities in dense white dwarfs and neutron stars [3]. The small amplitude waves and linear firehose and mirror instabilities have been investigated in anisotropic pressure plasma considering uniform rotation effect [4].

In the present work, the influence of non-ideal effects viz. Hall current and finite electrical resistivity are studied on the self-gravitational instability of uniform rotating quantum plasma with finite pressure anisotropy. The Chew-Goldberger-Low (CGL) fluid equations for anisotropic pressure quantum plasma are considered and generalized Ohm's law has been modified by Hall current and electrical resistivity. The general dispersion relation is derived and analyzed in parallel and perpendicular modes of propagations. In the parallel propagation, the criterion of Jeans instability, expression of critical Jeans wavenumber and Jeans length are derived which are independent of non-ideal effects and uniform rotation but in the transverse mode rotation affects the Jeans instability criterion. The unstable gravitating mode and stable Alfven mode modified by non-ideal effects are obtained separately. The criterion of firehose instability remains unaffected due to the presence of quantum Bohm potential and non-ideal effects. In the transverse mode finite electrical resistivity, quantum pressure anisotropy modify the dispersion relation but Hall effect does not contribute in the dispersion characteristics. From the graphical illustration we observe that non-ideal effects, rotation and quantum corrections are sufficient to stabilize the growth rate of system. The stability of dynamical system is analyzed using Routh-Hurwitz criterion.

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25/BP-04/P

HYDROMAGNETIC WAVES, LINEAR FIREHOSE AND MIRROR INSTABILITIES IN POLYTROPIC QUANTUM PLASMA

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Abstract

The small amplitude hydromagnetic waves and linear instabilities have been studied by many researchers separately in collisionless anisotropic pressure plasma [1], gyrotropic plasma using polytropic pressure laws [2], isotropic pressure quantum plasmas [3] and anisotropic pressure quantum plasma [4].

Therefore, looking to the space and astrophysical applications, in the present work the low frequency quantum magnetohydrodynamic (QMHD) waves and linear firehose and mirror instabilities in anisotropic quantum plasma have been investigated using generalized polytropic pressure laws. The QMHD model and Chew-Goldberger-Low (CGL) set of equations are used to formulate the model of the problem. The general dispersion relation is derived using normal mode analysis which is discussed in parallel, transverse and oblique wave propagations. The graphical illustrations show that quantum corrections have stabilizing influence on the mirror instability. It is also observed that the growth rate stabilizes much faster in parallel wave propagation in comparison to the transverse mode of propagation. The quantum corrections and polytropic exponents also modify the pseudo-MHD and reverse-MHD modes in dense quantum plasma. The phase speed (Friedrichs) diagrams of slow, fast and intermediate wave modes are illustrated for isotropic MHD and double adiabatic MHD or CGL quantum plasmas, where the significant role of magnetic field and quantum diffraction parameter on the phase speed is observed [5].

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26/BP-05/P

RAYLEIGH-TAYLOR INSTABILITY AND INTERNAL WAVES IN STRONGLY COUPLED QUANTUM PLASMA

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Abstract

The Rayleigh-Taylor instability (RTI) is fundamental hydrodynamic instability which has large significance in the astrophysical objects such as supernova explosions, white dwarfs, type Ia supernova and neutron star. The existence of strongly coupled and degenerate plasma state is obvious in these astrophysical systems.

In this work, we investigate the internal waves and Rayleigh-Taylor instability in both the incompressible and compressible dense degenerate strongly coupled quantum plasma considering isothermal compressibility of the ion. The generalized hydrodynamic model is formulated considering degenerate electrons and strongly coupled ions using smooth quantum potential for mixed quantum states. The modified dispersion relations of the internal waves and RTI are analytically derived using Fourier analysis and discussed in both the incompressible and compressible limit. In the incompressible limit, it is observed that the unstable RT modes grow below the critical value of wavenumber modified by quantum corrections and strong coupling parameter. The effects of compressibility, quantum corrections and compressional wave velocity of strongly coupled medium are observed in the condition of RTI in the compressible limit. The growth rates of unstable RT modes are solved numerically and plotted which shows suppression due to quantum Froude number (quantum corrections), strong coupling effects and isothermal compressibility of the medium. The results have been successfully applied for understanding suppression of RTI in the dense white dwarfs which consists degenerate electrons and strongly coupled ions.

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28/BP-06/P

DYNAMO EFFECT IN 3D DRIVEN MAGNETOHYDRODYNAMIC TURBULENT PLASMAS

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Abstract

Mean magnetic field generation in a 3D magnetohydrodynamic (MHD) medium from fluid velocity or fluid vorticity field is often called as Kinematic Dynamo. Such processes are of fundamental importance in both in laboratory as well as astro-physical conditions. These self generated large scale or mean magnetic fields, in turn affect the MHD turbulence and regulate the overall plasma dynamics. Most often to simplify things, this back reaction is not considered.

Existence of optimal scale to drive kinetic perturbations leading to generation of large scale magnetic field has been demonstrated recently [1] using 3D ABC flows as the drive field. This was again a kinematic dynamo.

Whether or not such preferred drive scales exist when one includes the back reaction of the magnetic field back on to the momentum dynamics is an interesting question. Here in this work we perturb a three dimensional plasma externally at selected length scales to generate dynamo effects and study the growth of magnetic field with complete dynamical equations for both velocity and magnetic field as well as for the total energy evolution. We use pseudo-spectral technique to simulate the visco-resistive 3D MHD equations. The details of the model equations and numerical results will be presented in this Talk.

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30/BP-07/P

PHASE BEHAVIOR OF PLASMA CRYSTAL IN PRESENCE OF ASYMMETRIC ION FLOW

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Abstract

Ion flow induced anomalous phase behaviour of plasma crystal is reported in presence of external magnetic field [1, 2, 3]. The interaction potentials between dust particles are modified near the plasma sheath due to asymmetric ion flow and magnetic field [4]. This modification results in the tuning in coupling strength between the charged dusts as a characteristic of ion flow speed and the strength of external magnetic field. An equilibrium Molecular Dynamic (MD) simulation is performed based on the interaction potentials [5]. The simulation results are used to study the thermodynamic properties of plasma crystal in both subsonic and supersonic flow regime. The study shows a repulsive Yukawa dominating phase in supersonic regime and a mixed phase of attractive Wake and repulsive Yukawa in subsonic regime of ion flow. The simulation results show an anomaly in phase behaviour of plasma crystal in subsonic flow limit. The thermodynamic study confirms the ion flow induced anomaly in phase behaviour and opens up new possibilities in dusty plasma experiment in near future.

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40/BP-08/P

ELECTRON TEMPERATURE VARIATION IN A MAGNETIZED PLASMA SHEATH

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Abstract

The understanding of the properties of magnetized plasma sheath has various beneficial applications in surface treatment, electron emission gun, ion implantation, nuclear fusion, etc. The effect of electron temperature variation on magnetized plasma sheath has been studied using the Kinetic Trajectory Simulation (KTS) model for given electron and ion density distributions at the sheath entrance. It has been observed that various plasma parameters (ion density, electron density, potential, electric field and total charge density) have been prominently altered by varying the electron temperature. The density of ion is highly influenced by the change in electron temperature compared to the electron density; causing both the ion and electron densities at the wall to decrease for increase in electron temperature. This will result in variation of other parameters as well, such as total charge density, potential, electric field, etc. The study is expected to provide better understanding of magnetized plasma sheath and useful in control of particles reaching the wall.

51/BP-09/P

NONLINEAR LANDAU DAMPING IN DEGENERATE PLASMAS

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Abstract

Landau damping has been a topic of long-standing interest in plasma physics. Such collisionless linear damping was first theoretically predicted by Landau in 1946 [1], and later confirmed experimentally [2]. Though, much attention have been paid to the classical regimes, there are many aspects which are still unexplored in quantum regimes.

Our starting point is the Wigner-Moyal equation coupled to the Poisson equation. In this system, the quantum effects can be seen to appear in a wide range of length scales. In the weak quantum regime in which the Langmuir wavelength is much larger than the typical de Broglie wavelength, the particle's resonant velocity still approaches the phase velocity of the wave as in classical [3] and semiclassical [4,5] theories. However, in the modest or strong quantum regimes, the resonant velocity in the linear theory is shifted due to finite momentum and energy of particles, i.e., at $v_{res}=\omega/k\pm\hbar k/2m$, where $\omega(k)$ is the wave frequency (number), $h=2\pi\hbar$ is the Planck's constant and m is the particle's mass. In the nonlinear evolution of waves, we show that there are also the possibilities of multi-plasmon resonances [6,7] with velocities $v_{res}=\omega/k\pm n\hbar k/2m$, where n=1,2,3,...respectively, correspond to one-plasmon, two-plasmon, three-plasmon resonances etc.

The purpose of this presentation is to consider the group velocity as well as these multi-plasmon resonances on the nonlinear evolution of Langmuir wave envelopes. We show that in contrast to classical or semiclassical plasmas, the group velocity resonance does not necessarily give rise the wave damping in the strong quantum regime where $\hbar k\sim mv_F$ with v_F denoting the Fermi velocity, however, the three-plasmon process plays a dominant role in the nonlinear Landau damping of wave envelopes in a degenerate plasma. The effects of this resonance on the evolution of envelope solitons are also discussed.

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56/BP-10/P

APPLICATION OF SINGULAR SPECTRUM ANALYSIS FOR INVESTIGATING CHAOTIC CHARACTERISTICS OF GLOW DISCHARGE PLASMA

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Abstract

Being a highly non-linear medium, plasma shows different kind of non-linear oscillations. These oscillations are sometimes triggered by external forcing or just spontaneous response of the system. In plasma experiment, both experimentally and numerically it has been observed that a change in the control parameter or external perturbation of an excitable system near the threshold generates complex non-linear phenomena like noise induced resonances, canard oscillations, mixed mode oscillations [1,2,3]. In the present study, spiking and bursting in glow discharge plasma are reported. Our goal is to analyze this type of bursting and spiking data of glow discharge plasma by using singular spectrum analysis (SSA) [4].

In the beginning of the talk, experimental set up will be discussed. Then the technical details of singular spectrum analysis will be shown and the importance and the applications of this method will be discussed. Finally, we will show how SSA technique reveals non-linear characteristics of bursting and spiking data.

In the experiment, discharge voltage is taken as the control parameter that is varied gradually and the pressure is kept as constant. It is observed that the characteristics of the oscillations change as we change the control parameter. We use singular spectrum analysis for analyzing the time series of the floating potential fluctuations (FPF), obtained at different discharge voltage. By using SSA technique we get a reliable estimate of the correlation dimension and lyapunov exponent of the FPF signals. We show that SSA technique can be used to reconstruct a vivid

state space picture from FPF data. As the nature of the FPF signals differ from each other, the corresponding state space picture also look different from each other.

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61/BP-11/P

VELOCITY VARIATION OF IONS IN A MAGNETIZED PLASMA SHEATH FOR DIFFERENT OBLIQUENESS OF THE FIELD

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Abstract

The velocity of ions in a magnetized plasma sheath has been numerically investigated by using a kinetic trajectory simulation model for varying obliqueness at constant magnetic and electric field. The in-streaming ions have to satisfy the Bohm-Chodura criterion to ensure the stability of the overall plasma. It has been revealed that the velocity of ions reaching the material wall can be controlled by the strength of applied magnetic field and its orientation. As the obliqueness of the field changes the separation of the mean values as well as the maximum amplitude of the three components of the velocity also change. Velocity of ion increases towards the wall as the obliqueness of the field increases. Ion velocity at presheath-sheath boundary is greatly affected by obliqueness of the field. Our results agree well with previous works from other models and hence, we expect to provide a basis for studying ion behavior in magnetized plasma sheath.

63/BP-12/P

ROLE OF TWO-TEMPERATURE *Q*-NONEXTENSIVE ELECTRONS ON COLLISIONAL PLASMA SHEATH

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Abstract

Plasma having two populations of electrons is similar to the plasmas with negatively charged ions and has importance in many areas of applications including fusion research [1]. The ion neutral collisions in the plasma sheath reduces the ion impact energy on the surface, hence it is very important in the study of plasma sheath [2]. In usual collisonless plasmas it is assumed that the quasi-neutrality condition is valid in the presheath-sheath edge region and the ions enter into the sheath region with the characteristic Bohm velocity. However, if the ion neutral collisions are more significant, the ions entrance velocity into the sheath region is much less than the characteristic Bohm velocity [3]. Studies have shown that Boltzmann-Gibbs Statistics may unable to explain correctly systems involving long range interactions, such as in plasmas with the Coulomb force [4], where the particle distributions may deviate from the usual Maxwellian distribution. A generalized Boltzmann-Gibbs Statistics proposed by C. Tsallis [5], which is known as Nonextensive Statistics is used to study such cases over last two decades.

In this work, a collisional sheath model comprising of cold fluid ions and two-temperature (cold and hot) q-nonextensive electrons is presented. By using Sagdeev potential method a modified Bohm criterion is derived and graphically explained. A detailed study of the sheath potential and density profiles is also presented here. It is found that the nonextensivity parameter, ion-neutral collisionality and the two-temperature electrons significantly affect the characteristics of sheath.

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64/BP-13/P

A STUDY OF NONLINEAR INTERACTION USING QUANTUM MODEL IN SOLID STATE PLASMA

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Abstract

Plasma is one of fourth fundamental state of matter. Plasma science has, in turn, spawned new avenues of basic science. Plasma is electrically neutral medium of unbound positive and negative particles and also very hot (millions Kelvin) ionized gases. In this paper the various parameters, Debye length, and plasma range and plasma frequency has been studied. We have showed that the quantum plasma is relatively new and rapidly growing field of plasma research .Using QHD model, the parametric instability and modulational instability piezoelectric and ferroelectric materials of semiconductor quantum plasma has been studied. We present an analytical investigation on compare the SBS and SRS in semiconductor plasma. In this article explained the various types of application, characteristics and uses of quantum plasma. The results obtained in this work are discussed, what help of plasma in developing new technologies of the universe.

Keywords: QHD model, Modulational and Parametric instability, SRS and SBS. Nonlinear interaction.

65/BP-14/P

UNDERSTANDING FLOATING POTENTIAL OSCILLATION AND ADL FORMATION BY PREDATOR-PREY MODEL

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Abstract

A simple Predator-Prey (PP) dynamic model is powerful tool for understanding the existing complex phenomena in natural science. The PP character of ions and electrons is observed in fusion and dusty plasma during the evolution of instability. In this model we assume prey as electron and predator as ion. The population of PP determines the growth of instability in floating potential oscillation that supports the formation of anodic double layer (ADL) in plasma under certain condition. The variation of population in PP model is described by set of first order non-linear differential Lotka-Volterra equations. The PP interactions can be of three types such as normal PP interaction, competitive interaction and mutual growth interaction. In the present work, we adopted PP model which obeys mutual growth interaction to describe the floating potential oscillations in the presence of DL in fronts of positively biased electrode inside the anode. From the PP modeling of plasma oscillations we observed variety of motion undergone by ion and electrons under different operating condition.

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73/BP-15/P

FEEDBACK MODEL OF SECONDARY ELECTRON EMISSION IN DC GAS DISCHARGE PLASMAS

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Abstract

The primary photo-electrons (PEs) emitted from the cathode in glow regime of a gas discharge amplifies ion current exponentially by avalanche breakdown process. Ions gains power from the field and feeds fraction of its power for secondary electron emission (SEE) from cathode. This process is same as the process happening in any feedback electrical amplifier (FEA). In the present work, we modeled the elementary processes happening in DC gas discharge as FEA and derived the expression for gain in the cases of with and without feedback. The expression for amplification provides the relation between power gained by ion at cathode to the effective secondary electron emission coefficient (ESEEC, γ_E). Using this feedback analysis, experimentally, we found how much fraction of ion power goes for SEE and how much is going for cathode heating. The glow discharge has been produced for three different cathode material of tungsten (W), Copper (Cu) and Brass having different γ_E value under identical discharge condition at a pressure of 0.5 mbar for the cathode bias of -600 V with anode (chamber) grounded. We found significant effect of γ_E on the total power of the discharge.

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85/BP-16/P

ELECTRONEGATIVE PLASMA SHEATH WITH *Q*-NONEXTENSIVE ELECTRON DISTRIBUTION

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Abstract

Various studies have shown that the multi-component plasma sheath including negative ions has practical interest in plasma applications as well as in research. As an example in many processing reactors commonly used gas mixture is combination of Argon and Oxygen. Oxygen being a electronegative gas, due to electron attachment, a large number of negative ions can be generated in the course of plasma discharge. Again studies have shown that Boltzmann-Gibbs Statistics may unable to explain correctly systems involving long range interactions, such as in plasmas with the Coulomb force [1], where the particle distributions may deviate from the usual Maxwellian distribution. Nonextensive statistics [2] may play an important role in such case. Nonextensivity comes as a difference in entropy of the whole system as compared to sum of entropies of the respective parts. Presently many researchers are using nonextensive particle distribution in studying various nonlinear phenomena including plasma sheath.

In this work a parametric and comparative study of sheath structure is presented in a three component plasma system comprising of nonextensively distributed electrons, Boltzmann distributed negative ions and fluid positive ions. Using Sagdeev pseudo potential technique a modified Bohm sheath criterion is established. A detailed investigation of density profiles and potential profiles of the sheath with the present plasma configuration is presented here. It is found that the nonextensivity parameter as well as the electronegativity has significant effects on the electrostatic sheath profiles.

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86/BP-17/P

ANALYTICAL MODEL FOR SHEATH INSTABILITIES IN HALL PLASMAS

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Abstract

Hall thrusters are cross-field devices where a large electric field can be generated and maintained in the bulk plasma due to the lowering of the electron conductivity by a magnetic barrier. Plasmas in these devices are usually in strongly non-equilibrium state due to presence of crossed electric and magnetic fields, inhomogeneities of plasma density, temperature, magnetic field and beams of accelerated ions[1-2]. In this paper, we investigated the effects of plasma parameters on the growth rate of the sheath instabilities by solving dispersion relation and also derived the analytical expressions for the growth rate of the instability under the presence of all the plasma parameters [3-5]. Sheath instability drastically affects the performance and efficiency of the Hall thrusters through plasma wall interactions. The growth rate of the sheath instability found to increase with electron temperature, density gradient scale length, drift velocities of plasma species and both wave numbers (azimuthal and radial) [5-6].

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93/BP-18/P

EFFECTS OF CHARGE EXCHANGE FORCE ON KINETIC ALFVEN WAVES IN PARTIALLY IONIZED PLASMA

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Abstract

It is claimed that there occurs the propagation of electromagnetic waves from solar photosphere toward the outer layers via the Alfvèn waves which heats up the Corona layer and are thus responsible for extremely high temperature of solar corona as compared to photosphere. Kinetic Alfven waves are basically the low-frequency wave modes of magnetized plasmas that are supposed to underlie the transfer of magnetic energy in solar and stellar winds. Moreover, in partially ionized plasmas, the charge exchange which is identified as the phenomenon in which an ion and an atom exchanges electrons in the presence of collisions occurs at a very high rate. The charge exchange plays a crucial role in propagation of magnetic waves in weakly ionised, but highly collisional environment. Due to charge exchange, the friction between ions and neutrals is absorbed into one fluid as the identity change is so frequent that it is impossible to distinguish between charged and neutral particles. We shall imply two potential theory and using Sagdeev pseudopotential method, kinetic Alfven solitary waves in partially ionized solar plasma consisting of ions, electrons and neutral atoms shall be investigated in presence of charge exchange forces. The results of present investigation shall be very useful to understand dynamics of electromagnetic waves in solar plasmas that may be responsible for anomalous heating of solar corona.

95/BP-19/P

EFFECT OF ION TEMPERATURE ON LARGE AMPLITUDE SOLITARY KINETIC ALFVÉN WAVES AND DOUBLE LAYERS IN PLASMAS WITH SUPERTHERMAL ELECTRONS

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Abstract

Effect of ion temperature on nonlinear wave structure of large amplitude magnetized plasma in presence of superthermal electrons is investigated. The fluid-dynamical system of equations governing the dynamics is reduced to a pseudoenergy-balance equation. An exact analytical expression for the Sagdeev Potential (SP) or energy integral equation is obtained. The amplitude of the solitary waves and the depth of the potential well are found to decrease with the increase of the direction-cosine of the wave propagation. The influence on the soliton characteristics of plasma parameters such as Mach number, the superthermal parameter, the direction cosine, ratio of thermal to magnetic pressure(β) has been investigated. A critical value of Mach number is obtained for the existence of solitary waves in such plasmas. Moreover, for Mach number (ω) > 1, in the supersonic regime, the potential profile breaks up into double layer structure and with increasing Mach number (ω).

Key words: Kappa distribution, Alfvén wave, Sagdeev Potential, Double layer

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99/BP-20/P

NONLINEAR SOLITARY STRUCTURES IN THE PRESENCE OF NON-MAXWELLIAN TRAPPED ELECTRONS

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Abstract

Particle trapping is commonly observed phenomenon in both space and laboratory plasmas, where the particles are confined to a finite region of phase space where they bounce back and forth. The presence of trapped electrons may significantly modify the wave propagation characteristics in plasmas. Using the reductive perturbation technique, the dynamics of nonlinear solitary waves are investigated in plasma comprising of warm fluid ions and non- Maxwellian (superthermal/nonextensive) trapped electrons. The dependency of solitary structures attributes to the parameters associated with the non-Maxwellian electrons and trapping mechanism has been shown in detail through various numerical analyses. The trapped electrons in the given plasma system support the formation of only positive polarity solitary waves. The comparison of results of the plasma systems with different distribution of constituents can help to find better knowledge in plasma physics. The results of the present investigation would also be useful to explain the basic features of the localized disturbances in the astrophysical and space plasmas such as the pulsar magnetosphere, the auroral zone, and the upper ionosphere.

113/BP-21/P

LOW FREQUENCY KINETIC ALFVÉN FREAK WAVES IN MULTICOMPONENT PLASMA

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Abstract

Among the variety of nonlinear structures, Alfvén waves and the magnetoacoustic waves (slow and fast modes) are the basic wave modes in the magnetohydrodynamic (MHD) systems in which Alfvén waves are the low frequency waves (below the ion cyclotron frequency) which play a central role in many laboratory, magnetospheric, space, cosmic as well as fusion plasmas, where the plasma β is typically much smaller than the electron to ion mass ratio. The propagation properties of ion acoustic kinetic Alfvén (IAKA) freak waves have been investigated in a plasma containing ions and multi-temperature electrons obeying superthermal distribution in the presence of immobile dust. The Korteweg-de Vries (KdV) equation has been derived using the reductive perturbation method (RPM) which describes the evolution of solitary structures. The effect of various plasma parameters on the characteristics of the IAKA solitary waves is studied. The dynamics of ion acoustic kinetic Alfvén freak waves (IAKAFWs) has also been studied from nonlinear Schrödinger (NLS) equation. The characteristics of freak waves have been studied in detail by varying various plasma parameters. The findings of the present investigation may be important in understanding the underlying physics of nonlinear structures in different environments of space and astrophysics, e.g., Saturn's magnetosphere, pulsar magnetosphere, solar wind etc.

154/BP-22/P

EFFECTS OF KINETIC IONS ON THE DRIVEN PHASE SPACE STRUCTURES IN A 1-D VLASOV PLASMA

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Abstract

In a collisionless, unbounded, one-dimensional plasma, understanding the formation of phase space structures or phase space vortices (PSV) is of fundamental interest, both in astrophysical plasmas as well as laboratory plasmas alike. For example, for Maxwellian distributions of electrons and stationary background ions, which are typical of extensive systems, characterized by additivity of energy, a small amplitude external drive, when chirped, has been recently shown to couple effectively to the plasma and increase both streaming of “untrapped" and “trapped" particle fraction, eventually leading to large, multi-extrema phase space vortices [1].

The generality of this mechanism has been shown to be effective in producing multi-extrema phase space structures in non-Maxwellian systems as well [2]. In these studies, the ions are usually assumed to be immobile. However, ion motion may significantly change the evolution of high (electron dominated) and low (ion dominated) frequency motions which in turn may affect the trapping and formation of PSVs.

In the present work, using a numerical Vlasov-Poisson solver which treats both electrons and ions kinetically, we bring out several interesting features of driven phase space structures in the dynamics of the background slowly moving ions, in Maxwellian plasma, the details of which will be presented [3].

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167/BP-23/P

MODIFIED SIMON-HOH INSTABILITY IN A MAGNETIZED INHOMOGENEOUS VARIABLE CHARGED DUSTY PLASMA

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Abstract

Simon [1], Hoh [2] and Thomassen[3] first studied the Simon-Hoh instability (SHI) in weakly ionized, inhomogeneous, collisional, magnetized plasma under a strong electric field perpendicular to the dc magnetic field. In collisionless, weakly magnetized-ion plasmas (where electrons are magnetized), a similar instability was shown by Sakawa[4] which was called the modified Simon-Hoh instability (MSHI). In our current work, we investigated the modified Simon-Hoh instability in a magnetized, inhomogeneous plasma in presence of constant and variable charged dust grain. In this case, ions and dust particles are unmagnetized but electrons are strongly magnetized. When we withdraw the contribution of dust grains from our plasma system, then the obtained dispersion relation exactly matches to the dispersion relation given by Sakawa et al[4]. In this research paper, we first derived the dispersion relation from momentum, quasi neutrality and continuity equation. Next, we numerically solved the growth rate for two different frequencies (i.e. one high frequency mode and another low frequency mode) choosing the parameters of the paper of Sakawa et al[4]. The study with variable charged dust grains gives a more realistic picture for natural plasma environment.

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187/BP-24/P

NONLINEAR ION ACOUSTIC SOLITONS IN AN ELECTRON-POSITRON-ION PLASMA WITH RELATIVISTIC POSITRON BEAM IMPACT

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Abstract

The inclination of research for electron-positron-ion (e-p-i) plasma can be found in many research papers [1-3]. Most of these researches were undertaken keeping the prime focus on relativistic effects in plasma including one recently published work [3]. Here, in this research work, we have investigated elaborately the effect of relativistic positron beam in an electron positron ion plasma to study nonlinear solitary structure for various plasma parameters. In our observations, some interesting results are found when we are examining the effect of positron beam velocity, positron beam concentration and positron beam mass ratio on the solitary wave amplitude, width and dispersion relation in our electron-positron-ion plasma model.

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193/BP-25/P

NONLINEAR DUST ION-ACOUSTIC SOLITONS IN MAGNETIZED QUANTUM PLASMA WITH ARBITRARY DEGENERACY OF ELECTRONS

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Abstract

The linear and nonlinear quantum dust ion-acoustic waves propagating obliquely in a non relativistic magnetized quantum plasma with arbitrary degeneracy of electrons are studied. The dispersion relation in the linear regime and the Zakharov-Kuznetsov equation in the nonlinear regime are derived using reductive perturbation method. The quantum mechanical effects through quantum diffraction, the role of immobile dust particulates, the effect of electron temperature and the obliqueness are studied numerically.

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200/BP-26/P

EFFECTIVE PLASMONIC RESONANCE IN ULTRASHORT INTENSE LASER IRRADIATED NANOPARTICLES

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Abstract

The field of "plasmonics" has extended to the ongoing ultrashort ultrahigh intensity laser nanostructure interaction for efficient charge particle and radiation generation [1]. Nanostructure intense light interaction is generally analytically comprehended by the "nanoplasma model" which considers a single nanoparticle interacting with light which predicts individual resonance density of $2n_c$ for nano rods and 3 n_c for nano spheres or gas clusters [2]. However when intense ultrashort laser irradiates these nanostructures of various shapes and geometries multiple nanoparticles present in the focal spot region simultaneously interact with the laser. The popular Maxwell Garnett (MG) electromagnetic mixing recipe [3] helps unveil the effective resonance density and optical properties of multiple nanoparticles interacting with intense light. This helps to simplistically model the otherwise complex optical properties of nano structured matter at high intensity. The effective resonance help choosing the nanostructure shape and fill fraction (f) to tune the resonant density for field enhancement and efficient energy deposition. In this paper we present an analytical study of identifying the resonance electron density and estimating the absorption of a collection of nanoparticles of various shapes. In particular the nanostructure composite response to applied laser electric field is studied for the case of solid spherical and solid cylindrical nanoparticles. This is extended for the hollow cavity counterparts like nano spherical voids and nano cylindrical cavities. The nano composite medium can be replaced by an effective medium based on the electrodynamically consistent MG theory. The density at which resonance occurs for a collection of nanoparticles is found to be dependent on fill fraction shape, geometry and incident laser polarization. The resonance density for nanospheres is $3n_c/(2f+1)$, for nano cylinders (applied field perpendicular to cylinder axis) it is $2n_c/(f+1)$ which shows that for solid nanostructures there is a decrement of resonance density as the fill fraction increases. Interestingly hollow nano structures show two resonances. For example the nano sphere cavities resonance occurs at two densities $3n_c /2(1-f)$ and n_c and cylindrical nano cavities (applied field perpendicular to cylinder axis) has two resonances at $2 n_c /(1-f)$ and n_c. This also has an important consequence of increasing the resonance density by increasing the proportion of the hollow structure, implying the heating can be tuned to occur at solid densities. Further, intense laser heated nanostructures also undergoes

a rapid hydrodynamic expansion leading to a time evolving fill fraction due to void closure. All such complex processes occurring in the nano plasma and its effect on the energy coupling in the nano-structured matter can be easily understood with the framework discussed in this paper.

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207/BP-27/P

BREAKING OF RELATIVISTICALLY INTENSE ELECTRON PLASMA WAVES IN AN UNMAGNETIZED HOMOGENEOUS PLASMA

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Abstract

The space-time evolution and breaking of relativistically intense waves in a plasma is a fascinating field of study. Wave breaking, which serves as a useful paradigm to elucidate the underlying physics behind a wide range of physical phenomena, induces by several non-linear processes. In this paper, we briefly review our work on the space-time evolution and breaking of large amplitude relativistically intense electron plasma waves in both cold and warm plasmas. It is shown by using Dawson Sheet Model [1] that in a cold plasma, relativistically intense oscillations/waves break when adjacent electrons start to cross each other due to temporal dependence of phase differences which arises because of relativistic mass variation effects (phase mixing). Analytical expressions for phase mixing time scales (wave breaking time) for an arbitrary longitudinal wave packet [2] & longitudinal Akhiezer-Polovin mode have been given [3, 4] and verified by using a code based on Dawson Sheet Model. We have further extended our studies on wave breaking to a warm plasma by using an in-house developed, 1-D Particle-in-Cell simulation code. A finite electron temperature effect has been added by loading a Jüttner - Synge distribution along with a longitudinal Akhiezer-Polovin mode; it is observed that in the low amplitude limit the resultant structure follows the dispersion relation given by Buti [5]. Further it is demonstrated that, like a cold plasma, in a warm plasma also wave breaks via phase mixing at arbitrarily small amplitude when perturbed by a small amplitude longitudinal perturbation. This is far below the existing theoretical results [6, 7, 8] presented in the literature. Variations of phase mixing time for a wide range of input parameters have been studied. Furthermore, parameter regimes exhibiting the phenomena of Relativistic Landau Damping [5] and wave breaking have been clearly delineated.

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212/BP-28/P

SHEET MODEL OF UPPER-HYBRID OSCILLATIONS

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Abstract

The phenomenon of phase mixing of electrostatic plasma waves leading to wave breaking have been extensively studied [1, 2, 3]; it occurs whenever the oscillation frequency acquires a spatial dependence. In the present paper phase mixing of upper-hybrid oscillations in a cold plasma in the presence of external inhomogeneous magnetic field [3] is studied analytically using Dawson Sheet Model [4]. An exact solution in parametric form is obtained and from it an approximate expression of phase mixing time is derived. These analytical results are further verified using an existing 1-1/2 D simulation code [5].

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216/BP-29/P

RELATIVISTIC MOTION OF A CHARGED PARTICLE IN AN ELECTROMAGNETIC WAVE IN THE PRESENCE OF RADIATION REACTION

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Abstract

The exact solution of the Landau and Lifshitz equation of motion for a charged particle placed in a transverse electromagnetic wave shows that, in contrast to the Lorentz force equation, a net energy gain by the particle [1]. This result has been recently derived for a charged particle placed in a linearly and circularly polarized light [2, 3]. In present work we have generalized the above calculations for an elliptically polarized light. We further compare the energy gain calculated using the Landau-Lifshitz equation of motion with other equations *viz*. Hartemann equation of motion[4] and Ford-O-Connell equation of motion[5]. It is found that the net energy gained is independent of the chosen model equation and irrespective of the initial phase of the wave seen by the particle, the observed energy gain is maximum for a linearly polarized light. We have verified the above results using a 3D test particle code.

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226/BP-30/P

EFFECT OF FINITE GEOMETRY ON THE ION-ACOUSTIC SOLITARY WAVES IN A BOUNDED PLASMA CONSISTING OF TWO-TEMPERATURE ELECTRONS AND NEGATIVE IONS

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Abstract

Nonlinear propagation of ion-acoustic waves have been theoretically investigated in a multi-component plasma consisting of two-temperature electrons, positive ions and negative ions bounded in a cylindrical waveguide sing pseudo potential method. The expression of Sagdeev potential has been derived and the solution of ion acoustic solitary wave in bounded plasma has been obtained. The effect of finite geometry of bounded medium on the solitary wave has been critically studied in plasma with graphical representation for different values of two-temperature electrons and negative ions. We find that both compressive and rarefactve solitary wave are excited in plasma and the presence of negative ions and two-temperature electrons give rise to create some fascinating features on solitary waves. For experimental observation of solitary waves in multi-component plasma our theoretical results will be very useful.

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230/BP-31/P

DEVELOPMENT OF A HELICON SOURCE AND PRELIMINARY EXPERIMENTS

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Abstract

A helicon plasma source has been developed and installed at CPP-IPR in order to study the role of electrons and electron affinity in basic plasma phenomena in inert as well as in electronegative gases such as Ar, O_2, Cl_2, etc. The design parameters of the source were determined by using the dispersion relation for Helicon waves and the parameters were optimized by using Helic Code. Basically, the experimental setup comprises of a vacuum chamber in which plasma was produced, a RF power supply (3 kW, 13.56 MHz) and an electromagnet system. The vacuum chamber consists of three parts namely i) a glass chamber of diameter 10 cm and length 60 cm over which a helical antenna is wound, ii) the expansion and iii) extraction chamber. The axial magnetic field required for the excitation of helicon waves is generated by six electromagnets. When compared with other helicon setups, this setup also consists of a magnetic cage in the expansion chamber. A turbo-molecular pump having pumping speed of 1000 l/sec backed by 32 m^3/h rotary pump is connected to the vacuum chamber to evacuate up to 10^{-6} mbar base pressure.

Here, we report details of the experimental setup along with its various components such as chamber dimensions, pumping system, electromagnet and discharge power requirements. Additionally, we also discuss about the preliminary characterization of the helicon plasma parameters such as the variation of plasma temperature, density and potential with magnetic field as well as the applied RF power by using Langmuir probe in Ar and O_2 gases.

240/BP-32/P

ELECTRO-STATIC DOUBLE LAYERS IN FULLY RELATIVISTIC PLASMA WITH NONTHERMAL ELECTRONS

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Abstract

Ion-acoustic double layers has been theoretically studied in a cold unmagnetized fully relativistic plasma consisting of positive ions and nonthermal electrons using the pseudo potential method. The expression of Sagdeev potential in fully relativistic plasma has been derived and the solution for ion acoustic double layers is obtained in which the relativistic term appears in exact form. Taking different values of ion-stream velocity and nonthermal parameter of electrons the profiles of double layers are drawn and discussed. The results are more general than that obtained by previous authors and it would be applicable for the study of ion acoustic solitary waves both in weak- and ultra- relativistic plasma.

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269/BP-33/P

ESTIMATION OF PLASMA FREQUENCY IN COLD PLASMA USING POWER BALANCE EQUATION AND ITS VALIDATION USING MICROWAVE ABSORPTION

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Abstract

Conventional methods using electric and magnetic probes prevail for the measurement of electron density in cold plasma. In the case where there is no access to the probe and one needs to get an estimation of the plasma density one can use the power balance equation[1] to get an approximate estimation of the density. In the present experiment easily available conventional tube lights have been used as a plasma source. The given work describes the theoretical estimation of the plasma density using the power balance equation. This equation takes into account the power dumped in the plasma as the main parameter to get an approximate estimation of the electron density. The plasma is made to interact with an incoming microwave (10-20 W in each tube) in the frequency range, 6-12 GHz. Our experiments on the wave reflection with plasma for varied frequency of the incoming microwaves, show a drastic reduction in the microwave reflection as the frequency approaches a critical range ~ 7.5-8 GHz, which matches well with the theoretically estimated plasma frequency. The calculated plasma frequency was in the range of 8-10 GHz and this very well matched with the experimental observations.

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279/BP-34/P

PROTON-DRIVEN PLASMA WAKEFIELD ACCELERATION: EFFECT OF AN EXTERNAL MAGNETIC FIELD

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Abstract

A stationary wave solution is obtained for the proton driven plasma wake field accelerator (PDP-WFA). Because of their higher energy and mass, proton can drive wake fields very efficiently over a very longer plasma lengths.[1] Considering the necessity of the external magnetic field to control focusing of the beam, studies on the effect of magnetic field on the stationary profiles of electric field and electron density have been performed. It is seen that with increase in the magnetic field strength the maximum electric field behind the pulse gradually increases. Also, the investigation in multi-bunch wave excitation in the context of PDPWFA is done.[2]

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293/BP-35/P

LINEAR AND NONLINEAR DUST ION ACOUSTIC WAVES IN QUANTUM RELATIVISTIC DUST-ION PLASMAS

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Abstract

The quantum and relativistic effects on the propagation of dust ion acoustic wave (DIAW) in a collisionless unmagnetized plasma containing positively charged ions and negatively charged dust particles have been theoretically investigated. A linear dispersion relation has been derived by using the method of normal mode of analysis and it has been analyzed for various modes of propagation. To describe the nonlinear propagation of the wave, we have derived a KdV-like equation by using the standard reductive perturbation technique. Numerically it is shown that the profile of the dust ion-acoustic KdV solitons depends significantly on the quantum and relativistic plasma parameters. The dust charge and dust number density are also found to have significant effects on the conditions for existence and properties of these solitons. The results of this investigation are expected to be useful for understanding the nonlinear propagation of DIAWs in some astrophysical and laboratory plasma environments.

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313/BP-36/P

PLASMA DYNAMICS IN PAUL TRAP USING TSALLIS DISTRIBUTION

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Abstract

Study of charged particle dynamics in a Paul trap [1] is of great interest in many applications like mass spectroscopy, quantum computing and even DNA sequencing. A Paul trap allows for the study of sub-atomic particle interaction with energy and matter in a well controlled environment. The motion of a single particle in these traps is well understood through the Mathieu equation. However, the collective behaviour of several particles confined in a Paul trap still has many open questions. An earlier work [2] has provided analytical solutions of the Vlasov equation for charged particles (of the same species and hence, non-neutral) in a Paul trap under the assumption that the initial plasma distribution is Gaussian. We have analysed the same problem by using a Tsallis (q-Gaussian) distribution [3] as the initial condition, since in most of the plasma experiments the distribution functions have been shown to have power tails. We have assumed the plasma to be non relativistic, collisionless and one dimensional. Since we have neglected the induced field of the charged particles, the electric field in the trap, which is a combination of a rf field and a static field is taken to be time-periodic and spatially linear.

Analytical expression for the time evolution of the distribution function are aperiodic in general. However, for a particular value of initial scale length, the distribution function becomes time periodic. For this special case, the time averaged distribution function is found to be double humped in velocity. The location of double hump changes with variation in Tsallis parameter and moves away from the bulk. A double hump in the distribution function is important since it is associated with the concept of instability in plasmas through the growing modes of Landau damping. The movement away from the center of the Paul trap indicates that the Tsallis distribution solutions seem to be more stable compared to the Gaussian distribution solutions. We have analysed the spatial variation of plasma temperature of the plasma within the permissible range of the Tsallis parameter (q). The temperature of such a non-equilibrium system has a spatial dependence which not only shows an increase in space but also with Tsallis parameter. This indicates that the Tsallis parameter is more than a mere number controlling the temperature and can perhaps be used to model rf heating which is experimentally observed in

many Paul trap experiments [4]. Thus, the Tsallis model can serve as a viable focal point for research undertaken in understanding temperature variations and rf heating in non neutral plasma in a Paul trap.

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324/BP-37/P

EFFECT OF SUPERTHERMAL ELECTRONS ON LARGE AMPLITUDE ION-ACOUSTIC SOLITONS IN A MULTICOMPONENT PLASMA WITH WARM NEGATIVE IONS

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Abstract

Arbitrary amplitude ion-acoustic solitons are investigated in a multicomponent plasma consisting of warm adiabatic positive and negative-ions and hot superthermal electrons. Using Pseudo-potential method an energy integral equation is derived for the system. By using it we have examined the existence regions of the solitary waves. Our numerical analysis shows that the system supports compressive/rarefactive solitons for some selected set of plasma parameters. It is also found that large amplitude ion-acoustic compressive and rarefactive solitons exist simultaneously for the same values of plasma parameters. Is is also investigated that an increase in the superthermality (i.e. decreasing the value of spectral index k) leads to shrinking the existing domain of the large amplitude ion-acoustic solitons. The amplitude of the compressive/rarefactive solitons increases with the increase in negative ion concentration (α). Whereas, on increasing ionic temperature ratio ($\sigma_1$or σ_2) the amplitude of the compressive/rarefactive soliton decreases. The effect of negative-ion concentration(α), temperature ratio of two ion species (σ_1 and σ_2), Mach number (M) and spectral index (k) on the characteristics of solitons are discussed in detail.

334/BP-38/P

NATURE OF KINETIC PROCESSES IN THE PRESENCE OF NONLINEAR PHASE SPACE VORTICES

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Abstract

Understanding the role of kinetic effects on the dynamics of a collision-free plasma is crucial to understand a variety of processes in interplanetary environments and in laboratory plasma systems. In astrophysical plasmas, due to the absence of collisional processes, kinetic effects, such as wave–particle resonant interactions, provide efficient mechanisms that transfer energy from plasma collective modes to the background plasma (and vice versa), which leads to damping (or growth) effects, particle trapping and interesting steady nonlinear phase space coherent structures or vortices with distributions far from Maxwellian plasmas. For driven collision-less 1D plasma formation of such finite amplitude, steady state structures with non-monotonous distribution has been demonstrated numerically [1,2].

Using a 1D, collision-less Vlasov-Poisson solver with stationary ions and kinetic electrons, we investigate the role of infinitesimal and finite amplitude perturbations on the stability of steady state non-monotonous solutions found earlier [1,2]. An extensive study of perturbations with a range of phase velocities, the details of which will be presented.

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378/BP-39/P

INTRINSIC PARALLEL CURRENT GENERATION FROM ETG TURBULENCE IN A CYLINDRICAL PLASMA

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Abstract

The mean axial current in a cylindrical plasma is shown to obey a collisional advection diffusion equation. In addition to turbulent diffusion of large scale electron momentum due to small scale turbulence, a negative turbulent viscosity appears, coming from $\langle k_y k_z \rangle$ symmetry breaking, the likely source of which is an initial seed current shear. Note that the current shear creates an asymmetry in the growth rate, and therefore a corresponding asymmetry in the fluctuation spectrum. When the negative turbulent viscosity exceeds the ambient positive diffusivity, the axial current shear goes modulationally unstable, leading to generation of intrinsic current in a current less non-inductive linear device. This modulational instability mechanism of intrinsic current in linear device is fundamentally different from the intrinsic current generation via $\langle k_{\|} \rangle$ symmetry breaking in tokamak pedestal[R Singh *et al* Phys. Plasmas 2017(accepted)].

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386/BP-40/P

NONLINEAR SOLITARY WAVES IN MAGNETIZED PLASMA WITH Q-NONEXTENSIVE DISTRIBUTED ELECTRONS

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Abstract

On the surface of fast rotating neutron stars and in the pulsar magnetosphere, a strong magnetic field exists, and this magnetic field has a significant impact on nonlinear wave propagation. In the present study, the nonlinear wave structures have been investigated in magnetized plasma consisting of electrons obeying nonextensive distribution and stationary ions. Using the reductive perturbation technique, the basic set of equations is reduced to Korteweg-de Vries (K-dV) equation and steady state solution of the K-dV equation is obtained. The basic characteristics of the solitary waves have been analyzed numerically and graphically for a wide range of values of the plasma parameters. The presented investigation shows that the presence of nonextensive distributed electrons causes reduction in the soliton amplitude. The magnetic field has no effect on the amplitude of solitary waves but it makes the solitons spiky. The effects of the ion to electron temperature ratio and angle of propagation in this situation are also discussed. This model may be helpful to understand the nonlinear features of localized electrostatic fluctuations in the presence of magnetic field, nonmaxwellian electrons, which is most common particularly in space plasmas such as Earth's magnetosphere, auroral region and heliospheric environments.

420/BP-41/P

ONSET OF 2D RAYLEIGH-BENARD CONVECTION IN STRONGLY CORRELATED LIQUIDS: A COMPARATIVE STUDY

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Abstract

Recently, using classical first principles-based molecular dynamics simulations of Yukawa liquid [1], it has been shown that when a 2D fluid subjected to gravity is "heated" from below and "cooled" from above, it gives rise to Rayleigh-Benard Convection Cells (RBCC). Several interesting results were obtained. Some of them are: (a) the onset temperature difference was found to increase with increasing correlation strength or coupling strength (b) Beyond the onset, the convective velocity was found to scale linearly with temperature difference (c) "Empirical" relationship between mean density and mean temperature with near linear dependence etc.

In this work, we propose to exploit a fluid dynamic model with effects of correlation incorporated via a memory term. This model is further augmented with a heat conduction model, external gravity and an ``empirical" memory term. These new set of fluid equations are subjected to a linear stability analysis [2]. The resulting eigenvalue problem is solved numerically. A qualitative comparison is made between the molecular dynamics based results of the onset and that of augmented fluid dynamics model, the details of which will be presented.

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484/BP-42/P

TRAPPED PARTICLE NONLINEARITY GENERATED COHERENT STRUCTURES AND THEIR STABILITY

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Abstract

Plasma supports different variety of coherent nonlinear structures due to its collective behaviour. These coherent structures like double layers, solitary electron holes, are frequently observed in astrophysical plasmas, fusion plasmas and also in lab plasmas where satisfy the collision-less conditions and evolve by means of strong kinetic nonlinear activity. The elegant collisional linear description, and its nonlinear counterparts, lose their applicability in this regime and plasmas begin to show strong departure from these conventional results. Finding a general nonlinear kinetic description of collective coherent structures defines the central idea of the modern plasma theory of collective waves and instability. In this regime, the non-thermal phase-space distributions with particle trapping represent collective structures, essentially corresponding to a possible infinity of valid nonlinear solutions of the collisionless Vlasov equation. The computer simulations are strongest means of exploring this interesting physics and validating few existing analytic approaches to stable nonlinear kinetic structures. The high resolution, multiscale, multispecies, fully kinetic simulations [4] of essentially nonlinear, collective kinetic plasma response to phase-space perturbations are done describing generation mechanism [1,2], and unstable evolution [3] of coherent phase-space structures in the present study. In the subcritical electron drift regime, where any perturbations must not grow according to the linear theory, the small phase-space eddy-like perturbations grow to a phase space electron hole and propagate at an arbitrary velocity in the simulations. These results support that the kinetic nonlinearity begins to act well below the linear instability threshold and follow a nonlinear dispersion relation (NDR) [3]. This questions the validity of plasma stability criterion based on linear approaches of Landau and Van Kampen that prescribe discrete and continuum collective mode spectra, respectively. Finally, existing nonlinear theories are critically compared from the viewpoints of their underlying approach to equilibrium.

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41/BP-43/P

STUDY OF THE FLOATING POTENTIAL USING LANGMUIR PROBE IN A GLOW DISCHARGE PLASMA

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Abstract

The Langmuir probe is one of the key diagnostics used by researchers interested in plasma characterization to measure the internal parameters of the bulk of the plasma in its edge region. . Among the important parameters measured are floating potential, electron density, electron temperature etc. Langmuir probe can be used in various plasma conditions e.g, DC, Radio Frequency, Microwave and Pulsed Plasma. If a Langmuir probe is inserted into the plasma, the surface of the probe is bombarded by electrons, ions and neutral atoms. Due to the high velocity of the electrons compared to the massive ions initially the floating probe draws more electron current. But after some time the negative potential of the floating probe prevents further accumulation of electrons and at this time ion current increases. At certain potential when electron current and ion current are equal is known as floating potential. At this potential, the probe draws no current.

Our experimental set up is a simple DC glow plasma Discharge device which consists of a cylindrical cathode made of stainless steel with diameter 10 cm and a wire anode of 1.6 mm thickness passing through the cathode. The whole setup is mounted inside the vacuum chamber, which is evacuated by an oil rotary pump to attain a base pressure of 0.003mbar and then filled with argon gas (Ar) to obtain the working pressure.

In this study we have measured DC floating potential with the variation of discharge voltage at different pressures ranging from 0.057mbar to 0.210 mbar using Langmuir probe. Experimental results show that at low pressure i.e. at pressure 0.057 mbar DC floating potential increases with the increase of discharge voltage, at pressure 0.082 mbar the increase is small but at pressure 0.100 mbar and above floating potential decreases with increase of discharge voltage. It is also observed that at low pressure rate of increase of floating potential with respect to discharge

voltage is large and this rate of increase becomes slower with the increase of pressure. Further increase of pressure shows opposite trend.

At very low pressure (0.057mbar- 0.082bbar) , with increase of discharge voltage, velocity of the electrons increase which make more ionization collision with the neutral particles. As a result electron current also increase. Therefore, more bias voltage is required to balance the electron flux by the ion flux consequently floating potential increases. If the pressure is 0.10mbar and above floating potential decrease on increasing the discharge voltage and applied pressure. Due to the increase of density of particles drift velocity of electrons and ions decrease. Due to the collision between neutral species and electrons less number of electrons can reach the probe. Thus less bias voltage is required to balance the electron flux by the ion flux.

43/BP-44/P

SELF-ORGANIZATION SCENARIO OF MULTIPLE ANODIC DOUBLE LAYERS

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Abstract

The framework of self-organized criticality (SOC) has been used to study the dynamics of multiple anodic double layers (MADLs) in glow discharge plasma. Multiple double layers are generated in a modified glow discharge plasma setup consisting of two isolated power supplies for both cathode anode. Multiple anodic double layers are produced in front of anode electrode submerged in cathode plasma when $\nu_d > 1.3\ \nu_{te}$. At this condition multiple, double layers consisting of three DLs with alternate dark and bright regions separated with luminous boundaries observed. The confinement of oppositely charged space charges in each layer is associated with the self-organization scenario. Above a certain threshold value of anode bias, MADL approaches a critical state where it began to collapse through the layer reduction process. The fluctuations in floating potential recorded during the critical state were analyzed. The analysis reveals long rage time correlations in fluctuations for time lags in the self-similarity range. The rank function indicates the existence of power law behavior in the tail of the PDF of the avalanche. The power law behavior in the autocorrelation function and power spectrum are in agreement with the above observation. These signatures provide strong evidence to support the argument of SOC in the system. The results provide conditions under which complexity can arise in cold plasma.

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47/BP-45/P

SPATIAL DISTRIBUTION OF CESIUM ATOM DENSITY IN A VACUUM CHAMBER

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Abstract

Ion sources are widely used in physics disciplines and many related application areas like fusion devices, accelerator for nuclear and particle physics, space propulsion etc. Historically, three methods for the formation of negative ions are known: Double-charge exchange, electron-volume process and surface production [1]. A novel technique for the production of negative hydrogen ion using cesium (Cs) coated tungsten (W) dust has been developed in the Dusty Plasma Laboratory of CPP-IPR [2]. For the effective Cs monolayer formation on the tungsten dust, optimization of Cs atom density is an important issue for H^- ion production and extraction experiment. Generally, Cesium is deposited on tungsten dust to reduce the work function [3] for the higher production of negative hydrogen ions. The information on the atomic distribution of Cs for different working pressures is essential to improve the Cs coverage on W dust. The experiment is carried out by inserting 4 nos of Cs ampoules in the Cs oven fitted into the chamber. Surface ionization Detector (SID) [4] is designed using tungsten wires to measure the Cs atom density. The heating of the tungsten wires are done by variac power supply and then Cs^+ ion current is measured by an analog micro ammeter. In this report, the results of the measurements of Cs spatial density profile for different Cs oven [5] temperatures at different working conditions will be presented.

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50/BP-46/P

SELF-ORGANIZATION AND EMERGENCE OF CHAOS ASSOCIATED WITH MULTIPLE ANODIC DOUBLE LAYERS IN GLOW DISCHARGE PLASMA

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Abstract

Multiple double layers (MDL) in plasma represent series of double layers comprising of opposite space charges self-organized in alternate layers with a potential drop of the order of $|\phi_0| \geq kT/e$ across each layer. In this study multiple, double layer are produced in front of a positively biased electrode (anode) immersed in cathode plasma. By maintaining a constant bias across anode and varying cathode bias in the range of 350V-650V different stages of MDL are produced. An initial state of MDL consisting of four concentric layers produced at a lower threshold value of cathode bias V_c= 350 V. The confinement of opposite space charges at different layers is attributed to the self-organization scenario of space charge particles. With increase in cathode bias, space charges at inner layer reorganize and collapse at anode surface. The process continues till all the layers vanishes at anode one by one with increase in anode bias. At 650 V, all the layers disappear and only an intense anode remained at anode surface. The analysis of floating potential at every stage using power spectrum, phase space trajectories, correlation dimension, and Lyapunov exponent and autocorrelation function reveals the emergence of chaos during this process.

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84/BP-47/P

OBSERVATION OF HIGH AMPLITUDE ION ACOUSTIC SHOCK IN MULTICOMPONENT PLASMA WITH NEGATIVE IONS

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Abstract

The properties of shock wave propagation have been studied both theoretically and experimentally in the context of multicomponent plasma, dusty plasma, space plasmas, fusion plasmas and other systems [1-6]. In plasma, when both the dispersion and dissipation effects are present/comparable, shock waves can propagate. The ion acoustic shock in low temperature plasma is represented by the well-known KdV-Burgers equation [7]. Ion acoustic shock normally appears in plasma when dissipative effect dominates over the dispersive effect of the medium in presence of nonlinearity. In a double plasma device, with $T_e >> T_i$, there often present Landau damping along with the normal dispersion which supports the formation of an oscillatory shock wave.

We study ion acoustic shock wave in multicomponent plasma composed of electrons, Ar^+ ions and F^- negative ions. The negative ion density ratio is maintained at r (= n_- / n_+) ~ 0.25. The unique characteristic of the present experiment is the excitation of very high amplitude shock (density perturbation up to 50 %) in negative ion plasma compared to a density perturbation of ~15% in normal two component electron-ion plasma. In order to excite the shock wave we have applied a positive ramp pulse to the anode of the source section. As the perturbation propagates in the target plasma, the leading edge steepens due to the nonlinearity in the medium. Both the dispersion and dissipation effects come into play to balance the nonlinearity leading to formation of the shock. The role of negative ion in high amplitude shock excitation will be discussed. The numerical solution of KdV- Burger equation is considered to compare the experimental results.

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91/BP-48/P

SELF ORGANIZED CRITICALITY OF FLOATING POTENTIAL FLUCTUATION IN A DC DISCHARGE GLOW PLASMA IN THE PRESENCE OF AN EXTERNAL BAR MAGNET

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Abstract

Plasma often shows complex dynamical behaviour. In our experiment we have observed the floating potential fluctuations in a DC discharge glow plasma in the presence of an external bar magnet. Magnetic field strength has been varied by varying the bar magnet distance from the cathode. Floating potential fluctuations of glow discharge plasma were found to exhibit different kinds of oscillations like mixed mode, chaotic etc. The recorded experimental time series data has been analyzed and quantified using power spectra, phase space trajectories. Lyapunov Exponent and Hurst Exponent were estimated to explore the complex dynamics of the system. It has been seen that with increasing the bar magnet distance from the cathode, the oscillation in plasma exhibits ordered – chaos- ordered behaviour. The power spectrum analysis also reveals that type of transition in dc discharge glow plasma. The variation in the chaoticity of different types of oscillations was observed with the study of Lyapunov exponents. Also by auto-correlation function analysis, it was seen all the data sets have a long range correlation and also show SOC (Self Organized Criticality) behaviour.

105/BP-49/P

ELECTRON/ION SHEATH CHARACTERISTICS IN LOW TEMPERATURE AND LOW DENSITY PLASMA

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Abstract

Sheath studies in magnetically filtered plasma are important for design of negative ion sources [1] and also payload design for satellite [2] to understand its interaction with ionospheric plasma [3,4]. We present here the characteristics of electron and ion sheath in a low temperature ($T_e \sim 0.25 - 2.5\ eV$) and low density ($n_e \sim 10^7 - 10^8\ cm^{-3}$) plasma. Argon plasma is produced by DC discharge in a plasma device with two plasma sections (source plasma and diffused plasma) separated by a magnetic filter. Electron/Ion sheaths are produced in front of a stainless steel plate (2 cm in diameter) by biasing it to positive/negative potential respectively. An emissive probe is used to measure the axial plasma potential profile from bulk into the sheath region. We found that in low temperature and low density plasma the Child – Langmuir electron and ion sheath are of nearly same dimension. However, the electron presheath is much longer and penetrates deep into the bulk plasma. Longer electron presheath has been demonstrated in a recent numerical simulation [5]. In low density plasma, Debye length is longer and therefore electron sheath and presheath study becomes feasible. Detailed characterization of the magnetically filtered plasma and sheath structures will be discussed.

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119/BP-50/P

PARAMETRIC STUDY OF A MAGNETIZED HOLLOW CATHODE PLASMA DISCHARGE

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Abstract

The characteristics of a plasma column produced by magnetically coupled hollow cathode plasma device are presented. The discharge is produced by applying a dc potential between a cylindrical hollow cathode and constricted anode, with axial magnetic field coinciding with the chamber axis. The obtained plasma has been found to extend over an axial distance of 0.5 m from the source. Measurements of axial and radial plasma parameters performed using cylindrical Langmuir probe have shown the prominence of two electron populations in the plasma column, whose characteristics vary with the axial distance from the source. It is shown that there is a good agreement between experimentally measured and theoretically predicted values of plasma density for a given discharge power. Thus a qualitative discussion has been presented to describe the global characteristics of the plasma produced by this device.

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128/BP-51/P

A LOCALIZED CATHODE GLOW IN THE PRESENCE OF A BAR MAGNET AND ITS ASSOCIATED NONLINEAR DYNAMICS

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Abstract

A localized glowing, fireball like structure, appears near the cathode surface of a glow discharge plasma device [1] when it is subjected to a magnetic dipole field produced by a bar magnet placed outside the plasma chamber. It is seen that the plasma density in the localized glow region and the luminous intensity of this structure increases with the increase in the magnetic field strength. The effect of such localized glow region on the plasma floating potential fluctuation dynamics is investigated. Floating potential fluctuations show that the emergence of such localized structure leads the system towards nonlinear dynamical regimes. Increasing the magnetic field strength reveals a transition from order to chaos via period doubling bifurcation. This transition is analysed by using bifurcation diagram, phase space plots, power spectrum plots, Hilbert Huang transform, and by estimating the largest Lyapunov exponent. The interaction of plasma with a dipole magnetic field produces a non-monotonic potential structure in the vicinity of the cathode surface. Thus, to understand the dynamical origin of such complex oscillations, we have carried out a numerical modelling for ion dynamics by considering trapping of ions inside the potential structure. Numerical results show the existence of period doubling route to chaos.

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134/BP-52/P

SHEATH IN ELECTRONEGATIVE PLASMA

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Abstract

Electronegative plasmas constitute an attractive field of research due to its immense application in microelectronics industries, high voltage switching technology, surface treatment, and generation of MeV range neutral beams. Since the charge to mass ration of negative ions are similar to that positive ions, not only the characteristics of the plasma but also the transport properties is highly modified. In electronegative plasma, negative ions production can be achieved by two different processes: Volume processes and surface processes. Volume processes involves negative ions production proceeded by dissociative attachment [1] while surface produced negative ions are the result of conversion of positive ions into negative ions or by ion induced sputtering of surface adsorbed atoms [2].

The floating potential measurement in electronegative plasma plays an important role in various plasma application such as in surface treatment and hence can also provide valuable information about the negative ion parameters. The floating potential on a planner electrode in an electronegative plasma has been revisited and its variation with electronegativity has been observed in an experiment which shows a good agreement with the theoretical result. It has been observed theoretically that the absolute value of floating potential increases with electronegativity up to a certain critical value, and then monotonically decreases for electronegativity greater than critical value. A phenomenological model has also been provided to estimate the negative ions temperature by comparing the floating potential verses electronegativity plot with the theoretical curve.

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143/BP-53/P

EFFECT OF EXTERNAL FORCING ON THE PERIODIC OSCILLATIONS OF A DC GLOW DISCHARGE PLASMA SOURCE

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Abstract

Effect of external forcing is studied on the periodic oscillations of a DC glow discharge plasma source. The experiment is performed in a DC glow discharge plasma system whose cathode and anode diameters are 70 mm and 2 mm respectively and are operating at a neutral pressure of 0.1 mbar. Due to the asymmetry in the sizes of the electrodes, an anode glow is formed around the anode surface area which results in the formation of anode glow oscillations in the plasma. These plasma oscillations are kept in the periodic regime such that floating potential oscillation frequency is around 110 kHz. Then, these oscillations are forced from the sinusoidal oscillations of a function generator and change in the dynamics is observed. It has been observed that with increase in the frequency (90 – 250 kHz) of the function generator signal for a constant amplitude, different types of nonlinear states emerged in the plasma oscillations. For a low amplitude forcing, an asymmetric frequency entrainment region (105 – 110 kHz) is observed while for a high amplitude forcing, a symmetric (105 – 115 kHz) entrainment region observed. Also, it has been observed that for a high amplitude forcing, higher harmonic entrainment get merged with each other. We have also done numerical simulation using forced Van der Pol equation and results are found to be in good agreement.

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186/BP-54/P

CHARACTERISTICS OF FLOATING POTENTIAL OF AN ELECTRODE IN MAGNETIZED PLASMA

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Abstract

The equilibrium characteristic of plasma is greatly modified when the magnetized plasma is coupled to an external electrode [1,2]. Under certain conditions, the transport properties of plasma confined by external magnetic field can be largely influenced by presence of electrical floating/biased metallic electrode [3]. This property has practical significance in many applications such as plasma discharges, radio-frequency antennas and limiting walls in tokamak etc. The magnetic field introduces anisotropy in the electron and ion energy distribution. The field lines can intercept the target at arbitrary angles, resulting in complex transport of charge particle flux to the electrode surface.

In this paper the behavior of floating potential of an electrode introduced in axially confined dc magnetized plasma has been investigated using electric probing techniques. The plasma has been produced in argon by applying dc potential between a constricted anode and cathode placed along an axial magnetic field. The magnetic field up to 6 mTesla has been produced by a pair of Helmholtz coil. The circular disc shielded at one face is used as an experimental electrode to investigate the change in the potential of the electrode as a function of magnetic field orientation with the electrode surface. It has been found that the floating potential tends to decrease on increasing the magnetic field strengths when the field lines are transverse to the electrode surface. The results have been discussed based on mathematical formulation of floating potential under the influence of magnetic field.

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191/BP-55/P

MEASUREMENT OF ELECTRON ENERGY DISTRIBUTION IN PRESENCE AND ABSENCE OF CURRENT FREE DOUBLE LAYER IN HELICON PLASMA

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Abstract

Electron energy probability functions (EEPF) are measured in upstream of current free double layer (CFDL) shows very clear change in the energies (E_{break}) correspond the CFDL potential drop. This break energy (E_{break}) distinguishes the low and depleted high energy electrons in the upstream. The temperature of high energy electrons is lower than the low energy electrons. The EEPF in the downstream shows the electron temperature more or less same as depleted high energy electrons in the upstream. In the Helicon plasma experimental system the CFDL is maintain at low pressure (below 0.7 mbar) when the location of magnetic field divergence and geometric expansion is coincide [1]. The CFDL structure can be removed by shifting the magnetic field divergence location away from the geometric expansion by keeping the other operating parameters are same. By doing so there is no depletion in EEPF is observed in the upstream of CFDL location. The results are presented to show that the difference in the EEPFs in the presence and absence of CFDL. This study is also important to understand the kinetics of the electrons in both cases.

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203/BP-56/P

HARMONICS GENERATION NEAR ION-CYCLOTRON FREQUENCY IN ECR PLASMA

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Abstract

Wave excitation at different frequency regime is employed in the MaPLE device ECR plasma [1] for varied excitation amplitude. At very low amplitude excitation, mainly fundamental frequency mode of the exciter signal frequency comes into play. With the increase in the amplitude of applied perturbation, harmonics are generated and dominant over the fundamental frequency mode. There is a fixed critical amplitude of exciter to yield the harmonics [2] and is independent of applied frequency. Observed harmonics and the main frequency mode has propagation characteristics which will be discussed here. Exact mode number and propagation nature are also tried to measure in the experiment. Detailed experimental results will be presented.

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251/BP-57/P

ELECTRON ACCELERATION DURING MULTIPLE DOUBLE LAYER FORMATION IN EXPANDING RF PLASMA

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Abstract

Multiple double layers (MDL) are created in expanding RF plasma of 13.56 MHz in a linear vacuum vessel in absence of any external magnetic field. Although RF discharge is known to be independent of device geometry in absence of magnetic field, but the initiation of RF discharge using a semitransparent cylindrical mesh with a central electrode results in acceleration of electrons and further expansion of plasma in the vessel. The dynamics of MDL formation are studied through electric probe diagnostics. The radial and axial profiles of plasma parameters measured on various locations inside the vessel, at different RF power, show signatures of MDL formation in our operational regime. Present study provides interesting information about the stability of plasma sheath and space charge effects in it. The visibly glowing uniform discharge is observed to evolve in to multiple intensely coaxial luminous plasma structures with increasing RF power. The simple geometry of our plasma source in a cylindrical vacuum vessel provides a good opportunity to study various features and phenomena in RF plasma sheath, which are of immense interest to basic as well as applied research work in plasma physics.

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276/BP-58/P

ON THE RADIAL EXPANSION VELOCITY OF PLASMA PRODUCED BY WASHER STACKED PLASMA GUN WITH AND WITHOUT EXTERNAL NONUNIFORM MAGNETIC FIELD

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Abstract

The experiment is carried out in a curved vacuum chamber [1] in which a washer stacked plasma gun is mounted at one of the radial ports. Argon gas is used to produce plasma from the gun by applying pulse of pulse width~140 μs and potential of 1.4kV. Two Langmuir probes separated by a distance of 0.01m are inserted inside the chamber to get the ion saturation current signals. Probes are biased at potential of about -70 V. All the signals are taken by an Agilent DSO-X 2014A digital storage oscilloscope. Another pulse forming network (PFN) which gives pulsed width~2 ms is used to produce the axial Magnetic field of 250 Gauss at the desired location inside the chamber [2]. Expansion velocities of the plasma structure produced from plasma gun in presence and absence of magnetic field are measured by time of flight method using both probe and high speed imaging diagnostic techniques. The experiment is carried out for the ambient pressure of 0.5 mbar.

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277/BP-59/P

SPECTROSCOPIC STUDY OF TWO INTERACTING PLASMAS IN A COMPACT PLASMA SYSTEM

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Abstract

Interaction of pulsed plasma produces from a washer plasma gun with background plasma (parallel plate type) in a compact plasma system is analyzed using spectroscopic diagnostic. A washer plasma gun is installed in one of the ports of the curved vacuum chamber [1]. Two parallel plate electrodes of copper material are used for background plasma set up inside the chamber [2] and a potential of 600V is applied between the two electrodes to produce static glow discharge plasma. Plasma from the gun is fired by applying a pulse of pulse width~ 140 μs with discharging potential varying from 1kV to 1.4 kV and interacted with the background plasma. Argon is used as working gas to produce plasma for both the systems. Low base pressure of 0.4mb is maintained inside the chamber throughout the experiment. An USB4000 spectrometer and allied optics network of Ocean Optics is used to get the spectrum of the plasma. By assuming that the plasma is optically thin and using the Boltzmann plot method [3] the excitation temperature T_{ex} of background plasma, plasma produced from washer plasma gun and interaction of both the plasmas are measured.

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305/BP-60/P

HELICON WAVE FIELD MEASUREMENTS USING A B-DOT PROBE

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Abstract

Helicon waves have been shown to increase the ionization in plasmas [1] thus making the Helicon wave heated plasmas a strong candidate for ion sources. A permanent magnet based compact Helicon wave heated plasma source has been developed based on conceptual design and performance simulations using HELIC [2]. The HELicon Experiment for Negative ion (HELEN-1) source is a single driver Helicon plasma source that is currently being studied for the development of a large sized, multi driver negative hydrogen ion source. The permanent ring magnet at the top of the source provides an axial dc magnetic field that is radially uniform in the source but diverges downstream of the source. The expansion chamber below the source has an array of multipole confinement magnets. This unique configuration of magnetic field affects the propagation of the helicon wave outside of the source. The magnetic field measurements using a B-dot probe [4] are carried out and the propagation of helicon waves in non-uniform plasma with axially varying refractive index and diverging axial field is being investigated in Argon plasma.

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310/BP-61/P

PROBE POSITIONING SYSTEM FOR LARGE VOLUME PLASMA DEVICE

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Abstract

Large volume plasma device [1] is a large sized, double walled, laboratory plasma device dedicated towards investigating physical phenomena's relevant to earth's magnetosphere a region where besides pressure gradients, role of energetic particles in exciting turbulence induced transport is relevant and turbulence induced plasma transport related problems of present day fusion devices. The device is presently undertaking a major up-gradation of its Machine Control System (MCS). Carrying out investigations over such large volume (~ 9 m^3) requires high level of accuracy in positioning of diagnostic tools at x, y, and z locations and this thus becomes a necessary requirement for the new MCS. The process automation system bringing various auxiliary systems like MCS under single framework is being implemented and a framework for finalizing hardware and software interfaces for process automation [2] has been developed.

An automated electro-mechanical system for positioning of plasma diagnostics have been designed and implemented. It consists of 12 linear electro-mechanical probe drive assemblies, orchestrated using Modbus communication protocol on 4 wire RS485 communications to meet the experimental requirements. Each assembly has lead screw based mechanical structure, bipolar stepper motor, micro-controller based stepper drive and optical encoder for positional correction of probe. The prototyping activities and interface performance has been communicated [3]. A high level application has been developed for simultaneous operation and scheduling of the system. Currently, all 12 assemblies are connected in the radial ports in horizontal mid plane of LVPD.

The novelty in the present system lies in the orchestration of multiples drives on single interface, fabrication and installation of systems for LVPD using in-house developed software and adopted architectural practices. The paper discusses the design, description of hardware and software interface, performance results in LVPD.

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311/BP-62/P

DATA HANDLING SYSTEM FOR LARGE VOLUME PLASMA DEVICE

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Abstract

Data handling system development is a challenging task in large laboratory plasma devices like Large Volume Plasma Device (LVPD) due to (a) multiple diagnostic tools, (b) burst mode of operation, (c) different types of data involved and (d) voluminous data generation, handling and processing. It requires availability of highly redundant hardware server as well as software for specialized hardware interfacing and time synchronization support. LVPD[1] is primarily involved in investigation of plasma phenomenon ranging from active wave plasma interactions, plasma transport especially, induced by Electron Temperature Gradient(ETG) driven turbulence which is considered as a major source of plasma loss in a fusion devices.

The data handling system is charged with the responsibility of uniform integration of various type of data (such as configuration data, raw data, electronic logbooks and processed data) originated from multiple hardware controllers. Machine control system is divided into PXIe based data acquisition system [2] and process automation system [3]. PXIe based data acquisition system offers high channel count (#40 presently), configurable sampling frequency range (60-1250 MHz) and burst mode of plasma discharges. On- going process automation system covers operation of various slow systems but presently limited to probe positioning system(12 no's linear probe drives) and high current filament system. These two systems will be integrated into a specialized data handing server grade hardware which is under final stage of procurements. The architecture handles the data into following tiers (a) local storage of data within plasma pulse on the I&C controller, (b) transfer of data streams to data handling system during inter-pulse operation, (c) off-line data processing on data server and (d) compression and backup mechanism. In case of PXIe where data generation rate is MS/s to GS/s, a RAID based local HDD hardware is used. The process automation system data will be locally on RAID-5 configured industrial PC. This will also collect binary data from various automation controllers, image data and video data from under-procurement IP cameras. All systems will be synchronized using NTP server. The data handling system will run on centralized 12 TB RAID configured Xenon dual processor server. The data handling system will use a hybrid solution of MDS+ [4] and Postgre SQL for software handling. The paper will present the architecture of the data handling system, hardware and software components, ongoing developments, chosen file formats and obtained results.

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314/BP-63/P

IDENTIFICATION OF KELVIN-HELMHOLTZ INSTABILITY IN IMPED PLASMA

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Abstract

Kelvin Helmholtz(KH) instability is commonly observed in hydrodynamic systems in presence of velocity shear. It is excited in Inverse Mirror Plasma Experimental Device [1], for a controlled study of its cause and effects in magnetized plasma. A sheared $E \times B$ rotation that occurs due to the presence of a radial electric field in the presence of a uniform axial magnetic field is identified as the cause of excitation of KH instability. The instability is further characterized by measuring the parallel and perpendicular wavelength, the fluctuation amplitudes of potential, density, etc. Using the control features of IMPED, the spatial localization of KH in IMPED is varied and the experimental data is presented.

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322/BP-64/P

EXPERIMENTAL RESULTS FROM UP-GRADED SMALL ASPECT RATIO TOROIDAL ELECTRON PLASMA EXPERIMENT IN C-SHAPE

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Abstract

A long confinement time of electron plasma, approaching magnetic pumping transport limit had been observed[1] in SMall Aspect Ratio Toroidal Electron plasma eXperiment in C-shape (SMARTEX-C)[2]. The observed long confinement in the presence of magnetic field with a droop (400 to 250 Gauss) is supposed to increase/improve with uniform-high magnetic field. The inner bore of present vacuum vessel limits the conductor size resulting high coil resistance. Further, Ohmic heating of TF coil due to high current causes droop in magnetic field. Keeping the same aspect ratio of the trap, vacuum vessel bore diameter has been increased to accommodate thicker conductor for TF coil. This facilitates uniform high B-field (expected 1000 Gauss for 2s) for experiments. This upgraded vacuum vessel along with new electrode assembly has been designed and fabricated. Vacuum vessel has been electro-polished to achieve 10^{-9} mbar during experimental operation. The trap has some new features from diagnostics perspective too; viz. capacitive probes mounted on various poloidal and toroidal locations have been re-designed to offer better spatial resolution to identify mode structure and velocity. Resistive wall destabilization[3] has been avoided by connecting these probes using Op-Amp based current amplifiers. Charge evolution will also be measured out using non-invasive technique. Radial charge density profile measurement will be attempted using either multiple Faraday cups or Micro-Channel Plates. Initial experimental results along with various phases of up-gradation will be presented in this poster.

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331/BP-65/P

DESIGN AND DEVELOPMENT OF A CIRCULAR WAVEGUIDE TERMINATOR FOR MICROWAVE PLASMA INTERACTION EXPERIMENTS

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Abstract

SYstem for **M**icrowave **PL**asma **E**xperiments (SYMPLE) is an experimental system to investigate the physics of linear and nonlinear interaction of high-power microwave (HPM) [1]. The coupling system uses circular waveguide components. The testing of these components requires terminators compatible with circular waveguides. Impedance mismatches in a radio-frequency (RF) electrical transmission line causes power loss and reflected energy. In an RF transmission system, the reflection of power from the receiving end reduces the efficiency of the system. Sometimes it may even cause damage to the generator. Matched loads or terminations are designed to absorb incident energy without appreciable reflection [2]. Coaxial terminators and waveguide terminators are collectively known as radio frequency terminators or microwave terminators. They are used to absorb energy and prevent a signal from reflecting back from open-ended or unused ports. The design and development of the matched termination for a rectangular waveguide operation on fundamental mode is well established [3-4]. However, circular waveguide terminators are not available conventionally. Hence, R&D efforts are required to have the terminator with circular waveguide.

Present work provides an account on the design and development of WC-281 circular waveguide terminator for microwave plasma interaction experiments and the systematic approach adopted. The developmental steps of the proposed termination assemblage inside the circular waveguide are as follows. Originally a slab of FR4 is placed along the axis of the waveguide to terminate the wave. Then, by changing this slab to a wedge shaped structure (inspired by wedge used in [5]) significant absorption of the wave is attained. To further improve the return loss a quad wedge is used. Subsequently, a resistive cone of Kanthal material placed after the quad wedge to further minimize the microwave energy at the receiving port. Finally, 2-discs of Teflon and a resistive disc are placed to increase the absorption and refine the results. Wedge shape geometry helps in gradually changing the impedance and thus decreasing the return loss S_{11}, while resistive material Kanthal attenuates the field before reaching to the receiving end. This makes the set-up suitable for use as finest microwave terminator. Simulation is carried out by student version of

CST microwave studio. Final model of terminator decreases the return loss (S_{11}) up to -37dB while reduces the transmission coefficient (S_{21}) immensely up to -62dB at 2.85 GHz. To the best of our knowledge, such a geometry of microwave terminator, compatible with circular waveguide has not been explored so far. Thus, the proposed terminator can be used for such applications where high performance, low VSWR, lightweight, and RoHS compliances are required. Further work for enhancing the bandwidth is in process.

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332/BP-66/P

DESIGN AND ANALYSIS OF TUNEABLE WAVEGUIDE DIRECTIONAL COUPLER FOR MICROWAVE PLASMA INTERACTION EXPERIMENTS

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Abstract

SYstem for **M**icrowave **PL**asma **E**xperiments (SYMPLE) is an experimental system to investigate the physics of linear and nonlinear interaction of high-power microwave (HPM) [1]. Directional couplers are in common use for the purpose of measuring the transmitted and reflected power into a waveguide circuit without perturbing the operating characteristics of the circuit [2, 3]. Present work mainly focuses on the design and analysis of tuneable (skewed) Bethe-hole directional coupler for microwave plasma interaction experiments. A MATLAB program is developed to analyze and calculate the various parameters of the proposed directional coupler. The coupler is designed for a coupling factor of 20 dB at 3 GHz. The design parameters are first calculated by analytically using MATLAB program and then validated by using CST Microwave Studio Simulation software [4] for dominant mode (TE_{10}) of rectangular waveguide. The proposed directional coupler is designed by using a standard WR340 rectangular waveguide of aluminium material. Length of the waveguide coupler depends on its design frequency and the directional coupler has a length, $3\lambda_O$ i.e. 30 cm at operating frequency 3GHz. The analyzed aperture distance is 150 mm and skewed angle is 41.23° for requirements specific to our experiments. The coupler shows -26.1dB coupling. By varying the radius of the aperture and skewed angle between the waveguides, coupling level and the directivity of the coupler can be optimized. This makes it suitable for practical use where different couplers are required for different amounts of coupling. Fabrication of this tuneable (skewed) waveguide directional coupler using WR340 rectangular waveguide is under way.

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367/BP-67/P

RADIATION BELTS AND PARTICLE DIFFUSION IN A PLASMA CONFINED BY A DIPOLE MAGNET

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Abstract

A compact table top experiment for investigating plasma confined in a dipole magnetic field by employing a permanent magnet has been developed. As different from earlier large experiments [1 -3], electromagnetic waves in the continuous wave mode have been applied to generate the plasma. It is found that the length scale of plasma confinement lies within ~600 – 1000 λ_D, where λ_D is the Debye length, and happens as a result of balance between the plasma and the magnetic pressure within $\beta \sim 0.4 - 1$ %, where β is the pressure ratio.

Visual observations of the plasma show alternate bright and less bright regions, similar to the radiation belts of the earth's magnetosphere [1-4], as a result of particle trapping. For experimental verification, optical emission spectroscopy (OES) measurements have been carried out by designing a special optical probe, so that the local optical intensity could be collected at each radial position in the plasma. A spectrometer capable of detecting emission spectra in the wavelength range of 200 –1100 nm, with an optical resolution of 0.22 nm is employed for this purpose. Experiments are performed in the pressure range of 0.4 – 2 mTorr for Argon as the test gas, and wave powers in the range 216 – 324 W. Careful investigation of the optical emission occurring at 750.3 nm, 763.5 nm, 772.4 nm and 811.5 nm of the argon plasma are carried out by measuring the radial variation of their intensities.

In order to estimate the plasma density and temperature using OES, the applicability of the Corona model [5] is verified. A modified Boltzmann formula [5] is employed to determine the electron temperature, and the Corona balance equation to determine the electron density. It is found that the results of the plasma parameters obtained using OES agree reasonably well with those obtained from Langmuir probe measurements, namely the plasma (ion) density is of the order ~ 10^{11} cm^{-3}, and the electron temperature lie in the range 2 - 13 eV. Finally, in order to understand the variation of the radial density profiles, the solution of the diffusion equation in the dipole geometry, obtained by modifying the fluid equation of motion along with the continuity equation is performed and the results are compared.

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381/BP-68/P

OBSERVATION OF ELECTRON DRIFT DOMINATED INSTABILITY IN THE NEAR ELECTRON ENERGY FILTER (EEF) REGION OF TARGET PLASMA IN LVPD

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Abstract

The installation of Electron Energy Filter (EEF) in LVPD divides the plasma column into three regions exhibiting different plasma characteristics. These regions are defined as the source, EEF and target plasmas. In this paper, results on plasma of near target region will be reported and compared for different excitation lengths of EEF. The plasma in the region is characterized by 1) flat plasma density and finite gradient in electron temperature and plasma potential, 2) radial electric field is perpendicular to the axial magnetic field and parallel to the electron temperature gradient, 3) weakly magnetized ions i.e. $\nu_{ci} < \nu_{in}$ and magnetized electrons i.e. $\nu_{ce} >> \nu_{en}$, 4) $E_x \times B_z$ drift velocity exceeds the ion sound speed, $V_{E\times B_z} > C_s$ but both exhibit magnitude ($\sim 10^3\, m/s$) similar to the magnitude of electron diamagnetic drift. Density fluctuations peak in the core region ($-30\, cm < x < 30\, cm$) and attains level of $\sim 7\% - 10\%$. The observed turbulence propagates in the ion diamagnetic drift direction. The joint wave number frequency spectra [$S(k,\omega)$] for density fluctuations shows that mode frequency lies between $\omega_{ci} < \omega << \omega_{ce}$.

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387/BP-69/P

PREPARATION AND STUDY OF PLASMA IN BOROSILICATE AND QUARTZ GLASS TUBE

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Abstract

Plasma of argon gas was prepared in glass tube using capacitive coupling and ground plate at particular range of pressure. For plasma preparation a Vacuum to a base pressure of 10^{-4} mbar was achieved in a Borosilicate glass tube with diameter 30mm and length of 400mm. The initial breakdown take place between capacitive coupler and ground by RF generator operating at 13 MHz at 10 watt and discharge builds up until the glass tube is fully filled with plasma. Surface wave is excited at the interface of glass tube and the plasma column and moves along the column. Various studies including pressure dependency on length of plasma column in glass tube and pressure dependency on input power (used in making plasma) were done.
The same experiment was repeated with Quartz tube and conclusion was made that there was a better coupling for making plasma in Quartz tube. Langmuir probe [1] was used to measure density of plasma in glass tube and found to be $6.5 \times 10^{11} cm^{-3}$. Density of plasma in glass tube can be increased by increasing the power by RF generator.

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389/BP-70/P

EXCITATION OF REFLECTED ELECTRON DRIVEN QUASI-LONGITUDINAL (QL) WHISTLERS IN LARGE VOLUME PLASMA DEVICE

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Abstract

Whistlers are electromagnetic waves ($\omega_{ci} < \omega < \omega_{ce}$) generally propagate along the magnetic field lines and at small oblique angles. Evidence of whistlers propagating at large oblique angles or almost perpendicular to the magnetic fields is rarely observed and such whistlers are treated with quasi-longitudinal approximation. Reported theoretical work suggests that the free energy source for such waves lies in energetic electrons or reflected electrons from loss cone distribution. In the present work, we report the observation of Quasi-Longitudinal (QL) whistlers excited by reflected electrons from magnetic mirror formed by the excitation of electron energy filter (EEF) transverse magnetic field in source plasma of Large Volume Plasma Device (LVPD). Experimentally obtained wave dispersion characteristics satisfies the frequency – wavenumber spectra, $S(k, \omega)$ for QL whistlers ($\omega \ll \omega_{pe}$) derived from theory. The mode is electromagnetic in nature and exhibits frequency and wave number ordering in the range of $45\ kHz \leq f \leq 80kHz$ and $0.8\ cm^{-1} < k < 1.2\ cm^{-1}$ respectively.

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391/BP-71/P

TWO-STREAM INSTABILITIES IN THE SHEATH-PRESHEATH REGION OF AR+HE TWO-ION-SPECIES PLASMA

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Abstract

Mechanisms of sheath formation and ions flow to the sheath in multi-ion species plasmas are not fully understood and are subject of frontline research as most of the plasmas in industrial applications, scrape-of-layer (SOL) plasmas of tokamaks, space plasmas, etc. consist of more than one ion species. Recent experiments shows that in two-ion species plasma with nearly equal ion concentrations, both ions having different masses reach the sheath edge with a common speed rather than with their individual Bohm speeds [1]. Theory and simulation suggested that instability enhanced collision friction generated by ion-ion two-stream instability leads to equilibrate the ion velocities at the sheath edge [2,3]. Several experimental observations supports the theory indirectly, however direct evidence of the existence of the instability in the presheath region has not been reported. In this paper we report the direct measurement of ion-ion co-streaming instability in the sheath-presheath region of mesh grid placed in an Ar + He mixture plasma.

Experiments are carried in a linear device in which the plasma is produced using hot-cathode filament discharge method in single and combination of gases. In Ar + He two-ion species plasma, the ion concentration of each species is controlled using mass-flow controllers. Sheath-presheath to be studied is produced around a floating metallic mesh grid, placed at the center of the chamber. Floating potential fluctuations are recorded from a cylindrical Langmuir probe placed near the sheath edge and from the grid. The frequency spectra obtained from the signals shows two distinct broad-band peaks in the range 10-30 kHz and 150-300 kHz. The frequency peak at 150 – 300 kHz range is identified as the ion-ion co-streaming instability as the peak disappears in single ion species plasma. The 10 – 30 kHz peak remains in both single and two ion species plasma and is identified to be ion-ion counter-stream instability [4]. The phase velocity and wave number of the waves are measured by cross-power spectrum of the signals acquired simultaneously from grid and a movable Langmuir probe. The measured wavenumber of both the instabilities matches fairly well with those calculated from the dispersion relations [5]. The identification, characterization and analysis of both the above-mentioned instabilities will be presented.

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394/BP-72/P

STUDY OF PARTICLE TRANSPORT DUE TO ELECTROMAGNETIC FLUCTUATIONS IN ETG SUITABLE PLASMA OF LVPD

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Abstract

Plasma transport in magnetically confined plasma devices remains an unresolved issue for fusion plasma fraternity [1, 2]. Although, significant progress has been made for transport over ion scales but electron scale transport still remains an unresolved issue. Pursuing this, in LVPD, successful demonstration of unambiguous ETG turbulence is made [3]. In high beta ($\beta \sim 0.6$) ETG plasma of LVPD, plasma transport due to electrostatic and electromagnetic fluctuations has been investigated. Observations show that the measured particle flux predominantly remains electrostatic ($\Gamma_{es} \approx 10^5 \Gamma_{em}$). Electromagnetic particle flux (Γ_{em}) results from correlation between parallel electron current ($\delta J_{\parallel e}$) and radial magnetic field (δB_r) fluctuations. A comparison of the observed electromagnetic particle flux with theoretical predictions for LVPD plasma will be presented.

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413/BP-73/P

INWARD TURBULENT PARTICLE FLUX IN ETG DOMINATED PLASMA OF LVPD

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Abstract

Understanding turbulent plasma transport in magnetized plasma is a subject matter of great significance from the perspective of understanding plasma loss in fusion devices. Significant progress has been made in understanding physics of ion thermal transport over the past decade but various aspects of turbulent transport in electron and particle channel still remains to be elucidated. In this background, successful demonstration of unambiguous excitation of ETG turbulence ($\nabla T_e \neq 0, \nabla n_e \approx 0, \nabla \phi_p = 0$ and $\eta_{ETG} = L_n / L_T > 2/3$, where $L_n \approx 300cm$ and $L_T \sim 50cm$) is made in Large Volume Plasma Device (LVPD) by using Electron Energy Filter (EEF). Radial profiles of turbulent particle flux and cross phase between density - potential, ($\theta_{ne-\phi}$) has been measured. It is observed that the net electrostatic flux ($\Gamma_{es} \sim -10^{18} m^2 s^{-1}$) is negative and is directed radially inward. The particle flux maximizes in core of EEF ON plasma, suggesting that the flux is due to ETG driven turbulence. Theoretical prediction suggests that existence of net particle flux results when phase difference, $\theta_{n_e,\phi} \neq 180^0$, this agrees well with the observations. Also, turbulence intensity maximizes roughly at radial locations where particle flux is maximum. Experimentally obtained phase angle and particle flux values agree well within 20% to the theoretical estimations. Comparison of experimental results with theoretical model, suggesting observed turbulent particle flux as thermo diffusive will be presented.

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419/BP-74/P

ANALYSIS AND APPLICATIONS OF SOFTWARE DEFINE RADIO IN PLASMA DIAGNOSTICS

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Abstract

Diagnostics signals from remote locations of plasma experiments can be directly fed to computer using SDR. Traditionally Radio components such as modulators, demodulators and tuners are implemented in hardware, but Modern computing allows most of these traditionally hardware based components to be implemented into software.

A software Define Radio (SDR) able to do demodulation in wide band of frequency range (20MHz to 1.7GHz). In this paper experiment study of various demodulation techniques like AM, FM, PM using RLT.SDR has been described. Comparison of experimental results was carried out between SDR and spectrum analyzer. Parameters like Frequency Spectrum and antenna power was measured. Analysis of RF filter was carried by SDR.

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424/BP-75/P

WETTING PROPERTIES OF ATOMICALLY HETEROGENEOUS SYSTEMS CREATED BY MICROWAVE PLASMA GENERATED LOW ENERGY NOBLE GAS ION BEAMS

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Abstract

A microwave plasma based ion source has been developed in our laboratory, that is capable of delivering both single broad ion beams and controllable multiple ion beamlets [1]. The uniformity of the broad beams was verified over a diameter of 2 cm and the micron beamlets could be extracted through sub-Debye length plasma apertures. In this work, we report the effect of extracted noble gas ion beam irradiation at 0.5 keV on the wetting properties of metallic thin films [2]. Traditionally, wettability was investigated by introducing physical [3] or chemical heterogeneity on the surface [4, and refs 6, 12 - 17 therein] and explained by the formalism of Wenzel and Cassie-Baxter.

Ion irradiation causes implantation of atomic impurities in the near surface atomic layers of the target which modifies the dispersive intermolecular interaction and thereby reduces the surface free energy making the metallic surfaces more and more hydrophobic. The distinction of the systems thus formed lies in the facts that firstly, since the embedded species are inert gas atoms, they do not introduce any chemical modification of the target. Additionally, such systems containing atomic scale heterogeneities are operationally homogeneous. Secondly, where the Wenzel and Cassie-Baxter models predict a linear variation of the unit area solid-liquid interfacial energy with physical and chemical heterogeneities, atomically heterogeneous systems exhibit a non-linear variation of the aforesaid interfacial energy with increase in the concentration of the embedded atomic species. The hysteresis of atomically heterogeneous systems arises primarily from liquid retention, whereas, for physically and chemically heterogeneous systems, pinning plays a key role in producing hysteresis.

In order to check the long term sustenance, we examined for more than a month and found that the ion implanted metallic surfaces retain the modified wetting character. Hence, the diffusion of ions is particularly small in this case. The probability of diffusion in this time scale will be checked by Fick's law of diffusion. However, the Fick's law does not take into account the crystalline character of the diffusion medium. Alternatively, the sustenance of the implanted ions may be understood by the probability of forming inert gas nano-bubbles which could form a

superlattice inside the metallic lattice [5]. Thus, wettability may be employed as a novel tool for estimation of doping concentration and (or) diffusion of interstitials within lattice network.

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426/BP-76/P

REVISIT OF CUSP LEAK WIDTH FOR ARGON PLASMA IN A MULTI CUSP PLASMA DEVICE WITH VARIABLE FIELD VALUES

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Abstract

Plasma confinement by multi-cusp magnetic field has found wide applications in the development of ion sources, plasma-etching reactors etc. The efficiency of multi pole cusp magnetic field plasma device depends on the plasma and energetic electron losses through cusp leak width. The leak width is the width of the profile of plasma escaping through the cusp. Many aspects of the experimental results are not understood and numerous explanations have been proposed to understand leak width. The exact scaling for the amount of plasma leaking is not known, though many scaling exist ranging from ion gyroradius to electron gyroradius apart from the so-called 'hybrid gyroradius'. Several theoretical explanations were given for the hybrid gyro radius leak widths obtained. The size of leak width depends on the micro turbulence, electron-neutral collisions and electrostatic effect in the plasma. In this article we discuss the instability at the cusp region, and then calculate leak width using this instability. We also discuss the effect of leak width on plasma mean densities and its fluctuation, particle confinement time.

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442/BP-77/P

INVESTIGATION OF THE HEATING MODE TRANSITION IN CAPACITIVELY COUPLED RADIO FREQUENCY DISCHARGE

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Abstract

Capacitively Coupled Radio Frequency (CCRF) discharges are sustained through two heating modes. At high pressures, *collisional ohmic heating* characterized by a Druyvesteyn or a Maxwellian-type EEDF (Electron Energy Distribution Function) dominates. At low pressures, *collisionless stochastic heating* characterized by a bi-Maxwellian EEDF is prominent, which is not yet fully understood [1-3]. Thus, investigation of the transition from collisional to collisionless regime plays an important role in the understanding of the power coupling mechanisms occurring in RF discharges.

The major drawback in determining EEDF from the second derivative of the electron current is associated with the noise already present in the I-V characteristic of Langmuir Probes (LP) that is amplified further by the double differentiation operation [4]. In this paper, a new approach for determining EEDF that is based on computation of the *marginal, 1-dimension probability density functions* (MPDF) and only requires the first derivative of the electron current to be computed is presented. By cutting down on one derivative operation, there is a drastic reduction of the noise that is invariably added during the numerical differentiation process. This improves the sensitivity of the EEDF to weak, high energy populations that are found in many plasmas. In fact, it is noteworthy that although such populations are actually detected by a Langmuir Probe (as obtained from a careful analysis of the LP data), these are lost when determining EEDF by the double-differentiation method. It is, however, possible to retrieve such populations using the single differentiation method proposed in this paper. Investigation of EEDF transitions from the collisional to stochastic regimes in capacitively coupled plasmas (CCP) using the above technique is underway and it is hoped that it should be possible to resolve the bi-Maxwellian populations mentioned above with greater clarity and reliability. The experiments were conducted in an asymmetric parallel plate CCRF discharge, using RF power at 13.56MHz in argon gas from 5mTorr to 500mTorr. A 3-stage, compensated LP was used for all LP measurements. Some of the results from the ongoing experiments will be presented in the conference.

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443/BP-78/P

OPTICAL EMISSION SPECTROSCOPY AND ELECTRICAL MODELLING OF ATMOSPHERIC PRESSURE MICRO PLASMA JETS

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Abstract

Cold atmospheric pressure plasma jets (APPJ) have received great interest due to its several applications in plasma medicine and environment. It is a non-equilibrium plasma, where the electron and ion temperatures are quite different [1]. Among the many different configurations of APPJ, the ring electrode configuration has been used in our experiment, where two ring electrodes are wound around a dielectric capillary tube, with a positive bias applied to one electrode, and the other electrode is grounded. Optical emission spectroscopy (OES) measurements have been carried out at different flow rates and inter-electrode spacing. We have particularly investigated: (i) at a fixed inter-electrode spacing, how does the optical intensity change with gas flow rate, and (ii) for a fixed flow rate, how does the optical intensity change with inter-electrode spacing. A typical optical spectrum reveals several emission lines such as N_2 (390 nm), N_2^+ (427 nm), He (587 nm, 667 nm, 706 nm), H-α lines (656.3 nm), O-I (777 nm) [2] etc. Results indicate that the intensity of the lines are a maximum at a particular inter-electrode spacing (~ 2.5 cm), and for this inter-electrode spacing the intensities increase with flow rate. The electron temperature (T_e) and the electron density (n_e) are determined from Boltzmann plot and stark broadening of the H-α lines respectively.

We have tried to electrically model the discharge. The APPJ is a dielectric barrier discharge (DBD) inside the quartz capillary tube, which exhibits collective phenomena of individual micro discharges that are short lived (few nanoseconds to microseconds)[3]. The electrical elements like discharge current and gap voltage are not directly accessible. Therefore, in order to understand the dynamics of the discharge inside APPJ, an electrical model is being developed for our APPJ system. The electrical circuit for the ring electrode configuration APPJ consists of gas capacitance (C_g), gas resistance (R_g) and capacitance of the quartz tube (C_d), which are in series connection with the HV electrode, however, when the discharge starts the capacitance and resistance of the gas changes non-linearly and have to be taken into account. Results of the optical emission spectroscopy and the electrical modeling will be presented in the conference.

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448/BP-79/P

STUDY OF MAGNETIZED PLASMA EXPANSION

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Abstract

The study of expanding plasmas in the presence of a magnetic field is an old but yet not fully understood problem. Introducing magnetic field to the plasma particles makes their dynamics more complex and interesting. In this paper, some aspects of dynamics of expanding plasma in a diverging magnetic field are presented. Argon plasma is produced by electron cyclotron resonance (ECR) heating mechanism in a small dielectric tube (I.D. 85 mm × Length 116 mm). This plasma is allowed to expand into a large volume stainless steel chamber. A permanent ring magnet (NdFeB) on the source side fulfils the ECR requirement and also offers a diverging magnetic field to the flowing plasma particles [1-2]. Langmuir probe measurements on the expanding plasma confirm the existence of two distinct electron populations everywhere in the expansion chamber irrespective of neutral pressure and microwave power. Measured bulk electron density is ≈ 10^{11}-10^{12} cm^{-3} with temperature ≈ 4-5 eV. Warm electrons have high temperature ≈ 60-80 eV and constitute of 0.1% of bulk electron density. Plasma expansion is found to be a polytropic process (polytropic index γ >1) which in turn indicates that plasma is accelerated at the expense of electron thermal energy. Primary signature of double layer structure formation near the source exit has been observed at low pressure regime (< 0.5 mTorr). This kind of structure accelerates the particles traversing through them and may be useful in ion beam production and thruster technology [3]. An ion energy analyzer is being installed in the system, which is expected to throw more light on ion acceleration in the expanding plasma.

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454/BP-80/P

STUDIES OF ECR PRODUCED HYDROGEN PLASMA FOR H^- GENERATION

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Abstract

Negative hydrogen ion (H^-) beams have great importance for neutral beam heating of fusion plasmas because they can be efficiently charge-neutralized to form neutral beams at particle energies of ~ 1 MeV. There are several research efforts going on worldwide to build H^- sources; nonetheless substantial production of H^- inside a plasma source still remains a challenging task due to the feeble electron affinity of H^- (~ 0.75 eV) and little understanding of the complex processes involved [1]. In order for the scheme to be successful it is important that one be able to produce high density, robust, very-large volume hydrogen plasma over a large cross-section so that the required ion current (~ 30 – 40 amps over an area of 1sq.m.) can be extracted. To make such a technology viable and sustainable, it is important to be able to produce the starting hydrogen plasma extremely efficiently in terms of power input to the device. With this aim in view, the current work aims to undertake a systemic study of hydrogen plasmas produced in Electron Cyclotron Resonance (ECR) discharges. Experiments were carried out in hydrogen plasmas inside a Compact ECR Plasma Source (CEPS) [2, 3] attached coaxially to a large stainless steel cylindrical chamber (length ≈ 75 cm, ID ≈ 50 cm). The CEPS consists of a cylindrical, stainless steel plasma source section (ID ≈ 9.1 cm, length ≈ 11.5 cm) which is surrounded by a coaxially placed NdFeB permanent ring magnet assembly. The magnets not only provide the ECR magnetic field, but also penetrate the larger expansion chamber into which the plasma diffuses. Cylindrical Langmuir probes (LP) were used for local plasma parameter measurements inside the source and expansion chamber as well. At 500W microwave power and 1 mTorr neutral pressure, the plasma density is found to decrease from $\approx 10^{11}$ to 10^{10} cm^{-3} over a distance of 20 cm from the source along the axis, while the electron temperature falls from ≈ 12 to 7 eV. A global model is also being developed to obtain a preliminary estimate of the plasma parameters in the discharge. Further results will be presented at the conference.

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456/BP-81/P

PRELIMINARY INVESTIGATION ON HIGHLY ASYMMETRIC PARALLEL PLATE GLOW DISCHARGE PLASMA

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Abstract

Plasma investigations have been carried out with a highly asymmetric parallel plate electrode system (cathode to anode surface area ratio ≈ 90; cathode: grounded) placed inside a grounded vacuum chamber. The experiments were performed by covering the electrode system by a cylindrical glass tube and mica discs at its two ends in three different configurations: (I) when the discharge was allowed only between the electrodes by covering them with a glass tube and mica discs at the ends, (II) when a deliberate leak had been introduced using smaller diameter mica discs that allow plasma to escape from the ends to reach the vacuum chamber, which itself acts as a cathode and (III) when the discharge is exposed to the whole chamber. In each configuration *I-V* characteristics of the discharge has been taken and the plasma parameters have been measured using a Langmuir probe. Preliminary experiments have revealed that there is a variation in the existence of the negative differential resistance and the associated anode glow dynamics in the three configurations. This variation is seemingly related to the bistable nature in the sustenance of the discharge. These experimental results and inferences will be presented in this paper.

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457/BP-82/P

STUDY OF EFFECT OF MULTI-LINE CUSP MAGNETIC FIELD ON PLASMA PARAMETERS

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Abstract

External magnetic field (MF) being used for the plasma confinement since several decades. It has been observed experimentally that the magnetic field geometry affects the plasma parameters. Cusp magnetic field geometry has been invented for the plasma confinement as many other magnetic field configurations. It has been reported in several works [1-3] that the multi-cusp magnetic field configuration confines the primary electrons and increases the plasma density by 2-3 order of magnitude. The plasma confined in multi-cusp geometry has less than ≤1% fluctuations (quite quiescent). It is very fascinating and demanding in the case of neutral ion beam source in which a quiescent, uniform and dense plasma is required and this field configuration is one of the best in this regard. People are also trying to use cusp magnetic field geometry in fusion reactors since 1970's.

Multi-cusp geometry has several kinds of magnetic field profiles depending on the alignment of magnets. In this paper, the effect of different multi-cusp geometries on electron temperature, density, and other plasma parameters will be reported. All measurements have been carried out in the collisionless regime of low-temperature argon plasma in Multi-cusp plasma device (MPD), fabricated in Institute for Plasma Research. The axial magnetic field is nearly zero in MPD, hence the radial and azimuthal component of MF playing a significant role in plasma confinement. The measurements have been performed using Langmuir probe.

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478/BP-83/P

EXPERIMENTAL MEASUREMENT OF ION CONCENTRATION RATIO IN Ar+He TWO-ION-SPECIES PLASMA

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Abstract

Ion-ion two-stream instability is believed to be responsible for driving individual ions to reach the sheath edge with equal velocity in two-ion species plasmas [1]. Several experiments have been carried out in different gas combinations to verify the theory [2-4]. Since the instability depends on the ion concentration ratio, it is a vital to know the ion concentration ratios in different partial pressure combinations. Since Ionization cross section is different for different gases, therefore ion concentration ratio does not vary linearly with their respective neutral density concentrations. Hence, individual ion concentrations are required to be measured. In this paper we present measurements of ion concentration ratio in Argon (Ar) and Helium (He) two-ion- species plasma by measuring the ion acoustic wave group velocity and the electron temperature.

Experiments are carried in a linear device made of stainless steel cylindrical chamber of length 50 cm and diameter 20 cm. The inner surface of the chamber is covered with poloidal array of permanent magnets forming a cusp configuration to achieve higher plasma density. Plasma discharge is maintained by hot-cathode filament discharge method. Chamber is evacuated up to 5×10^{-6} mbar base pressure before Ar and He gases are filled at different pressures. For the present experiment, the total pressure is kept fixed at 3×10^{-3} mbar and partial pressure of gases is varied by controlling gas flow using two mass flow controllers. The perturbations are launched from a grid (5×5 cm^2 area and ~70% transparency) immersed in a plasma by applying a sinusoidal burst of different frequencies using a function generator and detected by Langmuir probe (having tungsten tip of length 1 cm and diameter 1mm) at different locations away from the mesh. Time delay between the detected waves at different spatial locations is plotted with different probe locations and slope of curve gives velocity of ion acoustic wave. Using ion acoustic wave velocity relation, the ion concentration ratio is obtained as a function of partial pressure for both ions. An attempt is also made to measure the ion concentrations using spectral line intensity ratios.

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485/BP-84/P

ELECTRON ENERGY PROBABILITY FUNCTION AND L-P SIMILARITY IN INTENSE MICROWAVE PLASMA

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Abstract

In an earlier work, Chatterjee *et. al*. [1] performed Particle-in-Cell (PIC) simulation in order to investigate the effect of discharge length (L) and neutral gas pressure (p) on the Electron Energy Probability Function (EEPF) in a low pressure radio frequency (rf) Inductively Coupled Plasma (ICP) at 13.56 MHz. It was shown that the effect of varying L and p have qualitatively similar effect on EEPF and thus on the related plasma parameters such as electron temperature and electron density. This was called “L-p similarity”. The goal of the present research is to experimentally investigate the above mentioned L-p similarity in a magnetically bound intense microwave generated plasma at 2.45 GHz.

Earlier computer simulation was a gedanken experiment where the plasma system was bounded in only one direction and was infinite and unbounded in the other two directions. The discharge length was considered to be the distance between the boundaries in the bounded direction where the sheath is formed. However, for microwave ignited multicusp bounded plasmas [2], the plasma sheath is expected to form along the radial boundary and thus the radius of the multicusp should be considered as the discharge length. In order to verify the aforementioned similarity, we propose to measure the EEPF of plasmas formed inside multicusps of different radius. For this purpose, octupole (8 poles), decapole (10 poles) and duo-decapole (12 poles) multicusps of the same length have been fabricated and magnetic field has been measured along a radial direction in the middle. It was found that the minimum B-field at the central region is largely the same for the three multicusps. However, the location of Electron Cyclotron Resonance (ECR) was found to be nearer to the periphery for multicusp having greater number of poles. Therefore, during the experiments, the microwave power density should be kept fixed for all the multicusps and the wave power should be adjusted accordingly. We have fabricated two planar Langmuir probes. From the I-V characteristic of the Langmuir probe, the electron temperature, electron density and the EEPF can be evaluated [3]. Additionally, since the simulations were performed in an one dimensional system, 1-D particle balance model was employed to compare the simulation results. For the present case, 3-D particle balance model needs to be applied [4].

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489/BP-85/P

IMAGING OF ARGON PLASMA IN MULTI CUSP PLASMA DEVICE

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Abstract

In multi cusp plasma device (MPD) cusp magnetic field has been used to confine the argon plasma produced by six electromagnets. This device can be configured in many different cusp geometries as an advantage of use of electromagnet. The visual characterization of effect of cusp magnetic field on argon plasma under different cusp geometries and field strength will be presented.

480/BP-86/P

STUDY OF PLASMA INSTABILITIES IN ECR ION SOURCES

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Abstract

Plasma instabilities play a crucial role in order to determine the charge state distributions inside ECR ion sources. The ECR plasma is a highly dynamic environment which is prone to various instabilities that are driven by electrons of energy ranging from few eV to few keV. The confinement duration of ion should be long enough so as to ionize it to higher charge state or fully stripped state. The multiple ionization by electron impact leads to the formation of high charge states. It has been reported in various studies that the ion has to survive the instability events so as to survive in the confinement duration.

Tarvainen et. al. [1,2, 3] have recorded beam current oscillations from ECRIS together with their corresponding Fourier spectra. Two oscillation "modes" with different characteristics were observed; one with frequencies below 200 Hz and the other in the frequency range of 0.3–1.3 kHz. The higher frequency "mode" is achieved with low neutral gas pressure and strong solenoid magnetic field (Bmin> 0.75BECR). To increase the high charge state ion current by improving the ion confinement time and thus the plasma density, it is possible by increasing the magnetic field strength or the microwave power. But these conditions make the plasma prone to instabilities that can limit the average extracted currents of highly charged ions. It imposes the constraints on beam tuning parameters available for optimization. Normally a plasma cyclotron instability is associated with a burst of bremsstrahlung (electrons) driven by hot electrons interacting resonantly with electromagnetic plasma waves. It also shows millisecond timescale oscillations in the extracted beam currents. This study is being carried out in ECR ion sources presently operating at IUAC, New Delhi in order to understand their performance over a wide tuning range.

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31/BP-87/P

STUDY OF THE EFFECT OF EXTERNAL MAGNETIC FIELD IN A GLOW DISCHARGE PLASMA

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Abstract

The formation of Plasma by electrical discharge of a gas and its breakdown mechanism is of high interest. Plasma processing is widely used in semiconductor fabrication, sterilization of medical tools etc. From the technical point of view, the inter electrode distance has a crucial role to design and optimization of such devices. In this experiment, the state of matter transition from gas into plasma is investigated, allowing the study of Paschen's curve in which a voltage is applied between two cylindrical electrodes. According to Paschen law, the breakdown voltage is function of the pressure (p) and distance between the two electrodes (d). Argon plasma is formed between these two electrodes made of stain less steel. The size of the cylindrical cathode length is 20 cm and diameter 10 cm and central wire anode of diameter 1.6 mm. The whole setup is mounted inside the vacuum chamber, which is evacuated by an oil rotary pump to attain a base pressure of 0.003mbar and then filled with argon gas (Ar) to obtain the working pressure. A magnetic field is applied by using single bar magnet as well as double magnet (from opposite sides of the cylindrical cathode)

Initially we studied the nature of Paschen Curve in a glow discharge plasma in absence of the external magnetic field where pressure was varied from 0.05 m-bar to 0.5 mbar. The whole experiment was repeated twice in the presence of a single bar magnet and double bar magnets which were placed very close to the cylindrical cathode surface (~5 cm from centre of the cylindrical cathode). From our data it is very interesting to note that the effect of the magnetic field on Paschen curve is remarkable above pressure 0.1 mbar. We have also observed the effect of hysteresis in our results. Single glow in the plasma was observed when single magnet [1] was used and double glow was observed when both the magnets were used.

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458/BP-88/P

SOME EXPERIMENTS WITH DISCHARGE TUBES

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Abstract

An evacuated glass discharge tube was probably the first plasma devise ever built. This simple devise has lead to many epoch making discoveries like those of electrons, x-rays etc. The discharge tube was known as early as 1843 and perhaps even Michel Faraday was familiar with it. The discharge is notable for its colourful display of striations and standing waves. This makes it a popular item in science museums. But it is not confined to that. Even today research is being conducted on the plasma properties of discharge tubes both from the points of view of basic and applied sciences. Here we present some preliminary results of our studies on striations, standing waves and temporal fluctuations in discharge tubes.

120/BP-89/P

EFFECT OF PARALLEL CONNECTION LENGTH ON FLOWS, FLUCTUATIONS AND QUASI-STATIONARY EQUILIBRIUM IN A SIMPLE TOROIDAL DEVICE

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Abstract

The Topology of the toroidal magnetic field (B_T) in toroidal devices plays a significant role in controlling the plasma flows, fluctuations and hence equilibrium in these devices. However, without any external vertical field (B_v) the toroidal field lines are supposed to close on themselves, but due to misalignment of toroidal field (TF) coils or presence of uncompensated leads in TF coils may provide a vertical component of the magnetic field and it may lead to the opening of toroidal field lines. To study the phenomenon due to toroidal field topology, one needs to experimentally determine the inherent opening of these field lines. A simple yet novel method by Thatipamula et al.,[1] has been used in BETA by using a tiny plasma beamlet to experimentally determine the inherent offset in toroidal field line and hence topology of field lines. Moreover, application of an external vertical field (B_v) provides a significant control over the topology. Field lines can be nearly close and widely opened by applying an external vertical field.

BETA is a simple toroidal device (SMT) with the major radius of 45 cm and minor radius of 15 cm; the toroidal field can be applied up to 0.1 T. A detailed experimental study of flows, fluctuations and quasi-stationary equilibrium by varying the parallel connection length L_c by application of B_v and for a fix B_T has been performed in BETA [2]. It has been shown that as L_c varies with variation in B_v the nature of fluctuations and flows changes significantly which in turn affects the equilibrium and nature of fluctuations in simple toroidal devices.

It is well known, that L_c depends on the ratio of B_v and B_T. Therefore, B_v and B_T are varied simultaneously to study the effect of parallel connection length, L_c on quasi-static equilibrium, flows, and fluctuation in an SMT. In the present work, a detailed experimental study of variation of L_c with varying ratio of the vertical and toroidal field will be presented.

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90/BP-90/P

INVESTIGATION OF KURTOSIS SKEWNESS RELATION FOR OSCILLATION IN A DC GLOW DISCHARGE PLASMA FOR VARYING DISCHARGE VOLTAGE

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Abstract

The information in the amplitude probability density of a time series data of a fluctuating quantity is not always easy to estimate due to finite record length, and such reduced level of information can be more attractive. Experimental data obtained in different systems have indicated that third and fourth order moments i.e. Skewness and Kurtosis are not at all independent in case of low frequency turbulence. These two parameters are in a parabolic relationship for a turbulent system[1]. Floating potential fluctuation in DC Glow Discharge Plasma is subjected to different plasma parameters like- discharge voltage, pressure, externally applied magnetic field etc. Plasma oscillation is a great example of non-linear dynamical system- where the afore-mentioned parameters determine the behavior of the dynamics. Here we look into the floating point fluctuation for variation of discharge voltage for two fixed pressures and with no external magnetic field (except earth's magnetic field). Qualitative analysis of the data with FFT and Phase-Space Plot shows a transition from irregular mixed mode oscillations (MMOs) to ordered MMOs at lower voltages, and again irregularity at higher voltage. This transition is analyzed quantitatively with Lyapunov exponents. Also self-organized criticality is analyzed with Hurst exponent and autocorrelation function. Measuring the skewness and kurtosis of the pdf and analyzing their parabolic relationship we predict a low frequency turbulence present in the plasma.

59/BP-93/P

STABILITY OF DUST ION ACOUSTIC SOLITARY WAVES IN A COLLISIONLESS UNMAGNETIZED NONTHERMAL PLASMA IN PRESENCE OF ISOTHERMAL POSITRONS

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Abstract

A three-dimensional KP (Kadomtsev Petviashvili) equation is derived here describing the propaga- tion of weakly nonlinear and weakly dispersive dust ion acoustic wave in a collisionless unmagnetized plasma consisting of warm adiabatic ions, static negatively charged dust grains, nonthermal electrons, and isothermal positrons. When the coefficient of the nonlinear term of the KP equation vanishes an appropriate modified KP (MKP) equation describing the propagation of dust ion acoustic wave is derived. Again when the coefficient of the nonlinear term of this MKP equation vanishes, a further modified KP equation is derived. Finally, the stability of the solitary wave solutions of the KP and the different modified KP equations are investigated by the small-k perturbation expansion method of Rowlands and Infeld [J. Plasma Phys. 3, 567 (1969); 8, 105 (1972); 10, 293 (1973); 33, 171 (1985); 41, 139 (1989); Sov. Phys. - JETP 38, 494 (1974)] at the lowest order of k, where k is the wave number of a long-wavelength plane-wave perturbation. The solitary wave solutions of the different evolution equations are found to be stable at this order.

66/BP-94/P

MODULATIONAL INSTABILITY OF ION ACOUSTIC WAVES IN A MULTI-SPECIES COLLISIONLESS UNMAGNETIZED PLASMA CONSISTING OF NONTHERMAL AND ISOTHERMAL ELECTRONS

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Abstract

A nonlinear Schrödinger equation is derived to study the modulational instability of finite amplitude ion acoustic waves in a collision less unmagnetized plasma consisting of warm adiabatic ions and two distinct populations of electrons, one is due to distributed energetic electrons described by Cairns et al. [Geophys. Res. Lett. 22, 2709 (1995)] which generates the energetic electrons, and the other is the isothermal electrons. The instability condition and the maximum growth rate of instability have been investigated numerically. We have studied the effect of each parameter of the present plasma system on the maximum growth rate of instability. In particular, it is found that the maximum growth rate of instability increases with the increasing values of the wave number for any given set of values of the parameters associated with the present plasma system. It has also been shown that for any fixed value of the wave number, the maximum growth rate of instability increases with increasing values of the nonthermal parameter associated with the Cairns distributed energetic electrons.

81/BP-95/P

AMPLIFICATION OF UPPER HYBRID WAVE THROUGH NONLINEAR INTERACTION WITH LOWER HYBRID WAVE IN INHOMOGENEOUS PLASMA

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Abstract

We consider lower hybrid turbulence field supported by inhomogeneous plasma. Accelerated electrons which are in phase relation with lower hybrid turbulent field may transfer its energy to unstable upper hybrid wave through a modulated field nonlinearly. Thus, unstable upper hybrid wave may be generated at the expense of lower hybrid turbulent wave energy. Plasma inhomogeneity provides source of free energy to the turbulent wave besides momenta source provided by confining field. On the other hand dissipation of unstable upper hybrid wave energy is possible through radiation phenomena after conversion while propagating in this inhomogeneous plasma. We have estimated the growth rate of upper hybrid wave using magnetospheric plasma data.

82/BP-96/P

ON THE AMPLIFICATION OF ION ACOUSTIC WAVE IN BURNING PLASMA

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Abstract

Generation of high frequency ion- acoustic wave in burning plasma is investigated in presence of drift wave turbulence field. Drift wave turbulence is supported by plasma inhomogeneity of a burning plasma. This low frequency wave's phenomenon is playing a crucial role in accelerating plasma particles as they are found to be strongly in phase relation. Frequency of ion acoustic wave in burning plasma may be amplified when the accelerated plasma particles transfer their energy to ion- acoustic wave nonlinearly through a modulated field. Considering a particle distribution function for inhomogeneous plasma, we have evaluated fluctuating parts of distribution function due to drift wave turbulence using Vlasov equation. We have also obtained nonlinear fluctuating parts of distribution function due to modulated wave and ion acoustic wave. We have estimated the growth rate of ion acoustic wave using nonlinear dispersion relation for ion acoustic wave.

281/BP-98/P

TUNGSTEN HOT PLATE IONIZER FOR MULTI-CUSP PLASMA DEVICE: IMPROVED DESIGN

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Abstract

Fully ionized plasma will be produced by contact ionization of low work-function alkali atoms (like Cesium, Potassium etc.) on a very hot ionizer plate (~2300K) made of refractory metals (like Molybdenum, Tantalum, Tungsten etc.). The plate is so hot that it will contribute the electrons to plasma and ions will be produced by contact ionization, these electrons and ion (plasma) will be confine in Multi-Cusp Magnetic field. The new proposed design[1] of ionizer/cathode consist of grooved molybdenum plate coated with low work function material (LaB6) to replace the filaments which was used to heat the tungsten plate in earlier design. This improved design of the hot plate ionizer will be discussed in detail along with the operational problem of the previous design.

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460/BP-99/P

A NOVEL APPROACH TO CALCULATING TOWNSEND COEFFICIENTS IN ARGON GLOW DISCHARGE PLASMAS

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Abstract

This paper discuss about the variation of the two important coefficients involved in the Paschen's law, the first Townsend coefficient (α) and second Townsend Coefficient (γ) with the fundamental parameter, reduced field(E/p). The role of inter-electrode distance (d), electrode radii(r) and the d/r ratio on these Coefficients have successfully established. The results reported graphically and detailed explanations for the findings were included.

69/BP-100/P

EFFECTIVE SECONDARY ELECTRON EMISSION COEFFICIENT OF CATHODE UNDER ABNORMAL GLOW DISCHARGE CONDITION

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Abstract

Under abnormal glow discharge plasma condition, the non-ionic cathode directed species such as photons, metastables and energetic neutrals results from ion actively participate in the process of secondary electron emission (SEE) from cathode. The *effective* number of secondary electrons (SEs) emitted per ion is characterized by the value of effective secondary electron emission coefficient (ESEEC, γ_E) which is normally higher than ion induced secondary electron emission coefficient (SEEC, γ_i). In the present work, we measured the γ_E value of different cathode (Tungsten (W), Copper (Cu)) material using different operating gases (Nitrogen (N_2) and Argon (Ar)) for different pressures (0.15 mbar to 0.45 mbar) using a self consistent model proposed by us. In addition to discharge conditions, the results show that possible dependence of γ_E value on the material properties such as work function and Fermi energy of cathode.

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36/BP-102/P

NONLINEAR LANDAU DAMPING OF WAVE ENVELOPES IN A QUANTUM PLASMA

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Abstract

Landau damping is one of the most fundamental phenomena of waves in plasma physics. Such collision less damping was first theoretically predicted by Landau [1] and later experimentally verified by Malmberg and Wharton[2]. Since then, Landau damping of electrostatic or electromagnetic waves in plasmas has been a topic of important research [3-7]. However, in most of these investigations, Landau damping has been considered classically. When quantum effects are included, there appears a new length scale and new coupling parameter, as well as new collective modes for which new processes come into play. For example, the modifications of the linear Landau damping of electrostatic waves by the effects of arbitrary degeneracy of electrons [3], and the influence of linear Landau damping on nonlinear waves [8] in quantum plasmas. Although, there are some developments of Landau damping in nonlinear regimes (see, e.g., Refs.[4],[5]), however many of the effects of nonlinear Landau damping have not yet been explored, especially in the quantum regime. Recently, Chatterjee and Misra [4] advanced the nonlinear theory of Landau damping of electrostatic wave envelopes in an electron-positron (EP) pair plasma in the context of Tsallis' non-extensive statics.

In the present work the nonlinear theory of Landau damping of electrostatic wave envelopes (WEs) is revisited in a quantum electron-positron (EP) pair plasma. Starting from a Wigner-Moyal equation coupled to the Poisson equation and applying the multiple scale technique, we derive a nonlinear Schr¨odinger (NLS) equation which governs the evolution of electrostatic WEs. It is shown that the coefficients of the NLS equation, including the nonlocal nonlinear term, which appears due to the resonant particles having group velocity of the WEs, are significantly modified by the particle dispersion. The effects of the quantum parameter H (the ratio of the plasmon energy to the thermal energy densities), associated with the particle dispersion, are examined on the Landau damping rate of carrier waves, as well as on the modulational instability of WEs. It is found that the Landau damping rate and the decay rate of the solitary wave amplitude are greatly reduced compared to their classical values (H = 0).

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13/CM-01/P

ESTIMATION OF SPACECRAFT CHARGING IN NEAR EARTH SPACE

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Abstract

Spacecraft potential is the potential developed on a spacecraft by the accumulation of charges on its surface when it is passing through a plasma environment in Earth’s atmosphere or space. This effect is also termed as “Spacecraft charging” and it can have serious consequences for a spacecraft as it can affect the onboard equipments such as sensitive electronics, power supplies, etc. which are to be maintained within specified voltage levels, deviations from which may lead to complete system failure. Hence, it is very important to study the critical effects of spacecraft charging while designing a spacecraft in the initial stages as well as later during its operation. The spacecraft charging differs within and outside the Earth's atmosphere based on the primary source that causes the charging phenomenon. In the former case, the charging is due to the atmospheric friction and in the latter case, the Sun and the surrounding plasma environment play an important role in the development of a potential on a spacecraft. In order to measure the accumulated charge on a spacecraft, several measurement techniques are employed in various missions. Prior to design a spacecraft in which the spacecraft potential and charging effects are taken care, it is prudent to simulate the space environment and the charging of spacecraft on ground using numerical programmes.

Several softwares are available which are used extensively to precisely model the spacecraft-plasma interactions and estimate the subsequent charging. In this paper, the development of spacecraft potential is estimated numerically the Spacecraft Plasma Interaction System (SPIS) programme, is carried out with various geometries and different surface material.

22/CM-02/P

ION TRAPPING IN A MAGNETIZED SOURCE-COLLECTOR SHEATH

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Abstract

A bounded plasma is being simulated with a spatially generated source in the presence of an oblique magnetic field using Particle In Cell (PIC) technique. The plasma facing surface is considered as an absorbent for charged particles. The plasma flow is considered to be normal with respect to the surface and primarily controlled by the self-consistent internal electric field. In the presence of the oblique magnetic field, the ions are observed to be trapped inside the source-collector sheath [1-2]. The whole phenomena are analyzed in the light of distribution function analysis and an attempt is made to find out the depending parameters for this phenomena. Although the plasma is considered to be collisionless, a comparison has been also made with the consideration of collision.

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55/CM-03/P

CAN TEMPERATURE BE ACCESSED BY REAL SPACE VARIABLES: A NUMERICAL EXAMPLE USING FLOWING 2D COMPLEX PLASMA

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Abstract

Traditionally, mean kinetic energy of a system provides temperature which is a measure of how kinetic energy equi-partitions. This is true for both ideal systems as well as interacting degrees of freedom. For the latter case, an intriguing question is - as both kinetic and potential degrees of freedom co-mingle to provide attributes to the structure of phase space, is it then possible to estimate temperature from instantaneous positions of particles instead of their velocities?

For interacting systems, based on Rugh's idea [1] that the curvature and geometric phase space dynamics of the energy surface in a micro-canonical ensemble are intimately connected, we estimate temperature from both kinetic (read velocity) and configurational (read position) degrees for both equilibrium and non- equilibrium systems. For this purpose, we consider Complex (dusty) plasma as a prototype where instantaneous particle positions are routinely measured in both laboratory experiments as well as computer simulations and are often modelled as Yukawa systems.

We consider a 2D grain bed in a strongly coupled liquid state and perform molecular dynamics using two types of “thermostats” namely traditional Kinetic (velocity based) and a novel Configurational (or position based) [3]. For both equilibrium conditions and far-from-equilibrium unstable conditions of macroscale initial flow, we demonstrate numerically using equilibrium and non-equilibrium molecular dynamics, that not only can the magnitude of temperature be obtained from configuration space variables, but, an effective control over extremely unstable initial conditions such as Kolmogorov flow is possible. A detailed comparison using the two thermostats, of the evolution and dynamics of a Complex plasma bed starting from 2D Kolmogorov flow is explored. Such flows are known to give way to molecular shear heating [2,4], as well as laminar to turbulent flows beyond certain flow speeds, the details of which will be presented in this talk.

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67/CM-04/P

A METHOD TO CALCULATE EQUATION OF STATE OF HYDROGEN PLASMA IN WARM DENSE REGIME

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Abstract

Ion-sphere model for equation of state(EOS) is accurate for extremely dense plasma in which the ion-ion correlations can be neglected. On the other extreme where the plasma is dilute and at extremely high temperature i.e., 1KeV and above, the plasma becomes weakly coupled and Debye-Huckel theory gives accurate results for the EOS. In the intermediate regime where the ions and the electrons are strongly coupled few theoretical models for EOS exist[1]. In recent past we developed a method for calculating the Helmholtz free energy of a non-ideal plasma including ion-ion correlations. The method basically combines the orbital-free quantum hypernetted chain method with perturbation theory[2]. Thomas-Fermi-Dirac-Wieszacker theory has been used for electronic structure and hypernetted chain method has been used for ionic structure. Previously we assumed that the electrons are in ground state which limited the application of the method to temperatures much less than Fermi temperature. In the present work we include temperature dependence in the Thomas-Fermi kinetic energy which gives the main contribution to electronic energy functional. The improved method has been applied to hydrogen plasma and we observed a good agreement of our results with those of simulation data for wide range of temperatures.

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70/CM-05/P

FIRST-EVER MODEL SIMULATION OF ION ACOUSTIC SUPERSOLITONS IN PLASMA

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Abstract

Electrostatic solitary waves (ESWs) is a topic of considerable interest in space and laboratory plasma. Though they are well studied and analyzed in space and laboratory plasmas from last few decades, the recent discovery of “supersolitons” has renewed the interest in the subject. Supersoliton is characterized by wiggles like structures in the usual smooth potential profiles and subsidiary extrema on the typical bipolar electric field profile. The supersoliton was first introduced by Dubinov and Kolotkov in 2012 [1]. Later, many researchers proposed various theoretical models for the existence/nonexistence of the supersolitons in the multi-component plasmas [2, 3]. In these models, they used a conventional nonlinear pseudopotential theory, which is incapable of providing the understanding about the formation and evolution of supersoliton. Hence, their evolutionary dynamical behaviour and the stability were main concerns and were not yet explored. We performed the fluid simulation of ion acoustic supersolitons in a plasma containing two-temperature electrons having kappa distributions in the presence of cold fluid ions. Our simulation shows that a specific form of the initial perturbation in the equilibrium electron and ion densities can evolve into the ion acoustic supersolitons, which maintain their shape and size during their propagation. This is the first computer simulation of the formation of the supersolitons and their stability in plasma. This new structure will have significant implications in the plasma processes e.g. plasma transport, plasma heating, particle acceleration etc. in space and laboratory plasmas.

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72/CM-06/P

MODEL SIMULATION OF THE WAVE BREAKING PHENOMENON IN SUPERTHERMAL PLASMA ENVIRONMENTS

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Abstract

The Earth's or any other planetary magnetospheres are rich in the variety of plasma wave processes. The nonlinear propagation of these waves in laboratory plasma has a verge by the wave breaking threshold. The understanding of wave breaking of large amplitude plasma waves is a subject of both fundamental as well as practical interest due to its importance in heating and acceleration of the plasma. In many practical situations like, in particle accelerator experiments, wave breaking limits the maximum achievable "useful" accelerating electric field. In this situation, a pertinent issue is the maximum magnitude of the wave electric field that can be attained without wave breaking.

This wave breaking phenomenon is technologically difficult to observe in space plasmas, because of the prerequisite of multiple spacecraft to track the evolution of the wave breaking process. Consequently, performing computer simulation is the best way to tackle this unresolved problem in space plasma environments. Moreover, the recent spacecraft observation of Earth's and other planetary magnetosphere confirms the existence of the highly energetic particle which energy distribution is observed to be long-tailed non-Maxwellian distribution. Therefore, consideration of these superthermal particles in the model is very important to understand their role in wave breaking.

In this paper, we perform the fluid simulations to examine the effects of superthermal populations on the breaking of electrostatic ion-acoustic (IA) wave, which is a most fundamental mode, exist in the unmagnetized plasmas. We construct a fluid model for exciting IA waves by employing a kappa distribution function for the superthermal population of electrons along with inertial cold ions (protons). From the output of the simulation, we established the criteria for the onset of the various stages of the wave breaking like trough formation, pulse formation, steepening and breaking based on the variations in the phase velocity, ponderomotive potential. We also comment on the kappa dependence of the onset of wave breaking. This simulation study highlights the role of ponderomotive force in the wave breaking and formation of coherent wave structures in superthermal plasmas.

101/CM-07/P

ROLE OF KINETIC ION DYNAMICS IN A HALL PLASMA THRUSTER : A 1D-2V-MCC STUDY

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Abstract

Electric propulsion technology is believed to be one of the preferred methods for long time satellite station orbit keeping and deep space mission. Physics understanding of Hall Thrusters or Steady Plasma Thrusters (SPTs) is a rapidly evolving field. One of the core issue is the accurate spatio-temporal estimation of transport coefficients of particle species and energy in the cross-field region in an SPT. It has been found experimentally [4] that the effect of walls and magnetic field geometry as well as the location of virtual cathode are also fundamental to the understanding of SPTs. Thus realistic geometry, boundary conditions and particle level simulations and theory are essential to gain complete understanding of this important mechanism of thrust generation.

Particle cell simulation is an ideal tool for good understanding of plasma thrusters. Various 2D [1] and 3D [3] PIC, fluid and hybrid models have been reported with prescribed or self consistent cross field diffusion, wall collision and thruster geometry. 3D-3V PIC simulation gives more deep understanding of plasma thruster and for some geometries have resulted in a close match with experiments [5]. Physics of cross field diffusion and the resulting anomalous transport is still far from completely resolved. Search is underway for a minimal kinetic model with predictive capability which will facilitate efficient practical designing of SPTs.
To this end, we have developed 1D-2V PIC-MCC electrostatic code and have performed an exhaustive study of dependency of generated thrust on magnetic field profile, propellant mass properties, external wall potential profiles, the details of which will be presented.

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108/CM-08/P

PASUPAT: A THREE DIMENSIONAL FULLY ELECTROMAGNETIC RELATIVISTIC PARTICLE-IN-CELL CODE

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Abstract

Particle-In-Cell (PIC)[1] method is a powerful and popular tool to study interaction of charged particles with self generated and/or external electromagnetic field. PIC codes are widely used in the area of Laser-Plasma interaction, Plasma Physics simulation, Pulsed Power Vacuum Diodes, High Power Microwave devices etc. Open source 3-dimensional PIC codes like PIConGPU, SMILEI have their own limitations such as the absence of material boundaries. Here we present a three dimensional fully electromagnetic relativistic PIC code named 'PArallel Simulation Utility using PArticle-in-cell Technique (PASUPAT)' version 1.0. We have developed this code in C++ using its object oriented features. It uses Yee grid based Finite Difference Time Domain[2] (FDTD) Maxwell equation solver, Particle mover based on Boris method[1] and Esirkepov[3] algorithm to deposit currents at the FDTD grid. At present PASUPAT can handle conducting material boundaries. It has provision for imposing absorbing boundary condition for electromagnetic fields. More than one type of charged particles can be emitted/loaded into the simulation. We have used OPENMP API to parallelize PASUPAT. PASUPAT uses open source data analysis and visualization library VTK[4] (Visualization Tool Kit) and GUI application Paraview[5] to visualize the simulation data. We have validated the code against known analytical and published numerical results including single particle trajectories under imposed electromagnetic field, wave propagation in free space and its absorption at absorbing boundary and intense electron beam dynamics in vacuum diode/drift region.

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118/CM-09/P

PHASE TRANSITION IN DRIVEN ACTIVE MATTER AND EQUILIBRIUM STATISTICAL MECHANICS OF CONVENTIONAL MATTER

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Abstract

A hypothetical ideal gas or a cup of tea or plasmas are examples of conventional matter. For these systems, generally, energy input in the largest scale length of the system. On the other hand, "active matter" are examples of system where energy is driven at the individual particle length scale at certain intervals. For example, a group of birds or vibrating beads and rods on a 2D plate or molecular motors or colony of bacteriae. Thus dynamics in "active matter" may be expected to be novel as compared to conventional matter. Recently, a surprising connection between equilibrium phase transitions in conventional systems and driven active matter such as flocks of birds, bacteriae etc has been identified.

To explore this connection further, we have simulated a magnetic system with 2D Ising model [1] and have obtained critical points and their exponents using equilibrium statistical mechanics. To understand more of driven active systems, we have developed a fully parallel code and have simulated active systems of Vicsek type [2]. Our simulation results of driven active matter show similar kind of phase transitional properties as those of equilibrium phase transitions in conventional matter. In this work, we bring out the details and discuss possible variants of Vicsek-type models.

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125/CM-10/P

A STUDY ON PLASMA SHEATH FORMATION

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Abstract

The lunar surface being subjected to the solar wind and the UV radiation of the Sun results in the formation of a plasma sheath at the surface. In night time, the electrons present in the solar wind charges the lunar surface negatively resulting in the formation of the usual Debye sheath. However, during the day side of the lunar surface an inverse sheath is formed due to the emission of photoelectrons from the surface.

Our interest lies in studying the structure of the sheath formed during the day time. Here, we present the results of the Particle in Cell (PIC) simulations carried out to study the sheath formation at the lunar surface due to its interaction with the Sun.

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148/CM-11/P

MULTIPLE INTERACTION OF COHERENT PHASE SPACE STRUCTURES INDUCED PARTICLE ACCELERATION IN PLASMA

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Abstract

Wave-particle and wave-wave interactions are crucial elements of plasma dynamics. Such interactions provide a channel of energy redistribution between different plasma populations and lead to connections between physical processes developing on different spatial and temporal scales. We perform a one-dimensional Particle-in-Cell simulation of the head-on collision of multiple counter-propagating coherent phase space structures associated with the ion acoustic solitary waves (IASWs) in plasmas composed of hot electrons and cold ions. The chains of counter-propagating phase space structures of the IASWs are generated in the plasma by injecting the Gaussian perturbations in the equilibrium electron and ion densities. The head-on collisions of the counter-propagating electron- and ion- phase space structures associated with the IASWs are allowed by considering the periodic boundary condition in the simulation. Our simulation shows that the phase space structures are less significantly affected by their collision with each other. They emerge out from each other by retaining their characteristics, so that they follow soliton type behavior. We find that the electrons trapped within these IASW potentials are accelerated, while the ions are decelerated during the course of their collisions [1].

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173/CM-12/P

MODELLING AND SIMULATION OF CO_2 PLASMA JET

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Abstract

CO_2 plasma jet is being considered as one of the potential candidates for generating energy from waste due to its high heat transfer efficiency and cost effectiveness. Since the temperature and velocity of the plasma jet strongly influence the process efficiency, it is necessary to study the characteristics of the CO_2 plasma jet. In this study, a two dimensional axi- symmetric model is developed to simulate the characteristics of CO_2 plasma jet emanating from DC non-transferred arc plasma torch under different operating conditions. The plasma jet temperature, velocity and CO_2 mass distributions of CO_2 plasma jet issued into air atmosphere are predicted. The effects of gas flow rate, plasma power and surrounding atmosphere on the distribution of temperature and velocity in the plasma jet are clarified. Also, the plasma jet with various powers is impinged on a solid medium at different stand-off distances to study the effect of plasma power on heating of the material exposed to the plasma. The characteristics of CO_2 plasma jet are compared with that of argon plasma jet for same set of operating conditions. To validate the present model, predicted results are compared with both experimental and previously predicted results.

175/CM-13/P

NUMERICAL MODELING OF PLASMA ARC WITH GAS INJECTION THROUGH CENTRAL HOLE OF CATHODE

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Abstract

The transferred arc plasma, which is generated between rod like cathode and crucible anode, is used in industries for different material processes. It is expected that configuration of cathode with central hole for gas injection can transfer more heat energy from plasma to the material through convection. It is important to understand the arc behaviour inside the crucible to get better process efficiency. Since measurements on plasma arc is very complicated, numerical model of lab scale experimental set-up is developed to study the behaviour of the plasma arc inside the crucible with a hollow cathode through which the plasma generating gas is injected.

Two-dimensional steady state axi-symmetrical mathematical model of DC transferred plasma arc is simulated for arc created between a rod like graphite cathode with a central hole for gas injection and a graphite crucible anode. Several numerical models have been proposed for the analysis of free-burning arc columns [1]. Huang et. al. simulated transferred plasma arc in plasma reactor with cathode geometry consist of gas flow through hollow cathode, but the region of study was the portion of arc inside the confining wall of the arc plasma reactor [2]. In this piece of work the effect of gas flow through the central hole of the cathode on plasma arc characteristics is studied. The arc root attachment position at the anode bottom is determined by the resultant of gas dynamic force and induced electromagnetic force. The arc voltage was expected to increase with gas flow rate. In the developed model, though arc voltage increased with increase with gas flow rate, a decrease in arc voltage was observed when the arc root position at the anode moving towards radial direction from the centre. The present model was validated by comparing predicted results with previously published results.

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177/CM-14/P

NUMERICAL INVESTIGATION OF CO_2 ARC PLASMA

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Abstract

World is not only looking for technologies that suppress the CO_2 emission but is also looking for technologies that use CO_2 effectively. The CO_2 can be used to generate the plasma for high temperature applications. The material processing with CO_2 plasma is cost effective, environment friendly and efficient. The understanding of the characteristics of CO_2 arc plasma is important to optimize the process parameters for better process efficiency.

A two-dimensional axi-symmetric model is developed to study the characteristics of CO_2 transferred arc plasma at atmospheric pressure. The governing equations such as mass continuity, momentum in axial as well as radial directions, energy, electric potential and magnetic vector potentials in axial as well as radial directions are solved simultaneously with appropriate boundary conditions. The temperature dependent thermo-physical properties of CO_2 plasma is used for calculations. The Finite Volume Method (FVM) integrated in the commercial CFD software ANSYS-FLUENT is used for the same. The temperature, velocity, current density and electric potential of CO_2 plasma arc are simulated for applied currents of 100A and 200A. Characteristics of CO_2 arc are compared with argon arc. Energy generated in CO_2 arc is approximately twice that in argon arc for 100A. The arc heating efficiency of CO_2 plasma is compared with that of argon plasma for various arc currents. The present model is validated by comparing the predicted results with previously published results.

178/CM-15/P

COMPUTATIONAL STUDIES OF PLASMA TRANSPORT ACROSS MAGNETIC FILTER FOR ROBIN NEGATIVE ION SOURCE USING 1D AND 2D-3V PIC-MCC SIMULATION

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Abstract

The RF based negative ion source ROBIN has been setup at IPR, Gandhinagar to understand and investigate the different issues related to production, transport and extraction of negative hydrogen ions in negative ion sources for fusion applications [1]. The source consists of a driver, an expansion chamber, a magnetic filter and extraction grids. We require accurate computational models to completely understand the complex physics and plasma dynamics inside such negative ion sources. Magnetic filter plays an important role in reducing electron temperature inside the source, which is necessary to increase the negative ion yield [2].
We have developed an in-house 1D-3V Particle in Cell Monte Carlo Collisional (PIC-MCC) code to study the effects of a 1D filter field on plasma transport. The PIC-MCC model used for this study uses a simple, purely electro-static and explicit model which can be used to understand the collisional transport across magnetic filters under conditions similar to real ROBIN negative ion source (magnetic field, pressure, density etc.). In this model several approximations have been made such as detailed hydrogen chemistry and negative ion generation is not included, power absorption by electron is treated in a simple way, losses to the wall is not considered etc. However, simulation results from our simplified 1D model can reproduce some of the qualitative behaviors observed during the first phase ROBIN experiments such as decrement in electron temperature and similar plasma density profile across magnetic filter.

The 1D analysis clearly shows the requirement of higher dimensional model for such studies which can take into account real source geometry, complex chemistry, plasma instabilities and wall effects to get better match with experimental results. As a first step in this direction, we have developed a 2D-3v PIC-MCC code which can be used to simulate a 2D rectangular computational domain with periodic boundary conditions perpendicular to the magnetic filter and discharge axis, however this does not take into account the actual geometry of the source. Keeping all other conditions same in both the cases (1D and 2D), we have investigated different plasma characteristics such as plasma potential, electron temperature, electron and ion density profiles, electric field, current etc. in the case of a Gaussian shaped magnetic filter. We find that

qualitatively plasma transport is similar in both the cases, but there are quantitative differences. Unlike 1D, in case of 2D simulations we also observe appearance of instabilities particularly in the magnetic filter region under certain conditions. The role of these instabilities towards the plasma transport across the filter requires further investigation. We have also performed several studies to understand the effect of numerical parameters on the model results.

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194/CM-16/P

DYNAMICS OF A DELAYED VAN DER POL-MATHIEU OSCILLATOR

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Abstract

We analyse the dynamics of a time-delayed, dusty plasma inspired, van der Pol-Mathieu equation. Our analytic prediction of the slow-flow system correctly represent the dynamics of the original system, showing periodic creation and annihilation of multi-periodic limit cycles. We show that for large time-delay, the system undergoes a double-Hopf bifurcation, whereas for small delay, in undergoes a Bogdanov-Takens bifurcation.

253/CM-17/P

MODELLING AND SIMULATION OF 13.56 MHZ, RF-IGNITION SYSTEM FOR RF BASED H^{-} ION SOURCE

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Abstract

An RF based multicusp H^{-} ion source with external antenna operating at 2 MHz RF frequency, has been developed at the *Proton Linac Development Division*, RRCAT. This source having high operational life time and is most promising one to serve as a pre-injector to the high current proton Linac for the Spallation Neutron Source (SNS) applications. In order to produce properly dense Hydrogen plasma inside the main plasma chamber through inductive coupling of RF power to the neutral Hydrogen gas at 2 MHz, it requires sufficient background ionization inside main plasma chamber that can be created by a High voltage DC-Discharge, or by filament heating or using external RF antenna working on the same principle of Inductively Coupled Plasma (ICP) discharge as an igniter to the main plasma discharge. In this paper, we will report the simulation results of RF-ignition system operated at 13.56 MHz for RF based multicusp H-ion source, using COMSOL Multiphysics Software [1]. This Software solves a pair of drift-diffusion equations for the electron density (plasma density) and mean electron energy (plasma temperature) for ICP and uses magnetic field potentials for calculation of magnetic field due to the RF antenna. In this simulation model, the average reaction rates of most probable collision responsible for Hydrogen ions production and recombination [2], antenna current and gas pressure have been taken as main input parameters. Simulation results give the distribution of plasma parameters, i.e. density, temperature, plasma potential etc. inside the igniter plasma chamber along with electromagnetic field distribution due to antenna.

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304/CM-18/P

ZERO-DIMENSIONAL MODELING OF ECRH-ASSISTED PLASMA START-UP IN SST-1

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Abstract

Plasma start-up assisted by electron cyclotron resonance heating (ECRH) pre-ionization is theoretically studied for the Steady state superconducting tokamak SST-1(major radius, R_0= 1.1 m; minor radius, a = 0.2 m; and toroidal magnetic field, B_t =1.5 T) by using a zero-dimensional (0-D) model. A 0-D model was developed to analyze the plasma start-up for various tokamaks. This model, which describes ECRH-assisted start-up at ISX-B, was proposed by Kulchar et al. [1] and more advanced models were developed by Lloyd et al. [2]. The 0-D model consists of five temporal equations: the electron and neutral density equations, the electron and ion energy density equations, and the electric circuit equation with eddy currents induced in conducting structures. The effects of hydrogen ions and impurities (carbon & oxygen) are also taken into account. These equations are solved for spatially uniform plasma using fourth-order Runge-Kutta method. In this model, we assume that the major and minor radii remain constant and 80-90 % of the injected ECRH power is absorbed.

The calculation shows that the ECRH power is effective for plasma start-up under low loop voltage conditions. An ECRH absorbed power of ~200 kW (for SST-1 size devices) is required to start-up the plasma. There is a threshold in ECRH power for a successful start-up. The threshold depends on the initial neutral density, and greater ECRH power is required as the initial neutral density increases. In addition, it depends on the carbon and oxygen impurity densities because the radiation loss increases with increasing impurity densities. This implies that for a reliable start-up, it is important to control the neutral density and reduce the impurity densities. The calculation using the SST-1 parameters qualitatively reproduced the time evolution of the experimental results.

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346/CM-19/P

VORTEX DYNAMICS OF HIGH DENSITY PURE ELECTRON PLASMA COLUMNS

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Abstract

Pure electron plasmas confined in straight cylinder geometry with uniform axial magnetic field for radial confinement and electric field end-plugs for axial confinement have been excellent test beds for understanding vortex dynamics in fluid. Fluid dynamics becomes possible due to a one-to-one mapping between 2D pure electron plasmas and 2D Euler fluids leading to isomorphism which is accurate only for low density electron cloud. It is expected that this isomorphism would breakdown at higher plasma densities or for larger Brillouin fraction fb (fb quantifies the ratio of plasma density to magnetic field strength).

In this work, using a Particle-in-Cell simulation code PEC2PIC [1], we investigate numerically the above said breakdown of isomorphism by considering uniform density patches of various shapes (or poloidal mode numbers “m”) from low to high Brillouin values. In particular, we obtain the rotational frequencies for various “m” values as a function of Brillouin fraction fb and compare it with analytical frequencies obtained for low fb values.

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409/CM-20/P

TWO DIMENSIONAL FDTD MODELING OF A PLASMA ANTENNA

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Abstract

Plasmas, having a frequency dependent complex dielectric constant and conductivity, have the potential to transmit and receive electromagnetic signals thus providing an alternative for the conventional metallic radio frequency antennas [1]. In addition, the operation frequency and the radiation pattern of a plasma antenna can be dynamically tuned by controlling the plasma density which makes it a reconfigurable antenna. The possibility to switch the plasma in a plasma antenna on and off, on a millisecond time scale, makes the plasma antenna very attractive for defense applications. To improve the efficiency of a plasma antenna one needs to understand the underlying physics of its start to end operation. With that motive, we are developing a simulation tool box based on a finite difference time domain (FDTD) model for the electromagnetic wave propagation with plasma response included via a simplified Drude like model. Numerical details as well as preliminary results of the current two-dimensional version will be presented. In near future, we plan to develop a more sophisticated full 3D simulation suite wherein particle-in-cell based strategy to include detailed plasma response will be adopted.

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432/CM-21/P

EXPANSION OF DENSE PLASMA GENERATED BY SHOCK WAVES IN HIGHLY POROUS MATERIALS

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Abstract

Shock waves generated by plate impact or other forms of fast energy deposition in materials produce hot dense plasmas via thermal and pressure ionization processes. Extremely high temperatures produced on shocking porous materials amplify this effect due to enhanced thermal ionization. Closure of pores and compression of the material matrix occur first during shock wave transit [1]. Molecular dynamics simulations of model systems elucidate a sequence of processes involved: initial shocking of the solid matrix, shock break out at the pore interfaces and collisional energy dissipation of the ejecta [2, 3]. These processes give rise to formation of hot spots and local heating [4]. The high temperatures generated on shock loading of porous materials is due to the collisional energy dissipation, which also gives rise to anomalous expansion in the shocked state when initial porosity is high. With increasing pressure, the shocked volume of Cu increases, instead of decreasing, when initial porosity is more than two, thereby leading to double valued pressure on the pressure-volume Hugoniot.

We have developed a more general equation of state (EOS) for highly porous materials to model shock propagation. The occurrence of multi-valued pressure on the pressure-volume Hugoniot has lead to consider pressure and temperature as independent variables, in lieu of the usual volume and temperature, in thermodynamic modeling of porous materials. For higher initial porosities, the final shocked states of materials lie in the expanded volume region corresponding to the high temperature fluid phase. This is the case for Cu when initial porosity is more than two. For this application, first of all we developed a modified soft-sphere model valid in the entire fluid region. Our modification of the soft-sphere model is in determining all its parameters in terms of bulk modulus, cohesive energy and density of the solid at normal conditions.
Our model also includes the effect of fast expansion of the initially compressed plasma, which properly accounts for the energy loss from the shock due to the expansion. Neglecting this effect leads to incorrect prediction of final volume and temperatures. Shock wave parameters of Cu with a wide range of porosity (i.e. 2 to 10) are then computed and compared with experimental data [5]. Pressure-volume curves and shock speed vs. particle speed results show excellent comparison.

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472/CM-22/P

NUMERICAL SIMULATION OF STRONGLY COUPLED MULTI-ION PLASMAS

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Abstract

In plasmas, if several species of ions participate, the collective phenomena in such plasmas are known to become diversified and inherently multi-scale in space and time. One of the novel states of multi-ion plasma is pair-ion plasma. The pair plasmas represent a new state of matter with unique thermodynamic properties drastically different from ordinary electron-ion plasmas have attracted special attention. Recently, phase transitional study in strongly coupled 2D pair-ion Plasma system with soft core is carried out by S. Baruah et al. [1] and interesting phase co-existence between liquid-like and vapor-like phases is observed.

It is well known that in plasma experiments, the plasma particles collide with neutral gas atoms. Instead of treating the collisions explicitly, the Langevin dynamics method uses a stochastic approach to include their effects. Langevin dynamics is an extension of the MD method, in which a random (Langevin) force and a damping term are added to the equations in order to simulate the effects of liquid or gaseous background on micron-sized particles. This accounts for random kicks by fast moving particles as well as for the friction force caused by the liquid or gas drag. Quasi-steady state resulting due to external forcing, stochasticity and inter-particle interaction for pair-ion plasma using Langevin Dynamic simulation will be presented.

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481/CM-23/P

INVESTIGATION OF PLASMA FORMATION IN PSEUDOSPARK DISCHARGE GEOMETRIES FOR GENERATION OF HIGH DENSITY AND ENERGETIC ELECTRON BEAMS

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Abstract

In the recent decade, research is more focused towards the generation of high density and energetic electron beams for different applications [1]. One of the approaches for this cause is pseudospark (PS) discharge for the generation of high density and energetic electron beams. It can produce electron beams with rapid current rise up to 10^{12} A/s, high current density (>10^4 A cm^{-2}), high brightness (up to 10^{12} $Am^{-2}rad^{-2}$) and narrow beam diameter [2],[3]. The PS discharge geometry consists of hollow cylindrical cathode with centered hole at one end and flat anode surface separated by insulator gap. The PS discharge depends on the geometrical parameters, operating conditions, circuit configurations, etc. [4]. It is important to analyze the plasma formation and generation of required electron beams for different PS geometries at different operating conditions.

Analysis has been carried out for the plasma formation and resulting electron beams at different PS geometries and gas (Ar, He, H2, etc.) pressures. The investigation has been carried out by using 2-D electrostatic plasma simulation OOPIC™ PRO. Analysis has been performed for different cathode aperture sizes 1-10 mm, gas pressures 1-80 Pa for applied voltage up to 40kV. It has been observed that plasma formation process and resulting electron beam generation depend on cathode apertures as well as gas pressures. Increasing cathode aperture area for constant gas pressure results fast plasma formation inside hollow cathode but leads low density electron beam formation. Whereas, higher gas pressure at constant aperture area results fast plasma formation inside hollow cathode which leads high density electron beam formation. The behavior of potential penetration in the hollow cathode cavity is also responsible for the fast plasma formation and also generation of electron beams of different sizes. The simulations have been run until breakdown is achieved and peak current has been measure at the anode surfaces. Plasma formation, generation of high density and energetic electron beams, and also potential distribution within the hollow cathode cavity for different cathode apertures at different gas pressures have been successfully simulated and investigated.

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252/CM-24/P

A MATLAB CODE FOR MAGNETIC FIELD CALCULATION DUE TO ARBITRARY STRAIGHT AND CIRCULAR ELECTROMAGNETS (MMAEM V.1.0)

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Abstract

Electromagnets are used to generate magnetic fields of arbitrary shapes in tokamaks, spheromaks and other fusion type machines. The design of electromagnets for complicated magnetic fields requires a code for generating suitable shaped and sized electromagnets. EFFI and other similar codes were developed earlier based on LINUX type platforms. Institute for Plasma Research has two tokamaks, ADITYA and SST1 and is in progress of designing next level tokamaks. Upgradation of existing tokamaks and future machines with electromagnets' design require an easy user friendly, Windows based in-house customizable code. The present report discusses about the Matlab code designed and developed with easy EXCEL based input parameters of electromagnets in Cartesian or Polar coordinates, dimensions of electromagnet elements, space of interest of magnetic field in either coordinates and EXCEL/txt format magnetic field data and plots depicting electromagnets and magnetic field, Code Validation using standard examples and applications to various electromagnet systems in IPR.

213/CM-24/P

PIC SIMULATION OF BUNEMAN INSTABILITY

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Abstract

Spatio-temporal evolution of Buneman instability[1], both in the non-relativistic and relativistic regime has been investigated using an in-house developed 1D particle-in-cell code. For a wide range of initial electron drift velocities and electron to ion mass ratios, growth rate obtained from simulation in both cases agrees well with the growth rate obtained from numerical solution of the respective fourth order dispersion relation. It is found that in contrast to the well-known non-relativistic result [2] the maximum growth rate in the relativistic regime depends on the initial electron drift velocity, and reduces with increasing drift velocity. Further at the time of quasilinear quenching of the instability, the ratio of electrostatic field energy density to the initial drift kinetic energy density scales withγ_0(Lorentz factor associated with initial drift velocity of the electron beam) $as \sim 1/\gamma_0^2$. This numerically observed result has been explained theoretically using back-of-the-envelope scaling arguments[3,4].

Quasilinear quenching does not imply complete termination of the instability. Non-relativistic simulations have been carried out beyond the quasilinear regime, and en route to final thermalized state of electrons[5], electron phase space holes coupled to large amplitude ion solitary waves, a state known as coupled-hole soliton, are seen in our simulations. The propagation characteristics (amplitude - speed relation) of these coherent modes have been explained with the theory of Saeki et. al. [6]

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463/CM-25/P

STUDY OF CARBON IMPURITY TRANSPORT IN ADITYA TOKAMAK

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Abstract

Impurities, the unwanted non-fuel species, in a tokamak mainly originate from plasma-wall interactions, fuel reaction and deliberately introduced gases like Ne, Ar for radiative cooling. The presence and transport of these impurities play a vital role in determining the overall plasma performance [1]. Presence of impurities in high temperature plasmas may lead to increased radiation power losses especially in the core by central accumulation, dilution of fuel ions, reduction in heating efficiency and hence plasma reactivity. Therefore, it is important to understand the transport of impurities in tokamak plasmas in order to prevent the central accumulation and its deleterious consequences affecting the power generation in fusion reactor.

Transport behavior of carbon impurities in Aditya tokamak plasma have been studied through the modeling of radial profile of emissivity of carbon ions originating from the limiter surface made of Graphite. For our simulations, we have used the new version of STRAHL code [2] which is primarily extended for simultaneous treatment of many impurities in a single run. This code was earlier used for oxygen impurity transport study in Aditya [3]. The atomic reaction data has been taken from Atomic Data and Analysis Structure (ADAS) [4]. In this paper, we present the full transport modelling of carbon impurity in typical discharges of Aditya tokamak using STRAHL. The results are then compared with the experimental measurement of emissivity using multi-track visible spectroscopy system [5] to obtain diffusivity profiles of carbon impurity in these discharges indicating at different transport mechanisms.

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HIGH FREQUENCY ELECTROSTATIC SURFACE WAVE PROPAGATION AT THE INTERFACE OF TWO DIFFERENT PLASMA SYSTEM

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Abstract

The propagation of high frequency electrostatic surface wave at the interface of electron ion plasma and dusty plasma is investigated using the necessary boundary conditions. In dusty plasma region the presence of two well-known dust modes namely the Dust Ion Acoustic waves (DIAWs) and Dust Acoustic Waves (DAWs) is considered. Two separate cases have been studied, where in the first instant surface wave arises due to the presence of ion acoustic and dust ion acoustic volume waves and in the second case evolution of surface wave is considered due to the presence of ion acoustic and dust acoustic volume waves in the two regions. The plot of the general dispersion relation is found linear in both the cases. The normalized surface wave frequency is also seen to grow linearly for lower wave number and becomes constant for higher wave number in both the cases. It is observed that the normalised frequency depends on ion plasma frequencies when dust oscillation frequency is neglected.

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45/EP-02/P

3D INVESTIGATION OF TOROIDALLY TRAPPED ELECTRON PLASMAS USING PEC3PIC-MCC, A 3D PIC CODE WITH MONTE-CARLO-COLLISIONS

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Abstract

Non-neutral plasmas are, in general, single-component or multi-component collection of charged particles exhibiting collective behaviour with an unbalanced net charge in the system. Because of their gross non-neutrality these plasmas are characterized by large zeroth order self electric fields which adds unique features to their behaviour, setting them apart from quasi-neutral plasmas. The physics of non-neutral plasmas find application in high-intensity accelerators, positron and antiproton ion sources, and free electron lasers, to name a few.

A readily available form of non-neutral plasma that can be experimented on, is an electron gas. Popular experimental set-ups for magnetic confinement of electron plasmas included cylindrical Penning-Malmberg traps, toroidal trap of different toroidal aspect ratios, stellarators, and even magnetospherical configurations. In each of these arrangements electron clouds display a whole array of dynamics that can be modelled analytically or via simulation. For example, in the recent past the authors had developed a 2D3v PIC-with-MCC code, PEC2PIC-3MCC with they used extensively to model several collisionless and collisional phenomena in cylindrically confined, pure and partially neutralized, electron clouds [1,2].

The earlier numerical work of the authors on linear cylindrical traps has now been extended to include the interesting effects of trap-toroidicity and associated magnetic field non-uniformity on the dynamics of electron plasmas. To achieve this, the 2D3v PIC-with-MCC code has now been upgraded to a fully 3D version, PEC3PIC-MCC which simulates in 3D, the dynamics of electron clouds in toroidal traps.

The focus of the 3D simulation studies on toroidally confined electron plasmas, is on **a)** Modelling the dynamical evolution of a pure electron cloud as an initial value problem – does the non-neutral plasma, with all its self field driven effects, achieve toroidal mechanical equilibrium? **b)** Understanding the role of background gas ionization in the destabilization of the cloud through resonant particle effects **c)** Investigating the effects of non-ionizing collisions between the plasma and background neutrals on the dynamics of the cloud **d)** A qualitative and quantitative comparison of the above effects between the cylindrically and toroidally confined electron plasmas.

The major results form the 3D investigation of toroidal electron plasmas will be presented with coherent figures and plots.

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102/EP-03/P

CNOIDAL WAVES IN A QUANTUM DUSTY PLASMA

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Abstract

Cnoidal waves are surface gravity waves of fairly long wavelength. These are nonlinear waves whose solutions are in the form of Jacobi elliptical functions such as cn, sn. In the limit of infinite wavelength, cnoidal waves become solitary waves. The quantum effect in plasmas becomes important, when de Broglie wavelength associated with the particles is comparable to dimension of the system. The study of quantum plasma is important due to its applications in solid state physics, microelectronics, quantum dots and quantum wires, ultracold plasmas and in dense astrophysical environments. Employing the Quantum hydrodynamic (QHD) model dust acoustic cnoidal waves are studied in a three species unmagnetised plasma consisting of inertialess electrons and ions and inertial dust. Korteweg de-Vries equation is derived using reductive perturbation method and nonlinear periodic wave solutions are obtained. With the help of Sagdeev Pseudo-potential approach, the plots for dust acoustic cnoidal waves and solitons in phase plane are presented. The effect of quantum parameter is studied on the amplitude and width of cnoidal and solitary structures. The results will be useful to understand the nonlinear wave propagation in quantum plasma.

122/EP-04/P

SPIRAL WAVES IN DRIVEN DUSTY PLASMA MEDIUM

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Abstract

The spatiotemporal development of spiral waves in a two-dimensional dusty plasma medium is studied using Molecular Dynamics (MD)[1] and Fluid Generalized Hydrodynamic (GHD)[2] simulations. It is observed that when the amplitude of the forcing electric field is small, weak perturbations get excited which evolve as linear dust acoustic waves. However, when the amplitude of electric field is increased, the dusty plasma medium exhibits a nonlinear response and spiral wave evolution is observed. The dependence of the spiral wave form with the amplitude, rotation frequency of external forcing and the strong coupling parameter of the medium has been investigated in detail. It is shown that both MD and fluid depiction show qualitatively similar results.

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222/EP-05/P

DUST MAGNETOSONIC SHOCKS IN DUSTY PLASMAS

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Abstract

Dusty plasmas are present in most of the space and astrophysical environments as well as laboratory plasmas. The presence of dust particulates in the plasmas modify the properties of the plasmas and generate new wave modes, such as dust acoustic waves, dust Alfven waves, dust kinetic Alfven waves, dust lattice waves, and dust magnetosonic waves. In this investigation, we have studied the dust magnetosonic shock waves (DMSWs) in magnetized dusty plasmas, comprising of heavy negatively charged dust grains, electrons and ions. In order to study the DMSWs, we have derived the Korteweg - de Vries - Burgers (KdV-B) equation by using reductive perturbation method. From numerical analysis, it is observed that various parameters, such as dust number density, dust kinematic viscosity and plasma beta have significant effect on characteristics of DMSWs. This study may be useful in understanding the formation of nonlinear structures in space and astrophysical dusty plasma environments, such as Saturn's F-ring.

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223/EP-06/P

STUDY OF COLLISION BETWEEN TWO DUST ACOUSTIC SOLITONS OF DIFFERENT AMPLITUDE IN A STRONGLY COUPLED DUSTY PLASMA

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Abstract

Dusty plasma contains micrometer to nanometer size dust particles floating in the sea of electrons and ions which can be weakly or strongly coupled due to their heavy mass and large charge. This lead to the formation of gaseous or liquid or even crystalline like state depending upon the strength of dust interaction [1, 2]. Various collective phenomena are observed in these states of dusty plasma such as evolution of low frequency waves known as “dust acoustic waves”, formation of voids, vortices, Mach cones etc. In the nonlinear regime, dust acoustic waves get transformed into dust acoustic solitons. Interaction of solitons is an interesting topic of study in normal fluid and plasma which have been reported by many authors [3-6]. In one dimension (1D), there can be overtaking collision between two co-propagating solitons and head-on collision between two counter-propagating solitons. We have investigated the propagation characteristics of two unequal amplitude dust acoustic solitons undergoing head-on and overtaking collision in a strongly coupled unmagnetized dusty plasma. A radio frequency (rf) discharged dusty plasma is produced inside a cylindrical glass chamber at a pressure of 0.1 - 2 Pa by adding micron silica dust into the plasma [7]. Solitons are excited in the strongly coupled dust medium by applying short negative pulses to the exciter. Wave motions are recorded using a high speed camera with laser light illumination. We have observed that the incident solitons survive both head-on as well as overtaking collision with a small time delay after collision. Experimental results are compared with relevant theory.

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235/EP-07/P

PROPERTIES OF DUST ION ACOUSTIC WAVE IN IONOSHERIC PLASMA UNDER THE INFLUENCE OF RELATIVISTIC POSITRON BEAM

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Abstract

Low-temperature plasmas containing massive charged dust particles are frequently found in various space environments [1] as well as in laboratory devices [2] and industrial processes [3] in the form of complex plasmas. The presence of highly charged and massive grains of dust particles in an electron-ion plasma is responsible for the appearance of new types of electrostatic waves, depending on whether the dust grains are considered to be static or mobile.Again, energetic charged particles beam always play a crucial role on the propagation characteristics of solitary waves in plasma [4].

In this work, an investigation on the properties of non-linear dust ion acoustic (DIA) solitary waves propagating in a multi-components dusty plasma, including the effect of relativistic positron beam effect is presented. Here we consider ionospheric plasma consists of electron, positive ion and negatively charged dust along with a positron beam. The analytical solution of the Korteweg-de Vries (KdV) nonlinear wave equation is numerically analyzed and the effects of relativistic positron beam on various solitary wave properties are studied. It is found that the presence relativistic positron beam plays a key role in the formation of compressive DIA solitary wave in this plasma system.

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242/EP-08/P

HEAD-ON COLLISSION OF DUST ACOUSTIC SOLITATY WAVES IN DUSTY PLASMA HAVING POSITRONS AND NONTHERMAL IONS

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Abstract

The head-on collision of dust acoustic solitary waves in unmagnetized dustyplasma with Boltzmann distributed electrons, positrons , nonthermal ions, and negatively charged dust grains is investigated using the extended Poincare´-Lighthill-Kuo method. The effects of positronsand nonthermalionsin dusty plasma on the phase shift are studied. It is found that the presence of positrons and nonthermal ions in dusty plasma plays significant roles on the collision of dust acoustic solitary waves. This study would be useful for the investigations of plasma behaviour in astrophysical dusty plasma ofcometary tails, Jupiter's magnetosphere etc

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243/EP-09/P

ENVELOPE SOLITONS IN ULTRA-RELATIVISTIC DEGENERATE DENSE DUSTY PLASMA WITH POSITRONS

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Abstract

Envelope soliton of ion acoustic waves in dense plasma consisting of ultra-relativistic degenerate electrons and positrons, warm streaming ions and negatively charged static dust particles have been investigated using Fried and Ichikawa method. Nonlinear Schrodinger equation has been derived and the growth rate of modulationally unstable ion acoustic wave in such plasma are discussed. The solutions of ion acoustic envelope- solitons are obtained from the Nonlinear Schrodinger equation. The theoretical results have been analyzed numerically for different values of plasma parameters and the results are presented graphically. It is found that both bright- and dark envelope soliton would be excited in the ultra-relativistic plasma. Our results would be applicable for the study of nonlinear wave processes in degenerate dense plasmas of astrophysical objects, namely, in white dwarfs and neutron stars etc..

289/EP-10/P

STUDY OF COLLISION BETWEEN TWO DUST ACOUSTIC SOLITONS OF DIFFERENT AMPLITUDE IN A STRONGLY COUPLED DUSTY PLASMA

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Abstract

We theoretically investigate the interaction and propagation characteristics of two co/counter propagating Mach cones triggered by two projectile particles moving with supersonic velocities in the same/opposite directions through a dusty plasma medium [1]. The Mach cone solutions are obtained by solving a model set of fluid equations for a heavily charged dust fluid that includes the contributions of the projectile particles in the Poisson equation. The density profiles and velocity vector maps of the Mach wings show interesting structural changes when they interact with each other and form patterns similar to interference fringes. Compared to the co-propagating Mach cones, the wings of counter propagating Mach cones produce a larger number of maxima and minima in the pattern resulting from their mutual interaction. In addition, the time duration of the formation of two maxima or minima at a particular point decreases due to the interactions of Mach cones. Another notable feature is that the spacing between adjacent maxima increases, while the fringe angle decreases with the increase of relative velocity of the counter propagating projectile particles.

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DUST INERTIAL ALFVEN WAVES IN ELECTRON DEPLETED DUSTY PLASMA

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Abstract

Introduction of heavy, negatively charged dust grains in the usual electron-ion plasmas modifies the overall properties of the plasma. Effect of presence of dust in the plasmas is also reflected in the number of wave modes observed, where existing waves are modified and new wave modes are excited.

In usual electron-ion plasmas, inertial Alfven waves arises when the perpendicular wavelength is comparable to electron inertial length. In this case the electron inertia causes the dispersion of the wave and the dispersion relation is modified by electron inertial length. Thus to study the excitation of dust inertial Alfven waves, we considered dust-ion plasma, in which electron population is significantly depleted due to the attachment of electrons to dust grain surface. From linear analysis, it was observed that the dispersion relation of the wave is modified by inertial length of ions. Nonlinear analysis is carried out by using theSagdeevpseudopotential approach. From numerical analysis, it was observed that the characteristics of dust inertial Alfven waves are significantly affected by number density of dust, Mach number and angle of propagation. This study may be useful in understanding the formation of coherent nonlinear structures in space and astrophysical dusty plasma environments..

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351/EP-12/P

TURBULENCE AT SMALL REYNOLDS NUMBER: AN ATOMISTIC STUDY OF COMPLEX PLASMA

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Abstract

Turbulence is one of the outstanding open problems. Fluid flow past an obstacle is one of the simplest paradigms to understand transition to turbulence. For Navier-Stokes liquids, transition to turbulence is fully governed by Reynolds number (Re). Using classical molecular dynamics simulation of particles interacting via a Yukawa-type interaction, it is demonstrated unequivocally that for a given Re, the transition from laminar to turbulent flow is controlled by strength and range of inter-particle potential. For a wide range of inter-particle strengths and ranges, our simulation data is seen to collapse onto a Universal Strouhal-Rayleigh curve with new asymptotic values for a range of Re values, $2 \leq Re \leq 35$. From the emergence of vortex street structures behind the obstacle, it is evident, that the onset of turbulence is possible at low Re in Yukawa liquids. Growth rates of the instability are obtained for the first time using atomistic calculations and are observed to increase with a polynomial of ~ 2.4 with low values of Re.

406/EP-13/P

SINGLE PARTICLE AND COLLECTIVE FEATURES IN DUSTY PLASMA MEDIUM BY MOLECULAR DYNAMICS SIMULATIONS

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Abstract

When a collection of dust particles are immersed in plasma the electrons in the medium stick to their surface charging them negatively. This results in a three component medium with positively charged ions, negative electrons and negatively charged dust particles. These dust particles can often be quite large, i.e. of the size of microns and hence a large number of electrons ~ 10^4 in number can stick on their surfaces, making them highly charged. The electric field of the dust charge is shielded by the lighter electron and ion species of the plasma. The dust particles thus interact with each other via screened Yukawa potential [1,2] and display collective plasma behaviour. We demonstrate here using Molecular Dynamics (MD) simulations that single particle behaviour often also has prominent consequences. The interplay of single particle and collective phenomena [3] has been demonstrated.

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418/EP-14/P

STEADY EQUILIBRIUM CO-ROTATING DUST VORTICES IN COMPLEX PLASMA

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Abstract

Dust clouds suspended in a plasma represent the simplest model for various living/active systems of nature which are inherently complex and thermodynamic non-equilibrium [1,2]. Dynamics of such dust clouds confined in an axis symmetric cylindrical setup and in dynamic equilibrium with the background plasma is analyzed using hydrodynamic formulation for wide range of Reynolds numbers(Re) [2,3]. It revealed that any non-conservative forces associated with a species in a complex flow causes vortex flow of another slowly moving species in the system. Also in the nonlinear regimes (high Re), the dust flow structure mainly depend on the Reynolds number (Re) and aspect ratio (Lz / Lr) of the confined domain. For $L_z : L_r \gg 1$, the flow structure is characterized by symmetric and elongated circulation at linear regime (low Re), and is turned into new antisymmetric pattern in non- linear regime (high Re). The structural transition take place through small twinning at a critical kinematic viscosity $\mu*$ that signifies a structural bifurcation of the flow fields [3]. Then the flow structure turns into a system of identical structure co-rotating vortices of almost uniform core region and surrounded by shear layers. The proposed flow structural change is relevant withbiological activity like cell mitosis where cell division take place through a threshold criticaltransition similar to structural bifurcation.

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83/EP-15/P

EQUATION OF STATE OF THREE DIMENSIONAL YUKAWA GAS

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Abstract

Molecular Dynamics (MD) simulation is carried out to obtain an equation of state relating pressure (P_d) to volume (V_d) for three dimensional confined Yukawa gas. Confinement effects are taken into account by using perfectly reflecting boundary conditions. The results of the MD simulations show that the pressure of confined Yukawa gas can be written as the sum of two terms, first, the kinetic pressure and second, the electrostatic (ES) pressure. It is shown that ES pressure is much bigger than the kinetic pressure $n_d T_d$ even in the weak coupling regime and scales as $1/V_d^2$ (here $n_d$is number density and $T_d$is temperature of Yukawa particles). Results are compared with earlier theories and experiments

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92/EP-16/P

PROPAGATION OF SHOCK AND SOLITARY WAVES IN PRESENCE OF NEGATIVE DUST CHARGE WITH NEGATIVE ION TRAPPING

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Abstract

In this work, we have investigated the propagation characteristics of small amplitudes of electrostatics shock and solitary waves in unmagnetized dusty plasma in present of negative dust charge with negative ion trapping. In this respect we have derived the evaluation equations for dust acoustic shock waves in the form of trapped Korteweg-de-Vries Burger (TKdVB) equation with the help of standard reductive perturbative technique. Due to presence of trapped ion, the fractional nonlinearity appears in the TKdVB equation. In two different approximations, the TKdVB equation provides Trapped Burger (TB) and trapped Korteweg-de-Vries (TKdV) equations. To solve the equations the tangent hyperbolic method are used. The profiles of shock waves are analysed with the help of TKdVB and TB equations. For profile of solitary waves TKdV equation is employed. We have also analysed the effect of different plasma parameters for propagation characteristics of nonlinear waves obtained from above three equations and observed that the plasma parameters play important roles in formation and propagation of shock as well as solitary waves.

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104/EP-17/P

EXPERIMENTAL OBSERVATION OF DYNAMIC STRUCTURES IN DUSTY PLASMA FLOWING PAST AN OBSTACLE

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Abstract

Dusty plasma is a partially ionized gas, which contains negatively charged dust particles of micron to nanometer size in addition to normal electron and ions. Micron sized dust particles in a gas discharge plasma acquire a significant negative charge (~10^3 - 10^5 electrons) and form a quasi-stationary dusty plasma medium similar to a liquid or solid [1, 2]. In a number of studies, the dynamics of dusty plasma under external effects have been demonstrated, such as various flows in dust plasma structures and low frequency wave modes [3-8].

Fluid flow past an obstacle is a phenomenon which is omnipresent in nature and is of fundamental importance in many fields of sciences such as biology, engineering, fluid dynamics etc. [9]. Here, we present experimental observations of dusty plasma flow past a cylindrical obstacle. The experiment is performed in a cylindrical glass chamber where plasma production is achieved by applying RF discharge (5-10) W at an argon gas pressure of (0.8 – 5) Pa. A dust layer with (10×20) sq. cm area is levitated above a grounded plate by introducing gold coated silica dust particles of 5 micron diameter. A cylindrical obstacle is placed vertically above a stationary horizontal plate and dust particles from a nearby plasma section are allowed to flow past the obstacle at different velocities. Depending on the flow velocities, we observe the formation of structures in front and behind the obstacle. A bow shock is formed by the reflected particles in front of the obstacle. Another significant observation is the formation of an eddy vortex pair right behind the obstacle at a particular range of dust flow velocity.

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130/EP-18/P

INSTABILITY IN DUSTY PLASMA WITH ION DRAG

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Abstract

The effect of the ion drag on the stability of a self-gravitating dusty plasma has been theoretically investigated. The dispersion relation for the dust-acoustic waves in a self-gravitating dusty plasma in the presence of ion drag is obtained. Explicit expressions for the growth rates of the instabilities are presented. It is found that DA waves are increasingly damped as the coefficient of ion drag μ ,increases from 0 to a critical value μ_{crit}. For $\mu > \mu_{crit}$ a zero frequency (non propagating) perturbation grows when the drag due to ions on the dust grains overcomes the restoring force due to the electric field.

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131/EP-19/P

COLLECTIVE DYNAMICS OF LARGE ASPECT RATIO DUSTY PLASMA IN AN INHOMOGENEOUS PLASMA BACKGROUND: FORMATION OF THE CO--ROTATING VORTEX SERIES

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Abstract

The dusty plasma, which is an admixture of the electrons, ions, neutrals, and sub--micron to micron sized negatively charged solid particles has been a current topic of research due to its applications in space plasmas [1], plasma processing technologies [2], biological systems [3] etc. In the background of plasma, the highly mobile electrons and slower ions impinge on the dust grain surface and make it negatively charged. In the low-temperature plasma, dust grains get negative charges up to 10^3 to 10^5 times of an electron charge (e). The collection of these highly negatively charged grains exhibits the collective dynamics similar to the conventional two component plasmas. The result of the collective response of the dusty plasma medium is encountered as dust-acoustic modes [4] and vortex motion [5]. The collective dynamics of the large aspect ratio dusty plasma is studied at a wide range of discharge parameters in inductively coupled diffused plasma, which creates an electrostatic trap to confine the negatively charged grains. For introducing the dust grains into the potential well, a unique technique using the DC glow discharge plasma is employed. The dust dynamics is recorded in a 2-dimension (2D) plane at a given axial location. The dust grain medium exhibits wave like motion at low pressure and high power. The mixed motion, waves and vortices, are observed at an intermediate gas pressure and low power. Above the threshold value of gas pressure, the clockwise and anti-clockwise co-rotating vortex series are observed on the either sides (or edges) of the dust cloud, whereas central region grains show random motion. These vortices are only observed above a threshold width of the dust cloud. The streaming ions are considered the available free energy source to excite the waves in dust grain medium. The occurrence of the co-rotating vortices is understood on the basis of the charge gradient of dust particles which is orthogonal to the gravity. The charge gradient is a consequence of the plasma inhomogeneity from the central region to the

outer edge of dust grain medium. Since, a vortex has the characteristic size in the dissipative medium; therefore, a series of the co-rotating vortex on the both sides of dusty plasma is observed. The experimental results on the vortex formation and its multiplicity are compared to an available theoretical model and are found to be in close agreement. The detailed design of an experimental device and experimental results will be presented.

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163/EP-20/P

DUST DENSITY IN CO-GENERATED DUSTY PLASMA: TUNGSTEN & GRAPHITE

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Abstract

Tungsten wall is being considered instead of Graphite in modern fusion device, ITER, as plasma facing components. Therefore, the growth of co-generated tungsten dust particles was observed in argon plasma environment with bi-polar pulsed DC voltage power supply. Particles of different size distribution were sputtered from tungsten electrode inside a cylindrical vacuum chamber made of Stainless Steel. The dust distribution at different time interval was investigated with the help of Scanning Electron Microscope images. This distribution was then compared with the distribution of graphite dust particles following the same treatment. By varying different experimental conditions such as pressure, voltage, electrode spacing the dependence of dust size as well as dust density (No of particles per unit area) was recorded for both the cases. In case of Tungsten, the dust growth rate or the overall growth was much less than graphite.

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TWO CONCENTRIC VOIDS IN A COGENERATED UNMAGNATISED DUSTY PLASMA

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Abstract

We experimentally study the dust void around the positively and negatively biased probe. A transition point is observed when the probe potential crosses the plasma potential. At the positive probe voltage, we found that the apparent void is not completely empty of dust particles, within this a ring like dust structure is observed. A concentric small void is also observed within the apparent large void. The structure of the apparent void, dust ring and the small void is investigated. The variation of void size is complex. We explain the behavior with the help of dust size distribution, but need a further theoretical explanation.

288/EP-22/P

DYNAMICS OF DUST PARTICLES IN A FLOWING COMPLEX PLASMA

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Abstract

We report on an experimental investigation of the dynamics of dust particles in a flowing complex plasma. The experiments have been carried out in a Π shaped Dusty Plasma Experimental (DPEx) device [1] with micron size melamine formaldehyde particles in a background of argon plasma created by a direct current glow discharge. A stationary dust cloud is formed by precisely balancing the pumping speed and the gas flow rate and a flow is then generated by using single gas injection and dual gas injection techniques [2]. The dynamics of the dust particles are studied by measuring their velocity with time. In both the cases, the particles are seen to move from right to left and within a few hundred milliseconds these micro-particles attain a terminal velocity. The terminal velocity of the dust particles are measured for different gases and particle sizes over a wide range of background neutral pressure. A theoretical model is developed to explain the experimental observation..

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380/EP-23/P

EXPERIMENTAL INVESTIGATION OF CRYSTAL STRUCTURES AND PHASE TRANSITION IN DPEX

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Abstract

We present the structural analysis of a strongly coupled dusty plasma in a Π-shaped Dusty Plasma Experimental (DPEx) device [1]. The glow discharge plasma is produced by applying a DC voltage in between a circular anode and a tray cathode in the background of argon gas. Dust particles are then introduced into the plasma, which get negatively charged by collecting more electrons than ions and form a crystalline structure near the cathode sheath region by balancing the electrostatic and gravitational forces. The basic dusty plasma parameters like pair correlation function, inter-particle distance, number density, and particle temperature are measured over a wide range of discharge parameters. It is seen that the inter-particle distance and the particle temperature decreases significantly with the increase of background pressure, which essentially indicates that the crystalline structure changes its phase from solid state to liquid state. In some of the experimental situations, it is found that the co-existence of liquid and crystalline states simultaneously. The topological and the geometrical crystal defects are studied by constructing the Voronoi diagram and the Delaunay triangulation. This investigation suggests that the defects appear in the structures when the crystal starts to melt.

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469/EP-24/P

AN EXPERIMENTAL STUDY ON DIFFERENT ROUTES TO CHAOS IN GLOW DISCHARGE ARGON PLASMAS

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Abstract

Glow discharge plasmas exhibit various types of self excited oscillations. The behavior of such oscillations associated with the positive column has been investigated using nonlinear techniques like largest Lyapunov exponent. In the present work, it is seen that these oscillations go to chaotic state in different ways such as periodic doubling and intermittency routes to chaos according to the change in conditions like discharge voltages, and filling pressures. These results are unique from the other observations wherein the fluctuations have been observed to go from ordered to chaotic state.

97/EP-25/P

EXPERIMENTAL OBSERVATION OF SELF-EXCITED DUST ACOUSTIC WAVE IN NANO DUSTY PLASMA

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Abstract

Last few decades, there has been much interest in the plasma containing charged particles (dust grains) because of its importance in the study of space environment like interstellar clouds, comet tails, and rings of Saturn etc. and also due to its presence in low temperature laboratory discharges and in plasma aided manufacturing devices. These dust grains may be metallic, conducting, or made of ice particulates of size ranging from micrometer to nanometer [1]. The dust grains are charged by electron and ion collection, secondary electron emission, UV radiation etc. In laboratory discharged dusty plasma, the dust particles are negatively charged by the inflow of highly mobile electrons compared to less mobile ions. Various dust dynamical structures like void formation, vortex motion, oscillations and instabilities are observed in dusty plasma [2,3]. Various kinds of wave like DAW and DIAW have also been observed experimentally [4].

In this present experiment, dusty plasma with nanometer sized particles is produced in a glass chamber of diameter 3 cm and of length 15 cm using rf discharge (5-10 W) at a pressure of 0.01-0.001 mbar by externally injecting the nano dust particles into argon plasma. A dense dust cloud, trapped inside the plasma, is observed under the laser light illumination (532 nm and 50 mW). Self-excited dust acoustic wave (~ 50 – 100 Hz) is detected in the dust cloud using a high speed camera (@240 fps). The average dust charge is estimated from Orbital Motion Limited theory using experimentally measured parameters. The measured wave parameters are used to determine other dusty plasma parameters such as dust density and average inter particle distance. The screening parameter and Coulomb coupling parameter is also determined [5].

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265/EP-26/P

CHARACTERIZATION OF PARTICLE GROWTH IN A CO-GENERATED DUSTY PLASMA

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Abstract

A Direct Current glow discharge argon plasma is produced in between the graphite made cathode and the anode. Due to the ion bombardment, the carbon particles will be eroded from cathode surface at a particular discharge condition. These carbon particles will be charged negatively by collecting more electrons than ions and will be levitated in the cathode sheath region by balancing electrostatic force with gravitational force. It is expected that the eroded particle density increases at a particular location as time evolve. A red He – Ne laser is used to illuminate the levitated carbon particles. The time evolution of scattered light from the growing carbon particles are captured using a CCD camera (with frame rate ~ 60 fps) and the images is stored in a high-speed computer.

The pair correlation function (g(r)), defines the probability of finding a particle at a distance r from another particle [1,2], will be calculated with the known x and y coordinates of the particles. The location of first peak in g(r) vs r plot (as shown in figure) gives the inter-particle distance (d), which can be used to calculate the particle density ($n_d=3/(4\pi d^3)$). As the time evolves, the peak in g(r) shifts towards left, which essentially implies the decrease of inter-particle distance and hence increase of particle density.

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“PLASMA BROOM” AN APPARATUS FOR SURFACE CLEANING AND DECONTAMINATION USING ATMOSPHERIC PRESSURE PLASMA JET

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Abstract

Health and hygiene is primary concern of everyone. However, now a day it is quite difficult to maintain hygienic condition under certain circumstances such as while travelling in aircrafts, other public transport as well as in few places like hospitals. Aircraft and other public transport means carry millions of commuters every day. Many of them may carry infectious diseases. The pathogens they carry with them will cause health care associated infections. The passenger seats of aircraft, airport, public transport like buses and trains, hotel's mattress, pillows, curtains etc. In hospitals, number people are treated in the same bed. The seats of aircraft, trains as well as mattresses and pillows provided by the hotels and hospitals should be decontaminated before further use as they may carry infectious pathogens.

The conventional methods of decontamination have certain limitations regarding its usage in terms of its effectiveness, environmental effect, process time, and economic cost. In addition, decontamination approaches, such as the use of hydrogen peroxide H2O2, phenol and alcohol based compounds require time for dehumidification particularly in aircraft. And also such methods require evacuation and cannot be used in the presence of the passenger and cleaning personnel.

Majority of the disinfectants are oxidizer, and the interior of an aircraft contains many materials susceptible to damage from cleaning products and disinfectants. Metals used in the construction of the aircraft may corrode, safety-critical cables and wires may deteriorate and aircraft furnishings may have their fire resistance properties reduced upon exposure to such products.

In this paper development of a device using Atmospheric pressure plasma jet (APPJ) which is a source of low temperature plasma with chemically reactive species is discussed. The Plasma has positive and negative ions, radicals of reactive species, intense electric fields, and UV radiations. Such chemical and physical property of the plasma can be helpful to kill the pathogens and to maintain hygiene conditions which may provide substitute for conventional disinfectants. APPJ can be effectively used for cleaning and decontamination of surfaces of seats of aircrafts and other public transports as well as beds, pillows and curtains of hospitals which will help in maintaining the hygiene in such places.

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32/IP-02/P

RECENT TRENDS IN PLASMA TECHNOLOGY FOR WASTE TO ENERGY APPLICATIONS

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Abstract

The concept of thermal plasma torch for waste remediation was come up to the mid of 1970s during energy crisis. Due to the great applications of thermal plasma, plenty of work has been done using DC, RF and microwave plasma sources.

Experimental investigations are made to understand gas heating and dissociation in a microwave (MW) plasma torch at atmospheric pressure. The MW induced plasma torch operates at 2.45 GHz frequency and up to 2 kW power. Three different gas mixtures are injected in the form of axial flow and swirl flow in a quartz tube plasma torch to experimentally investigate the MW plasma to gas energy transfer. Air–argon, air–air and air–nitroge n plasmas are formed and their operational ranges are determined in terms of gas flow rates and MW power. Visual observations [1], optical emission spectroscopy [2] and K -type thermocouple measurements are used to characterize the plasma. The study reveals that the plasma structure is highly dependent on the carrier gas type, gas flow rate, and MW power. However, the plasma gas temperature is shown not to vary much with these parameters. Further spectral and analytical analysis show that the plasma is in thermal equilibrium and presents very good energy coupling between the microwave power and gas heating [3] and dissociation. The MW plasma torch outlet temperature is also measured and found to be suitable for many thermal heating and chemical dissociation applications. Study reveals that microwave plasma torch can be used to treat the modern waste in terms of valuable byproducts and energy.

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68/IP-03/P

METHANE-AIR FLAME SPEED ENHANCEMENT USING NANOSECOND PULSE EXCITED PLASMA DISCHARGE

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Abstract

This paper presents the experimental studies on the effect of non-thermal plasma on a methane/air premixed combustion. High voltage nanosecond pulse discharge can generate high energy electrons and ions without much gas heating. These high energy electrons enhance the combustion by producing active radicals (e.g. O, H, OH), electronically and vibrationally excited molecules via electron impact excitation, dissociation, ionization and recombination reactions, the rate of which have a strong exponential dependence on reduced electric field (E/N) [1,2]. A coaxial reactor is made such that methane/air premixed mixture passes through a volumetric dielectric barrier discharge(DBD). The reactor can be configured for different plasma discharge gaps by varying the inner electrode diameter such that wide range of electric fields can be obtained. Volumetric DBD is established in the gap using a 30 kV nanosecond pulse generator whose pulse repetition rate (PRR) can be varied from 1 Hz to 3.5 kHz. An experimental study of the methane/air laminar flame speed for different equivalence ratios and the effect of different plasma parameters like electric field, pulse repetition rate (PRR) on the flame speed are carried out. Upto 70% increment in the flame speed has been observed for reduced electric field values less than 250 Td whereas low temperature (<500 K) ignition has been observed in plasma region for higher reduced electric field values (>250 Td). Besides applied voltage and discharge current waveforms are captured for input electric energy calculation and will be presented in the final manuscript.

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160/IP-04/P

STUDY ON EFFECT OF ATMOSPHERIC PRESSURE AIR PLASMA ON JUTE FIBER PROPERTIES

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Abstract

Jute is a low cost natural fiber abundantly available in our country with many advantageous properties such as high strength, good thermal and sound insulation, antistatic etc. However it is presently being used in cheap household commodities like sacking, ropes and carpet backing cloth (CBC). The surface modification of jute fibers is necessary in order to develop diversified jute products [1]. The Jute fiber consists mainly of cellulose, hemicellulose and lignin. The various surface chemical treatments such as sodium hydroxide, peroxide, organic and inorganic acids are being used for delignification and bleaching of jute fibers. However, such chemical treatments are not environment friendly and require more energy, time and water. The objective of present work is to understand the interaction of cold plasma with jute fibers and develop eco-friendly alternative for surface modification of jute fibers.

In the present work, atmospheric pressure air plasma has been used for surface modification of jute fibers. Plasma induced physio-chemical changes in Jute fibers are studied by using FE-SEM (Field Emission Scanning Electron Microscope), ATR-FTIR (Attenuated Total Reflection-Fourier Transform Infrared Spectroscope) and Spectrophotometer as a function of plasma exposure time . The air plasma exposure significantly lightens the color of jute fibre. Spectrophotometric evaluation shows the L (Lightness index) value of jute fiber increases from ~ 50 to ~ 70 for 30 minutes plasma exposure. This bleaching effect of air plasma on jute fibers can be attributed to oxidation of lignin. The morphological and chemical analyses demonstrate the oxidation and partial removal of lignin from the jute fiber surface. This study confirms the air plasma can be used as an eco-friendly alternative for delignification and bleaching of the jute fibers.

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181/IP-05/P

INFLUENCE OF WATER VAPOUR ON STRUCTURAL AND THERMAL CONDUCTIVITY OF POST-HEAT TREATED PLASMA SPRAYED LZ AND YSZ COATINGS

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Abstract

In this work, the role of water vapour content during the post-heat treatment on the microstructure and thermal conductivity of atmospheric plasma sprayed lanthanum zirconate (LZ) and yttria stabilized zirconia (YSZ) coatings were studied. For this purpose free standing LZ and YSZ coatings with thickness about 300-400 micron were prepared and post-heat treated at 1100°C for 50 h and 100 h with and without water vapour content. Phase stability and microstructure were investigated using X-ray diffraction and scanning electron microscope respectively. Thermal conductivity of as-sprayed and post-heat treated coatings were measured by laser-flash thermal diffusivity method and results obtained show that the thermal conductivity of post heat treated coatings increased significantly in both coatings. Further, the thermal conductivity of the coatings increased with increasing heat treatment time. Overall observations show that the presence of water vapour during the post-heat treatment has significantly influenced the microstructures as well as thermal conductivity in both coatings. Thermal conductivity of post-heat treated lanthanum zirconate and yttria stabilized zirconia coatings with presence of water vapour is 2.12 W m^{-1} K^{-1} and 2.48 W m^{-1} K^{-1} respectively which is 46% and 41% higher than as-sprayed coating.

225/IP-06/P

CHARACTERIZATION OF ATMOSPHERIC PRESSURE PLASMA JET USING OPTICAL EMISSION SPECTROSCOPY

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Abstract

An atmospheric plasma jet is developed for various bio medical applications. The plasma stream is generated with a dielectric barrier discharge (DBD) and Argon as a flowing gas. For the jet to be qualified for its usage in bio-medical applications, it needs to possess a cold gas temperature and the same needs to be established before the trials. Also it is important to characterize the plasma jet for its electron temperature, gas temperature and identifying the main species for the optimization of the performance of the jet.

This study describes a detailed experimental investigation of the argon plasma jet discharge. The jet was operated for a range of voltages 2.2 kV to 2.7 kV and at flow rates of 10 lpm to 25 lpm. For all the above settings, the jet is found to be enriched with energetic Ar meta stables (696nm – 950 nm) , excited oxygen atoms(777nm) and OH molecules at near UV range(306-312nm).The electron temperature of the Ar jet was determined using Boltzmann plot of Ar atomic lines. The gas temperature was determined by fitting of the experimental OH band spectra to the simulated OH spectra and also using the Boltzmann plot method on rotational transitions in R and P branches of same OH band. The gas temperatures is found to be very near to the room temperature (~300K) and the excitation temperature is ~0.1 eV. No appreciable change in gas temperature was observed when the plasma jet was operated in the range of 2.7 kV - 2.2kV and flow rates of ~10-25 lpm. Whereas the electron temperature decreases from ~0.1eV to ~0.07 eV when it is operated at the above operational parameters.

266/IP-07/P

EXPERIMENTAL STUDY OF ATMOSPHERIC PRESSURE PLASMA JET (APPJ) AND ITS APPLICATION FOR POLYMER SURFACE MODIFICATION

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Abstract

Atmospheric Pressure Plasma Jet (APPJ) has attracted much attention in recent year due to its possible application in material processing, surface modification and biomedical application. Present work reports the generation of APPJ at 20 - 30 kHz frequency using high voltage power supply. The variation of the jet length with applied voltage and gas flow rate has been investigated. It is seen that there was increased in jet length with increase in applied voltage and gas flow rate. Jet has been characterized by optical and electrical methods. In order to characterize the plasma jet, its electron temperature has been determined by optical emissions spectroscopy. The electron temperature and electron density of plasma jet have been measured. Results showed that the electron density was of the order of 10^{16} cm^{-3} as determined by stark broadening method while electron temperature is estimated to be about 0.6 eV by using intensity ratio method. The jet sustained in argon environment has been used to modify the surface properties of Polypropylene (PP). The surface properties of the untreated and plasma treated PP samples was characterized by contact angle measurement and Fourier Transform Infrared Spectroscopy (FTIR) analysis. The contact angle was used to determine the surface energy and its polar and dispersion components. The effects of treatment time, applied voltage, gas flow rate and distance of sample from the nozzle on the wettability of the sample were studied. It was found that the contact angle of water in untreated PP samples was 93.5^{o} which decreased to 58^{o} in water after 2 min of treatment time. Moreover, it was found that the best plasma treatment can be obtained with voltage of 5 kV and a distance of 1.5 cm between the surface of sample and jet

nozzle. Result showed that non thermal plasma can be effectively used to enhance the surface wettability and surface energy of PP.

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267/IP-08/P

DEVELOPMENT OF ATMOSPHERIC PRESSURE PLASMA JET AT 50 HZ FOR SIO_2 FILM DEPOSITION

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Abstract

This work reports generation of Atmospheric Pressure Plasma Jet (APPJ) using line frequency and its application for SiO_2 film deposition. The potential difference of 6000 to 9000 volts were applied in between counter electrodes to produce plasma plume using argon as working gas. The electron densities of the discharge was determined using stark broadening method and were found to be 2.3888×10^{16} cm^{-3} at 6000 volts, 2.4007×10^{16} cm^{-3} at 7200 volts and 2.588×10^{16} cm^{-3} at 9000 volts. These results shows increment in electron density with increase in applied voltage. The discharge so produced was used to deposit SiO_2 thin film using hexamethyldisiloxane (HMDSO) as precursor liquid. The precursor was introduced in the plasma environment from additional inlet which was transported and deposited on glass substrate. The presence of Silicon has been confirmed by optical emission spectra of Jet. Profilometry analysis was used to determine thickness of film and was found in the range 155 nm to 160 nm.

316/IP-09/P

EFFECT OF PLASMA TREATMENT ON OPTO-ELECTRONIC PROPERTIES OF FTO THIN FILMS PREPARED BY SPRAY PYROLYSIS METHOD

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Abstract

For a transparent conductor like Fluorine doped Tin Oxide (FTO), having high transparency while maintaining minimum resistance is of paramount importance. FTO thin films were deposited on glass substrate by spray pyrolysis method at a temperature of 450 °C from a mixture of Dehydrate Stannous Chloride [$SnCl_2$. $2H_2O$] and Ammonium Fluoride [NH_4F] as precursor solutions. The optical and electrical properties of thus prepared thin films were investigated before and after the plasma treatment. Plasma treatment was found to be in favor of decreasing resistance and at the same time increasing transmittance. For a particular sample with thickness 420 nm, after plasma treatment, the peak transmittance increased from 70% to 76% and the sheet resistance decreased from 50 Ω/□ to 45 Ω/□. This trend of slight decrease in sheet resistance and increase in transmittance is observed across all samples.

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373/IP-10/P

INVESTIGATION ON WELDABILITY OF ALUMINIZED 9CR STEELS

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Abstract

Aluminide coatings with a top alumina layer on 9Cr steels are considered candidates for fusion blanket applications. α-Al2O3 + FeAl coatings have been found promising for resistance to Pb-17Li corrosion attack and are reported to have reduced hydrogen permeation reduction factors. Such aluminide coatings have an Al reservoir of ~50-80 microns on the surface for acting as self-healing coating. In addition, FeAl materials with a top Al_2O_3 protective film are currently being studied for a number of applications including power plants, automobiles, nuclear reactors, molten carbonate fuel cells etc. However, the presence of aluminides in the form of FeAl or Fe(Al) also poses a threat on the mechanical and structural properties of the bulk material. One of the critical issues associated with such coating is the fabrication sequence. It is therefore important to investigate the metallurgical aspects of the weldability of aluminide coated 9Cr steels. The investigation has been made by bead on-plate experiments by varying the welding parameters for both coated and bare 9Cr materials through conventional gas tungsten arc welding process.

The samples were prepared with varying heat input by varying the travel speed (200A weld current at travel speed such as 100,125,150 mm/min). The effect of α-Al_2O_3+FeAl coatings on depth of penetration (DOP) and microstructure were investigated and compared with bare welded samples. The weld shape and dimensions were analysed through optical microscopy. The presence of oxides in the Al-Si coated layer caused the Marangoni convection and at full DOP, the bead width of coated samples was narrower and depth was more as compared to the bare 9Cr samples. The average grain size was higher in the weld zone for both coated and bare samples. However, the grain size observed was small in weld metal for coated sample as compared to the bare one due to the presence of Aluminium. The distribution of Al was

examined with the help of X-ray diffraction (XRD), followed by scanning electron microscopy equipped with energy dispersive x-ray (SEM-EDX) by mapping at weld zone, heat effected zone and base metal. The micro hardness was measured in transverse direction across the weld. The hardness was maximized in the weld pool and decreased from the HAZ to base metal. However, the hardness was higher of coated sample compare to the bare one due to the presence of oxides such as Al_2O_3 in the weld pool as well as heat affected zone

361/IP-11/P

INFLUENCE OF THE GAS INJECTION CONFIGURATION ON THE CHARACTERISTICS OF A DC NON-TRANSFERRED ARC PLASMA TORCH

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Abstract

Characteristics of DC plasma jet are always a matter of importance for the users as well as for the scientific community because of its large number of application in different areas. The characteristics of the plasma jet emanating from the plasma torch is affected by many factors including current, type of gas, gas flow rate, gas injection configuration and torch geometry etc. However, there are limited experimental studies concerning with the influence of the gas injection configuration on the plasma jet characteristics. The present experimental study focuses on the influence of the shroud gas injection configuration on plasma jet operated in nitrogen at atmospheric pressure.

A 25kW DC plasma torch used in this study consists of three electrodes such as tungsten cathode, copper anode and copper nozzle (floating electrode). The torch has facility of two gas inlets, one for the plasma generating gas (axial gas) and the other for shroud gas. The three different nozzles such as normal, sheath and twisted nozzles were used for injecting shroud gas. The plasma torch was operated over a wide range of gas flow rates (5-80lpm) and current (70-150A). Torch power and electro-thermal efficiency were measured using calorimetric method. The plasma torch is characterized by using measured arc voltage and electro-thermal efficiency of the torch. The I-V characteristic curves have both negative and positive slopes if the plasma generating gas (upto 35 lpm) is injected through normal nozzle whereas the same have only negative slope if the plasma generating gas (upto 35 lpm) is injected through other nozzles. Electro-thermal efficiency torch with normal nozzle is higher than that with other nozzles.

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461/IP-12/P

WATER UPTAKE MECHANISM AND GERMINATION STUDY OF BROWN CHICKPEAS AND MUNG SEEDS TREATED BY RADIO-FREQUENCY (RF) AIR PLASMA

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Abstract

The use of cold plasma (also called as low-temperature plasma*)* is the fastest emerging field in area of food processing technology, bio-medical application, waste management and agricultural discipline [1]. In particular, cold plasma treatment is well known as a suitable tool for improvement of physical and chemical properties of various surfaces, which result in a dramatic change of wetting behavior of treated surfaces. It has been further demonstrated that wettability and seed germination of plants seeds such as lentils (Lens culinaris), beans (Phaseolus vulgaris) and wheat (Triticum aestivum) can be modified by air plasma treatment using RF (10 MHz) power source [2].

In this study, we have attempted the surface modification study of brown chickpeas (Cicer arietinum) and mung (Vigna radiate) seeds by air RF (13.56 MHz) plasma for wettability and germination enhancement. These seeds have been treated in a capacitively coupled plasma reactor by varying treatment time ranging from 5 min to 30 min with fixed 50 watt coupled power and 1 mbar pressure. The initial contact angle measurement results show improvement of hydrophilic properties of plasma treated seed as compare to un-treated seeds. The contact angle measured for un-treaded seeds are 78.7° and 92.7° for brown chickpeas and mung, respectively. While, RF air plasma surface treatments for 30 min reduce contact angles to 27.9° and 48.3° for brown chickpeas and mung, respectively confirm the improvement of wettability of plasma treated surfaces and hence hydrophilic properties. The detail results for water uptake (imbibitions) and germination will be discussed and presented in during conference.

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471/IP-13/P

SURFACE MODIFICATION OF POLYAMIDE BY 50 HZ DIELECTRIC BARRIER DISCHARGE (DBD) AT ATMOSPHERIC AND NEAR ATMOSPHERIC PRESSURE

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Abstract

The industrial application of the dielectric barrier discharge (DBD) has a long tradition. However, lack of understanding in some of its fundamental issues, such as the stochastic behaviors, is still a challenge for DBD researchers. In this project, considerable efforts to understand the fundamental aspects of DBD have been made. The work was carried out at line frequency, 15KV, and at atmospheric and near atmospheric pressure (40 torr). This work focuses on the study of the electrical and optical characteristics of DBD at atmospheric and near atmospheric pressure to determine a suitable condition for utilization of the device for surface modification of Polyamides (PA). Several diagnostic tools such as high voltage and current probe, high-speed camera imaging, contact angle, surface free energy measurements are employed for the investigation. The outcomes of the experiments proved that the modification of surface properties via plasma treatment reaches to its saturation point after certain treatment time reducing the necessity of further treatment.

124/IP-14/P

DIAMOND LIKE CARBON COATING FOR FRICTION REDUCTION ON STEEL COMPONENTS

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Abstract

Most of the daily life appliances, machineries, tools and automotive parts are made up of steel materials, which is strong and more abundant in the earth. But the main disadvantage of this includes rusting and corrosive to chemicals, particularly in oil and water engines. In order to overcome these problems, nowadays alloys like carbon steel and stainless steel etc. are in practice, especially in automotive and machineries. The main challenge in automobile industry is the high wear and friction on sliding surfaces which lead to loss in overall efficiency of the system and also failure of components with time.[1-3] Surface engineering help us to protect the components from wear loss and frictional loss which result in improved efficiency and lifetime of the devices by means of nano-scale low friction coatings/solid lubricants like TiN, CrN, DLC, etc.[4, 5] Where DLC is the most common and cost effective material for surface protection. Another challenge over here is poor compatibility of DLC with steel alloys and delamination. So this work is based on optimization of deposition parameters for DLC coating on stainless steel components for high wear resistance and low friction application by combining magnetron sputtering and Plasma Enhanced Chemical Vapor Deposition method for interlayer deposition [6] and DLC synthesis for the better adhesion. The surface properties of DLC also having major role in the tribological properties as it interact with liquid lubricants in different ways in wet conditions.[7] These tests have been done mainly for tribological behaviour and adhesion of the deposited films.

224/IP-16/P

PHYSICS AND APPLICATION OF THE FIREBALL

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Abstract

Plasma fireball is a localized phenomenon generally observed near the highly positively biased electrode. Subject to the global particle balance, the positively biased electrode may develop an electron sheath [1]. This electron sheath can potentially turn into a localized ionization zone due to acceleration of the electrons. These energetic electrons can ionize and excite the gas in the sheath resulting in the localized glow [2]. Once the number of ions produced due to the ionization reaches sufficient level it can establish a quasi-neutral region. This leads to a complex phenomenon of the fireball which depends on many parameters e.g. background pressure, discharge current, global particle loss, number of anodes in the system, external driving circuit and the current imposed on the electrode by it [3].

A specialized low cost devise was studied for the properties of its fireball [3-5]. The copper anode is placed in a water cooling housing with permanent magnets behind the electrode. The strength of the magnets at the pole location is approximately 2000 gauss but the field drops quickly as we move away from the anode. The magnetic field restricts the available area of the anode and forms a fireball. A large sized fireball was sustained near the anode with localized magnetic field. Density inside the fireball was found to be almost an order of magnitude higher than the ambient plasma density. The fireball was found to have a potential double layer near the visual boundary [3].

Such device can be potentially used as a broad beam ion source owing to its low pressure operation and relatively high localized plasma density. It was tested as working example to fabricate patterned nanodots on GaSb substrate [5]. The pattern can be varied by changing plasma parameters, which ultimately changes the ion energy and the flux hitting the sample. The patterned sample have shown excellent hydrophobic nature. This opens up a variety of possibilities where a designated ion source would have required which is both complex and relatively costly.

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42/NF-01/P

MODELLING AND PIPING FLEXIBILITY ANALYSIS OF EXPERIMENTAL HELIUM COOLING LOOP (EHCL)

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Abstract

Experimental Helium Cooling Loop (EHCL) is a high pressure-high temperature helium gas system. EHCL is similar to the First Wall Helium Cooling System (FWHCS) of LLCB TBM and in this loop First wall mock ups up to one fourth (¼) size of TBM can be tested.

EHCL modelling consists of equipment arrangement, pipe routing, support, cable tray routing, instrumentation arrangement and tube routing. EHCL lab floor dimensions are 18m x 18m length and width respectively while the vertical height is 5 meter. The lab is divided in three major areas: process area, control room and free space for maintenance activities. The process and control room covers 9m x 9m and 14m x 5m floor area respectively.

The EHCL is designed to operate with helium gas at 8.0 MPa (gauge) pressure and at 300-400 C temperature. The flow rate varies from 0.2 kg/s to 0.4 kg/s. The selected size for the connection pipes is DN 50. The high temperature pipes in this loop are at 400 C and at 8 MPa pressure, and these pipes are connected to equipment in a limited space. The detailed flexibility analysis was carried out, to ensure safety of the piping system and to maintain the structural integrity under loading conditions (both external and internal), which may occur during the lifetime of the system. SS 316L is used as structural material for piping and equipment.

This poster presents the modelling of EHCL and the results of detailed flexibility analysis of EHCL pipes. To carry out the analysis, the entire piping system of the loop was modeled and the static and dynamic analysis was carried out in CAESAR II software. For the floor response spectra, the floor level in two horizontal and one vertical direction was computed.

As IPR lies in seismic zone –III, and the process loop is planned to be located at ground level at IPR campus, accordingly the FRS was used to find out the induced stress in the process loop. The dynamic effect and weight effects are considered in the design so that the stresses created by the combined loads do not exceed the allowable stresses prescribed by the design

codes. Finally the piping layout satisfying the code requirements along with the results are presented in the poster.

Summary: This poster presents the modelling of EHCL and the results of pipe stress analysis of EHCL pipes.

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46/NF-02/P

VISCO-RESISTIVE MHD STUDY OF INTERNAL KINK(M=1) MODES

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Abstract

Investigations of the m = 1, n = 1 internal kink mode have been carried out by numerical studies using the CUTIE[1][2] code to examine the effect of flows in a periodic cylinder geometry using a reduced magnetohydrodynamic(RMHD) model . We have observed that viscosity modifies the effect of flows on the (1,1) mode in both the linear and nonlinear regime. In the absence of flow and with poloidal flow, our results are in good agreement with analytical scaling laws of the linear growth rate for the (1,1) mode with resitivity and viscosity obtained by Porcelli[3]. However, there is a significant change of scaling dependence in the presence of axial flows compared to the no flow case. Axial flows increase the linear growth rate for low viscosity values, and for higher viscosity stabilise the mode, while poloidal flows decrease the linear growth rate in all cases. Additionally, we have observed strong symmetry breaking, observed earlier for tearing modes[4], in the linear growth rates for the modes for different helicities of helical flows at higher viscosity, which is absent for pure axial and poloidal flows. In case of nonlinear saturation; in axial, poloidal and most helical flow cases, we report stabilisation in the high viscosity regime and destabilisation in the low viscosity regime.

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136/NF-03/P

OVERVIEW OF ACTYS PROJECT ON DEVELOPMENT OF INDIGENOUS STATE-OF-THE-ART CODE SUITES FOR NUCLEAR ACTIVATION ANALYSIS

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Abstract

Rigorous activation calculations are warranted for safer and efficient design of future fusion machines. Suitable activation codes, which yield accurate results with faster performance yet include all fusion relevant reactions are a prerequisite. To meet these, an indigenous project called ACTYS-Project is initiated and as a result, four state-of-art codes are developed so far.

The goal of this project is to develop indigenous state-of-the-Art code suites for nuclear activation analysis. The first of the family is called *ACTYS*, a nuclear activation code. It computes the radioactive/stable inventories formed within materials when exposed to neutron flux through either continuous, pulse irradiation or mixed. *ACTYS* is based on linear chain solution method for coupled Bateman system. For fusion reactors having large size and a wide variety of materials, highly resolved nuclear activation analysis and radiation waste classifications are warranted. For such cases, fast and accurate multi-point activation solvers which simultaneously computes the radiological response of neutron irradiated materials are required. *ACTYS-1-GO* is 'a multi-point' activation code developed for this purpose. The mathematical and computational details of simultaneous multipoint activation problem will be presented along with solution strategies. A module called *ACTYS-ASG*is developed which realize one to one coupling between *ACTYS-1-GO* and either Attila or MCNP. The radioactive responses like activity, decay heat and dose are calculated from radioactive daughter isotopes, they are indirectly related to the parent isotopes present within the material. Such a quantification of the parent constituents contribution should serve as an impact indicator. A mathematical model to tackle this problem is developed and implemented into a computer code called *'METTA'*, which is the fourth code of ACTYS family. Finally, a number of visualization tools as an aid to nuclear designers are also developed to supplement the studies

138/NF-04/P

DEVELOPEMENT ANDVALIDATIONOFMULTIPOINT ACTIVATION CODE ACTYS-1-GO AND COUPLING WITH ATTILA

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Abstract

In nuclear devices, activation study of structural material is very crucial from an operation, maintenance and safety point of view. Apropos to this,a project is being carried out at ITER-India to develop suitable indigenous codes for such studies. As a first step, a single-point nuclear activation code 'ACTYS' is developed [1]. To encompass the geometric variation in flux spectrum for large devices, a relatively fast and accurate algorithm for multipoint activation calculation is developed. The present algorithm readsmaterial definition and neutron flux spectra generated by transport codes and then performs activation calculation at each location where the material is located. It speeds up the calculations by generating a reduced common coefficient matrix for every material in the device based on one or more radiological quantities. The reduced matrix generated yields radiological quantities with more than 99% accuracy and reduces the run time by 98%. The algorithm is implemented in a computer code named 'ACTYS-1-GO' [2]. Computational performance and comparison for fusion-relevant problems have been carried out with the sequential use of activation code FISPACT and 'Fornax' module of Attila computer code.

ACTYS-1-GO is also coupled with deterministic transport code ATTILA under the name ACTYS-ASG, to evaluate shutdown dose rate using R2S method [3]. ACTYS-ASG reads geometric details from and neutron flux from 'ATTILA' files and generates gamma source file that can be read by ATTILA. The entire process is automated and the results are validated against ATTILA inbuilt activation solver, FORNAX. ACTYS-ASG provides high definition activation solution for large devices because of its faster speed and ability to couple with existing transport codes.

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150/NF-05/P

DESIGN AND ANALYSIS OF MANIFOLDS FOR INDIAN HCCB BLANKET MODULE

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Abstract

Helium-cooled Ceramic Breeder (HCCB) is one of the candidate Indian breeding blanket concepts for its DEMO. The design of manifolds is an important part in a breeding blanket design since it determines how helium is getting distributed in to different circuits for cooling different zones and components in blanket module. The flow scheme for HCCB blanket has been optimised based on its flow parameters. The inlet helium coolant of 300 C comes out at 360 C from FW and is then distributed into breeding unit zones, grid plates, top plate and bottom plate in parallel configuration. Hydraulic analysis of different circuits using ANSYS CFX has been performed to estimate the flow distribution from manifolds, velocities and pressure drop in different circuits. Heat transfer coefficients have also been evaluated using the obtained velocities in different cooling channels. The detailed design and analyses of the flow schemes in different circuits of blanket module and the purge helium flow have been discussed in this report. The thermo-mechanical design and analysis at using ANSYS mechanical has also been performed at design and operating conditions for p type and s type damages including fatigue and discussed in this report.

158/NF-06/P

Study of temperature distribution of Li_2TiO_3pebble bed using finite element simulation

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Abstract

Lithium based ceramics have been considered as a tritium breeder material in the breeder blanket in the fusion reactors. Indian Lead Lithium Ceramic Breeder (LLCB) blanket as a Test Blanket Module (TBM)will be tested in ITER.Li_2TiO_3 pebbles of ~1 mm diameter in the form of packed pebble bed will be kept inside the canisters of the LLCB TBM. In the fusion environment pebble beds will be subjected to severe conditions such as neutron irradiation, cyclic mechanical compression and high thermal flux. It is very essential to study thermal characterization of these materials as pebble bed under fusion relevant conditions. Thermal conductivity of a packed bed (Effective thermal conductivity) is one of the important parameter for the design of the breeder blanket modules of a future fusion reactor. Effective thermal conductivity of pebble bed depends on the pebble material, size distribution, packing factor, internal porosity, filling gas type, pressure phase and porosity.

Several experimental investigations can be performed to study the effective thermal conductivity of the candidate ceramic breeder pebble bed using steady-state and transient method. At IPR experimental setup for the measurement of thermal conductivity of pebble beds using steady state method have been developed and the development of transient technique is in progress. In this paper, the Hot Wire method which is a transient technique to measure the thermal conductivity of material is discussed. This technique to estimate the effective thermal conductivity of Li_2TiO_3pebble bed is simulated in ANSYS to optimize pebble bed geometry.

246/NF-07/P

3D MAGNETO-HYDRODYNAMIC ANALYSIS FOR Pb-Li FLOW INSIDE LLCB TBM

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Abstract

The first wall (FW) of Indian LLCB TBM is cooled by high pressure helium gas, whereas LLCB TBM internals, such as the breeder plates, top and bottom plates are cooled by molten lead-lithium (Pb-Li), which enters the TBM from bottom inlet plenum after passing through a circular manifold region having several bends. Further Pb-Li flows through five parallel channels around four ceramic breeder cassettes and gets collected at the top plenum of TBM. It then flows downwards through thePb-Li channel adjacent to the FW and finally exits the TBM through the bottom outlet plenum.As the LLCB TBM will be placed within the plasma-confining toroidal magnetic field,the electrically conducting Pb-Li encounters strong electromagnetic forces due to the MHD effects.As a consequence of this,velocity distribution as well as flowconfiguration of Pb-Li changesinside the LLCB TBM and an additional pressure drop occurs because of flow opposing MHD Lorentz force J×B.

In order to investigate the Pb-Li flow characteristics inside theLLCB TBM,a 3D MHD numerical analysis has been performed at 4T magnetic field (Ha~17000) and for the Pb-Li flow rate of 12.5 kg/s. For the numerical analysis, finite volume method based, ANSYS FLUENT MHD module has been used and electric potential method has been chosenfor solving the coupled MHD equations. M-type velocity profile has been observed between the side walls of Pb-Li parallel channels and it is observed to be asymmetric in nature due to the electrical coupling of Pb-Li channels. Due to the complex flow geometry of LLCB TBM manifold and significantly higher flow velocity, most of the pressure drop (>95%)occursacross the manifold of the LLCB TBM. The details of simulation model as well as MHD analysis results of LLCB TBM will be presented.

280/NF-08/P

EFFECT OF EXTERNAL POLOIDAL FLOWS ON ELECTROMAGNECTIC MICROINSTABILITIES IN LARGE ASPECT RATIO TOKAMAKS

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Abstract

One of the key issues to achieve magnetically controlled fusion in tokamak is the problem of energy and particles confinement. In the last ten years, a great deal of work has been done to study the poloidal rotations of the plasma that are induced by strong equilibrium electric fields[1]. It is indeed observed that these rotations improve energy and particle confinement.

Self generated large scale flows induced by self consistent radial electric fields (E × B flows) are known to act as a regulating agent on the plasma turbulence resulting form short scale microinstabilites[2]. As a step towards understanding the role of flow in this work we focus on the study of the effects of an externally applied poloidal flow on plasma instabilities. A gyro-averaged kinetic model or a gyro-kinetic model has been derived to estimate the effect of flows on linear properties of microinstabilities[3][4].

In the first part, details of the formulation will be presented and in the second part preliminary results on the effect of the equilibrium flow on the microinstabilities using a global gyrokinetic eigen value solver will be discussed.

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297/NF-09/P

PRELIMINARY THERMAL ANALYSIS OF GRIDS FOR TWIN SOURCE EXTRACTION SYSTEM

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Abstract

The TWIN (Two driver based Indigenously built Negative ion source) source provides a bridge between the operational single driver based negative ion source test facility, ROBIN in IPR and an ITER-type multi driver based ion source. The source is designed to be operated in CW mode with 180kW, 1MHz, 5s ON/600s OFF duty cycle and also in 5Hz modulation mode with 3s ON/20s OFF duty cycle for 3 such cycle[1]. TWIN source comprises of ion source sub-assembly (consist of driver and plasma box) and extraction system sub-assembly. Extraction system consists of Plasma grid (PG), extraction grid (EG) and Ground grid (GG) sub assembly. Negative ion beams produced at plasma grid seeing the plasma side of ion source will receive moderate heat flux whereas the extraction grid and ground grid would be receiving majority of heat flux from extracted negative ion and co-extracted electron beams. Entire Co-extracted electron beam would be dumped at extraction grid via electron deflection magnetic field making the requirement of thermal and hydraulic design for extraction grid to be critical. All the three grids are made of OFHC Copper and would be actively water cooled keeping the peak temperature rise of grid surface within allowable limit with optimum uniformity. All the grids are to be made by vacuum brazing process where joint strength becomes crucial at elevated temperature. Hydraulic design must maintain the peak temperature at the brazing joint within acceptable limit.

Preliminary thermal analysis of all the three grids of TWIN source extraction system has been done keeping the reference cooling scheme similar to SIGNAP accelerator design [2]. The analysis approach has been the steady state thermal coupled to structural and also a preliminary CFD analysis has been done using ANSYS. The initial results obtained with this preliminary analysis would be the basis for further optimization on the hydraulic cooling scheme of the three grids of TWIN source in order to achieve better cooling efficiency, uniform flow rate across cooling sections and pressure drop within limited values.

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298/NF-10/P

CONDUCTANCE CALCULATION AND VACUUM SYSTEM DESIGN FOR TWIN SOURCE EXPERIMENTS

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Abstract

The TWIN (Two driver based Indigenously built Negative ion source) source provides a bridge between the operational single driver based negative ion source test facility, ROBIN in IPR and an ITER-type multi driver based ion source. The source is designed to be operated in CW mode with 180kW, 1MHz, 5s ON/600s OFF duty cycle and also in 5Hz modulation mode with 3s ON/20s OFF duty cycle for 3 such cycle[1].TWIN source comprises of ion source sub-assembly (consist of driver and plasma box) and extraction system sub-assembly. TWIN source experiments has been planned for two modes of operation i.e. Air mode and Vacuum mode. First phase will be air mode operation where ion source will be kept at atmospheric condition and extraction system will be inside vacuum enclosure. Second phase will be vacuum mode operation where both ion source and extraction system will be placed inside vacuum chamber. Current configuration of vacuum chamber facilitate the easy transformation of air mode to vacuum mode of operation without disturbing assembled configuration of ion source with vessel. Vacuum vessel is consist of two parts i.e accelerator vacuum box (vessel-1) and driver vacuum box (vessel-2). Vessel-1 needs to be pumped to pressure of less than 10^{-05} mbar whereas vessel-2 needs to be pumped to a pressure of less than 10^{-03} mbar. For this purpose TMP is connected to accelerator vacuum box (vesse-1). For the medium vacuum pumping of vessel-2 a conductance path has been provided between vessel-1 & vesse-2 via DN 100 port. Both part of vacuum vessel would be pumped with separate rotary pumps for rough pumping.

Ion source (plasma box and drivers) needs to be pumped at a vacuum level of less than 10^{-05} mbar prior to operation. As the ion source would be pumped through the extraction system that consist of multi-aperture grids (PG, EG and GG) connected in series, conductance path through grids aperture holes need to be calculated for effective pumping speed. For the RF based plasma production during the operation phase, a hydrogen gas puff would be supplied in to the drivers at a pressure of 0.3-1 Pa. Sizing and selection of pumps needs to be done keeping in view the high gas throughput requirements for the operation phase. The base pressure inside the vacuum chamber should not fall above 10^{-03} mbar during the gas puff. Conductance calculation for the various flow regime (viscous to molecular low) of three grids in series has been done and effective pumping speed with pump down time has been calculated analytically. Also several criteria have been defined for safety interlock as an input to DAQ system.

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318/NF-11/P

3D SIMULATION OF TOROIDALLY DISCONTINUOUS LIMITER SOL CONFIGURATION OF ADITYA TOKAMAK USING EMC3-EIRENE MODEL

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Abstract

The 3D simulations of plasma transport in the SOL of non-axisymmetric limiter configuratioin Aditya tokamak are done for both its original ring limiter (RL) configuration and a block limiter (BL) configuration similar like upcoming Aditya-upgrade. The complexity of connection lengths and variation of long and short connection length is obtained from EMC3 field line mapping for Block limiter but high connection length is seen in the LCFS region and very short in limiter shadow region for Ring Limiter [1,3]. The enhanced ionization in longer connection lengths in RL case is seen responsible for a radially growing perpendicular flux but a conventional concave radial density profiles in the BL case. This indicates that for equivalent wall conditions, the localized wall recycling can be expected less intense in the BL case. The simplicity of the 3D model keeping uniform perpendicular diffusivity and only limiter wall recycling explains similar like observation in Alcator-C-Mod [2] having radially diverging flux keeping nonuniform diffusivity and wall recycling. A relatively smaller total recycling flux is recovered for the BL configuration over the complete range of diffusivity values and for three different core-SOL density values analyzed in the present study.

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353/NF-12/P

DISCRETE ELEMENT METHOD (DEM) SIMULATION OF PEBBLE FILLING UNDER GRAVITY AND INFLUENCE OF WALL EFFECT ON PACKING FRACTION OF PEBBLE BEDS

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Abstract

In LLCB TBM, ceramic pebble beds are composed of nearly spherical particles in the state of random closedpacking. The packing structure of pebble bed is important to understand thermo-mechanical responses of pebble beds, e.g., mechanicalstresses and effective thermal conductivity. Discrete Element Method (DEM) is implemented to generate the random packing structures by pouring thepebbles into rectangular and cylindrical shaped containers under gravitation force. The microstructure of a packed bed in both the bulk region and near wall regions can be determined. The packing fraction and packing structure is not same in all direction due to presence wall effect. The degree of wall effect in direction of gravity is observed little higher than the other directions. In addition to that, it is found thatthe filling strategies can change the packing fraction of pebble bed. DEM resultswill be compared with theexperimental results of pebble beds,including the packing factors and visual justifications of regular close-packed structures within thepebble bed assembly. The initial configurations of pebble beds with considering gravity effect is more realistic than the initial configuration generated through the random close packing algorithms and can be used to investigatethe overall behavior of pebble beds under fusion-relevant conditions.

358/NF-13/P

DETERMINATION OF RESIDUAL STRESSES IN LARGE SIZED CERAMIC TO METAL BRAZED INSULATOR OF HIGH VOLTAGE BUSHING (HVB) OF DIAGNOSTIC NEUTRAL BEAM (DNB)

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Abstract

DNB HVB [1] utilizes two electrical insulators for 100 kV voltage isolation i.e. ceramic insulator (for voltage and vacuum isolation) and Glass Fiber Reinforced Polymer (GFRP) (for voltage isolation and structural support of HVB). Ceramic insulator of HVB consists of ceramic (Alumina) ring -metal (Kovar, trademark of CRS Holdings, inc., Delaware) ring brazed assembly. The transition from ceramic to metal is needed so that metal ring can be clamped with connecting flanges of HVB. This is a large sized insulator with Inner Diameter (ID) 1006mm, thickness 50mm and height 348mm.

Brazing process [2] used for joining the ceramic ring with metal ring develops the residual stresses in the brazed assembly due to the fact of differential coefficient of thermal expansion of these materials.Such residual stresses clearly reduce the strength of the brazed joint and can lead to catastrophic failure at the interfaces, even during the brazing process itself. Therefore, the determination of residual stresses to characterize the mechanical behavior in the ceramic-metal brazed joint using finite element method (FEM) is essential.

In the present work, ANSYS, a large scale general purpose finite element code, is used to determine the non-linear thermo-structural behavior of the brazed assembly. The metal and ceramic materials are Kovar and high purity Alumina whereas eutectic Ag-Cu active brazing alloy has been used as a brazing filler metal alloy for the analysis. Temperature dependent material properties and plastic deformation of the braze material are taken into account which is the important aspect for the simulation as stress relaxation in the brazed joint occurs as the braze filler metal deforms plastically

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362/NF-14/P

TOROIDAL FIELD RIPPLE ESTIMATION FOR THE LARGE ASPECT RATIO 3.4 SST-2 LIKE TF COIL REQUIRED FOR NBI PORT ALLOCATION IN THE TOKAMAK

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Abstract

Toroidal Field (TF) Ripple [1] is an important aspect to be addressed for the future large reactors, as it may lead to the large particle loss from the NBI beam for plasma heating. Thus TF ripple must be reduced to a level of 1% with only TF at the plasma separatrix [2]. In this poster we present, for given plasma configuration with aspect ratio 3 the minimum size requirement of the TF coil for SST-2 like reactor [3] and ripple estimation of a larger TF coil for a plasma of aspect ratio 3.4 due to the NBI port allocation in the tokamak.

EFFI code has been used to model the TF coils for ITER and thereafter SST-2 like TF configurations to evaluate the magnetic fields on the appropriate grid. TF ripple for ITER calculated using EFFI output is benchmarked with the reported value of that, hence the same method has been used to estimate the TF ripples for TF coil of SST-2 like reactors. It has been shown that the empirical formula by D. J. Ward [4] to estimate the ripple can be used for the estimation for the minimum size requirement for TF coil of SST-2 like reactor. As NBI port dimension in the tokamak plays an important role to decide the size of the machine which eventually implies the increased size of the TF coil and plasma with larger aspect ratio, a larger TF coil has been considered. The TF ripple for this larger TF coil with plasma of aspect ratio 3.4 inside it is 0.35 % which is well within the permissible limit for successful operation of the tokamak.

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412/NF-15/P

DESIGN DEVELOPMENT OF BELLOWS FOR THE DNB BEAM SOURCE

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Abstract

Establishing a procedure and mechanism for alignment of Ion beams in Neutral Beam (NB) sources for ITER like systems are complex due to large traversal distances (~21 m) and restricted use of flexible elements into the system. For the beam source of DNB, movement requirements for beam alignment are the combination of tilting (±9mrad), rotation (±9mrad) and translation (±25mm).

Due to large number of closely spaced feed lines (hydraulic lines, gas feed lines, bus bars, RF lines, diagnostic lines) and separated by a specific distances due to their voltage differences, it becomes extremely difficult to incorporate the flexibility with the standard avialable system of single flexible bellows to allow the specific movements. It is, therefore, essential to design a customised system in form of 'combination of bellows' which together can address the 'combined movements' in lateral, transverse and angular direction. Further, due to co-ordinate difference in the point of application of movement i.e pivot point and reference axis for above mentioned movements, it was essential to 'transport' the axis from pivot point to bellow location to see the net effective movement.

Additionally, such flexible connection forms the water to vacuum boundary and therefore imposed with stringent requirements in form of restricted use of metallic hoses and multiply bellows. In addition, it is also important to assess the manufacturing feasibility of the design.

The present work describes the design development of a system composed of three single ply 'Gimbal' type bellow system, placed in series, in L-shaped hydraulic lines (size DN50, DN20 and DN15) and . The paper shall detail out the generation of initial requirements, transformation of movements at bellow locations, selection of bellows / combination of bellows, minimizing the induced movements by optimization of bellows location, estimation of movements through CEASAR II and the design compliance with respect to EJMA code [1].

References:

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414/NF-16/P

NEUTRONIC OPTIMIZATION STUDY OF INDIAN SOLID BREEDER BLANKET CONCEPT FOR DEMO

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Abstract

India is focusing on the development of two breeding blanket concepts viz. Lead–Lithium cooled Ceramic Breeder (LLCB) and Helium Cooled Solid Breeder (HCSB) under its breeding blanket R&D program for DEMO. The blanket concept addressed in this paper HCSB [1], is having an edge on configuration and it is one of the variants of helium cooledsolid breeder blanket concepts proposed by several other countries. Indian HCSB aims at utilizing the low energy neutrons at the rear part of the breeder canister units and has RAFMS as the structural material, Lithium Titanate (Li_2TiO_3) as tritium breeder with Beryllium (Be) as neutron multiplier. The study presented here explores two important aspects of the design of solid breeder blankets: (i) Bottom line conclusion for the amount of Li-6 enrichment in the breeder material (Li_2TiO_3), and (ii) Relative importance of the volume fraction of neutron multiplier material (Be) to Li-6 enrichment in Li_2TiO_3 w.r.t. the tritium breeding ratio (TBR) of the HCSB blanket.

Neutronic calculations are performed using the 1-D discrete ordinate code ANISN to assess the overall nuclear performance of HCSB. The general conclusion which can be made from the TBR results is that the change in Be volume fraction has more pronounced impact on TBR. The paper proposes a strategic conclusion derived from the neutronics calculations for HCSB blanket design for DEMO. The nuclear heating data obtained from this study is used to evaluate the thermal hydraulics performance of the HCSB blanket. In future, a 3-D CAD model of Indian DEMO is thought to be utilized when available to estimate the nuclear responses in the HCSB blanket.

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427/NF-17/P

DESIGN DEVELOPMENT OF HEAT TRANSFER ELEMENTS FOR CHARACTERIZATION OF NEUTRAL BEAM WITH POWER DENSITY OF 65 MW/M2 IN INTF

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Abstract

INTF Second Calorimeter is a thermal target system going to be installed in Indian Test Facility (INTF), being constructed at ITER-India laboratory in IPR. It will be placed inside the vacuum vessel on the extreme end which is at 20.6m from the exit of –ve ion beam source located on opposite end. Functionally, this calorimeter will characterize the focused beam having power density 65 MW/m2 after it gets transported upto the distance of 20.6m. To achieve this function, actively cooled heat transfer elements (HTE) made of CuCrZr alloy are placed vertically and mounted on a frame in form of two panel in 'V' shape. The orientation of panels in 'V' shape configuration and there by the beam exposed area is optimized in such a way that the incident power density is reduced from 65MW/m2 to 9 MW/m2, for an accelerated beam with power of 2.8 MW. Additionally, the configuration also take into account the beam duty cycle of 3sec ON and 20sec OFF with 5Hz modulation. The base design of HTE is adopted from SPIDER Beam Dump [1] and it is upgraded to handle higher heat load which are expected in INTF operational conditions.

The paper describes the design of this calorimeter including Beam power estimations, panel configuration and its optimization, HTE orientation with respect to beam axis, profiling of HTE, hydraulic calculations, thermo-mechanical and thermos-hydraulic assessments of severely loaded Heat Transfer Element in ANSYS for both normal and off-normal conditions of 5mrad beam. The design has been further validated for structural code SDC-IC, which is essentially for ITER in-vessel components.

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428/NF-18/P

MATHEMATICAL FORMULATION TO DETERMINE PARENT ISOTOPIC AND ELEMENTAL CONTRIBUTING FACTORS FOR MINIMIZINGNUCLEAR RADIOLOGICAL RESPONSES AND OPTIMIZEMATERIAL COMPOSITION

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Abstract

Activated waste products and the resulting harmful consequences in terms of radioactive responses such as activity, decay heat and dose[1,2] have been a subject matter of extensive study as well as concern for the next generation nuclear facilities like Gen-IV fission reactors and fusion plasma. Apart from identifying the harmful activated products and daughter radionuclides formed from activation, it is equally imperative to understand and quantify the impact of individual parent element or isotope present within the material on major radiological responses. The specific targeting of parent constituents of a material is a new approach towards developing better nuclear materials. Such quantification of parent isotopes/elements serves as an impact indicator. In the present work, we have developed a method to aid this quantification, which would eventually offer a complete material activation analysis. Here, an exact mathematical formulation has been derived starting from general first order linear ODE Bateman equations to account for the contribution of the parent constituents of any irradiated material towards the radiological responses. The final set of derived expressions have been adapted into indigenous code ACTYS[3] and are easily adaptable to other activation solvers[4]. The mathematical formulation provides user with 'contributing factors' of parents that highlight the individual importance of the constituents. These factors can be used to determine the impact of elements on radiological quantities and how much tailoring of these elements will affect the radiological response of the material. All these can be done in a single run of the code using the expressions. More importantly, improved response of a modified material composition after reducing harmful parents can be directly calculated using the derived contributing factors without re-running the solver. Thus, an optimized composition of the material either isotopically or element-wise can be easily obtained. A few major results highlighting the application of this technique and its importance will be provided.

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430/NF-19/P

STRUCTURAL INTEGRITY ASSESSMENT OF TORUS CRYO PUMP HOUSING (TCPH)

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Abstract

The ITER Torus Cryo-Pump Housing (TCPH) is a penetration located on the Cryostat cylinder with main functions to accommodate and support the Torus Cryo-Pump (TCP), connect it to the Vacuum Vessel and provide tritium confinement and primary vacuum boundary.TCPH consist of inner cylinder to support cryopump and tritium confinement whereas the outer rectangular box structure provides Re-generation volume for TCP. They are interconnected through vertical ribs for providing stiffness and transferring load of cryopump to the Cryostat.

Based on manufacturing feasibility study and IO proposal, changes in supports were identified (e.g. change in ribs & connecting vertical plates) in TCPH design after Final Design Review. To qualify the changes, structural integrity assessment of TCPH was performed in accordance with ASME Section VIII Div. 2Part 5. Structural &Thermal analysis was performed based on load specification document to qualify the structure for protection against Plastic Collapse, Local Failure, Ratcheting, Buckling and Fatigue. The structure was successfully qualified for the required ASME criteria and proposed design changes approved and incorporated in the new design by IO.

This poster shows the structural integrity assessment of TCPH based on ASME Section VIII Div. 2 Part 5 for Protection against Plastic Collapse, Local Failure, Ratcheting, Buckling and Fatigue.

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433/NF-20/P

TORUS CRYOPUMP HOUSING (TCPH): MANUFACTURING CHALLENGES

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Abstract

The ITER Torus Cryo-Pump Housing (TCPH) is a penetration located on the Cryostat cylinder with main functions to accommodate and support the Torus Cryo-Pump (TCP), connect it to the Vacuum Vessel and provide tritium confinement. The ITER Torus Cryo-Pump Housing (TCPH), thus forms a primary vacuum boundary, which is to be manufactured from SS304/304L material. TCPH consist of inner cylinder to support cryopump and tritium confinement whereas the outer rectangular box structure provides Re-generation volume for TCP. They are interconnected through vertical ribs for providing stiffness and transferring load of cryopump to the Cryostat.

Having completed the design, it is essential to assess the feasibility of manufacturing this complex structure. This assessment mainly includes: (1) design of weld configuration which ensures the full penetration weld configuration and 100% volumetric inspectability (2) generating the special requirement of raw material to mitigate the risk of lamellar tearing for highly restrained 'T' joint (3) understand the functional tolerances and their achievability for main flange and cylinder with consideration of interfacing components i.e cryopump flange (4) assessing the requirement of post assembly dowel machining and tooling requirements (5) identification of need of handling fixtures of large size bellows in assembled condition during transportation (6) optimized manufacturing sequence.

The present paper describes the Manufacturing feasibility study conducted to access the above mentioned points along with proposal of suitable feasible alternates. This shall also presents the compliance with respect to welding and NDE requirements of ASME Sec-VIII, Div.2 and ITER Vacuum handbook.

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[2] ITER Vacuum Handbook

445/NF-21/P

CONCEPT DESIGN FOR REAL TIME INTERACTIVE CONTROL SYSTEM WITH HAPTIC FEEDBACK FOR TELE-MANIPULATION RH SYSTEM

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Abstract

In the field of Remote Handling (RH) and robotics, there is a growing need to provide robot with the ability to interact with the dynamic, complex and unstructured environments. RH operations in such environments pose significant challenges in terms of sensing, planning, and control [1]. In particular, it is critical to design control algorithms that account for the dynamics of the robot and environment. The remote maintenance operations in environments such as in Joint European Torus (JET) shows that the most efficient and effective RH operations are achieved only when the operator has the sense that they are themselves performing the manipulation at the workspace rather than by means of a remote controlled device[2].

Remote operations require an accurate perception of a dynamic environment. The aim of this work is to design a prototype platform to give the operators the same unrestricted knowledge of the task scene as would be available if they were located in the remote environment. The RH operators can be trained in executing a task without any risk to real hardware. All the robots will be visualized at their actual positions within the 3-D model of the work-cell. An efficient control system has been designed to interface the haptic interaction from the virtual reality to the remote handling slave arm in real time. This shall allow working with a man in loop with a master-slave control loop to simulate and control RH operations with force-feedback. This is hugely beneficial for RH application in tokamak like environment as the torus can be accessed without exposing any workers to radiation. Any replacements, repairs or adjustments that are required should be possible remotely. The control system shall be able to detect and avoid the collisions and interferences in real time using an optimized path planning algorithm.

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446/NF-22/P

DESIGN AND ANALYSIS OF A ROTARY JOINT FOR REMOTE HANDLING EQUIPMENT

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Abstract

The tokamak relevant Remote Handling (RH) equipment is an articulated system with multi-DOF and several links connected by intermittent joints. The RH equipment has a long reach and needs to handle heavy payload within the tokamak environment. The RH equipment operates in the cantilevered mode, the farthest joint from the payload is subjected to highest structural loads, and the actuation torque requirement for each joint depends on the DOF (pitch, yaw and roll). The handling of the umbilical is managed through the central bore provided in the applicable bodies and joints.

To avoid collision with the internal components of tokamak and provide high joint torques, the RH equipment is driven at very low speeds. However, for qualification of the design, the RH equipment needs to be subjected to high speed operation on test stand, where very high dynamic forces are experienced by the joints and structure. The joints associated with RH equipment are specialized and composed of high velocity actuating motors integrated with high reduction ratio gearbox.

This paper presents a benchmarking study for the farthest rotary joint. A conceptual model of the high reduction gearbox has been developed and reduction ratios were verified by kinematic and analytical approach. The reaction forces calculated from structural moments are desired for the design of link bodies. Input torque requirements have been optimized as per the payload and speeds of operation, motor specification have been arrived.

Kinematic and transient simulations have been performed. Dynamic forces on the joints have been estimated by Rigid Body Dynamics (RBD) and Integrated finite element analysis of joints and link bodies were performed to validate the joint performance.

451/NF-23/P

PRELIMINARY ANALYSISOF ACCIDENT IN SST-1 CURRENT FEEDER SYSTEM

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Abstract

Steady-state tokamak-1 (SST-1) has 16 superconducting Toroidal field (TF) and 9 superconducting poloidal field (PF) coils rated for 10kA DC. All the TF are connected in series and are operated in DC condition whereas PF coils are individually operated in pulse mode during SST-1 campaigns. SST-1 current feeder system (CFS) houses 9 pairs of PF current leads and 1 pair of TF current leads [1]. During past SST-1 campaign, there were arcingincidents within SST-1 CFS chamber which caused significant damage to PF superconducting current leads as well as its Helium cooling lines of the current leads. This paper brings out the preliminary analysis of the mentioned arcing incident, possible reasons and its investigation thereby laying out the sequence of events. From this analysis and observations, various measures to avoid such arcing incidents have also been proposed.

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475/NF-24/P

IDENTIFYING INTERSTITIALS AND CHARACTERIZING INTERSTITIAL DIFFUSION IN BCC AND FCC METALS

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Abstract

The reactive-diffusive transport of interstitials and their recombination with vacanciesor coalescence with each other is an important aspect of material modification due toirradiation [1]. Molecular Dynamics (MD) simulations can provide insights into thedynamic atomistic processes involved in such transport provided the activationenergies are sufficiently small. Several methods have been proposed to identify interstitials from MDsimulations [2,3 and references therein]. Most of these methods except Weigner-Seitz cell method, use an assumed cut-off value and thus their results are affected by their chosen value. The Weigner-Seitz cell method does not provide the details of the interstitial configuration which changes during the diffusion.

We have developed a novel unsupervised learning algorithm [5] to identify interstitials without any specified inputs other than the atom positions which is effective even at high temperatures. This method is compared with some widely used effective sphere methods [1,4] for several bcc and fcc crystals [6]. The cut-off radius obtained using our method shows a linear variation with the crystal temperature [6]. As the interstitial diffuses, there are several MD frames where it is in a dumbbell or crowdion configuration. We have also used a graph-tree data structure across MD frames to identify the interstitial diffusion path [5]. We present the migration energies and diffusion coefficients for bcc Fe, Mo, Nb and fcc Ag, Cu, Ni, Pt.

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479/NF-25/P

DESIGN AND PERFORMANCE STUDIES OF PASSIVE ACTIVE MULTIJUNCTION (PAM) ANTENNA FOR ADITYA -UPGRADE TOKAMAK

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Abstract

The upgradation of the ADITYA Tokamak provides an opportunity to commission a new type of lower hybrid wave launcher on it. Unlike the grill launcher [1] which was used earlier, a Passive Active Multijunction (PAM) antennais designed to deliver 250kW of power and hence drive the lower hybrid waves onto the plasma at 3.7 GHz. The PAM antenna increases the coupling of the RF power to the plasma, even at densities close to cut off and reducesthe reflection to the high power vacuum source, klystrons

The PAM antenna is designed to launch $N_{||}$ of 2.25 +/- 0.375 since the ADITYA-U would operate at toroidal magnetic field of 1.5T with line average density lying in the range of [0.8 – 3.0] x 10^{19} m^{-3}. The designed antenna would have two active and two passive waveguides in a module with 2 modules in the toroidal direction and 3 in the poloidal direction. The design consists of 4 parts viz. PAM Multijunction, Tapered Divider, Mode Convertor and Ceramic Vacuum window. The PAM Multijunction consists of the active and passive waveguides and step phase shifters to provide appropriate phasing. The Tapered Divider section facilitates translation of the Mode Convertor output to the PAM Multijunction input dimensionally. The Mode Convertor is used to convert the input TE_{10} mode to TE_{30} mode to feed the 3 poloidal modules. Finally the Ceramic Vacuum Window provides separation between the pressurized gas and vacuum sections.

This poster presents the design of the proposed PAM antenna and discusses it with regards to various constraints imposed by port size, space available for the installation of the antenna and support structure of the ADITYA-U tokamak et cetera. The RF, thermal, stress and disruption analysis of the antenna is presented. The design has been validated on various solvers like COMSOL Multiphysics and CST Studio. The performance of the antenna, when loaded with plasma, has been studied with the help of the ALOHA coupling codes [2] and the return loss obtained is less than 5%.

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483/NF-26/P

DESIGN OF A HIGH CW POWER CIRCULATOR FOR LHCD SYSTEM OF SST-1 TOKAMAK

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Abstract

Circulators are indispensible in high power microwave systems to protect the vacuum tube based sources against reflection. The Lower Hybrid Current Drive (LHCD) system of SST-1 Tokamak commissioned at IPR, Gandhinagar in India comprises of four high power circulators (each rated for 250kW CW) to protect klystrons (each rated for 500kW CW at 3.7 GHz) which power the system. This poster presents the design of a Differential Phase Shift Circulator (DPSC) capable of handling 500 kW CW power at 3.7 GHz. As the DPSC comprises of mainly three components, viz., magic tee, ferrite phase shifter and 3dB hybrid coupler, the design of each of the components is described. The design of these components is carried out factoring various Multiphysics aspects of RF, Heating due to high CW power and magnetic field requirement of the ferrite phase shifter. The primary objective of this paper is to present the complete RF, Magnetic and Thermal Design of a high CW Power Circulator. All the simulations have been carried out in COMSOL Multiphysics. The designed circulator exhibits an insertion loss of 0.13 dB with a worst case VSWR of 1.08.

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37/NF-27/P

A LOW-COSTGROUND LOOP DETECTION SYSTEM FOR ADITYA-U TOKAMAK

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Abstract

Aditya-U is a medium sized Limiter-DivertorTokamak machine. Different set of Magnetic Coils are installed for the generation of Magnetic field for the Plasma Initiation and Control in Pulse Mode. Support Structures with proper electrical Insulation are provided to Align and Hold these Magnetic Coils for the Plasma Operation. As machine operates at very high currents of kA's range, very high vibrations are created during operations which can result in the breakdown of Electrical insulation between different coils/systems/structures. These conditions can result in the formation of conducting loops leading to bigger ground loops as all structures and systems are separately grounded in star configuration. For Pulsed Power operations, the induced current in the toroidally shorted structure can result in generation of unwanted magnetic fields affecting plasma and can meddle the magnetic diagnostic signals. Unintentional induced currents can also flow into the pumping lines connected to the vacuum vessel and into the diagnostic system, which is undesirable from the safety point of view of the subsystems connected with the Tokamak. Furthermore, in diagnostics and their associated electronics, several in number, ground loops may be formed even after taking good care in implementation of proper grounding scheme resulting in noisy signals. Hence, continuous monitoring of ground loops is required to prevent the formation of these loops for safe and proper operation of tokamak and its associated subsystem and diagnostics.

Ground loops detection with conventional approach for such a complex tokamak system is very time consuming. Therefore, in order to detect ground loops without disturbing the wired grounding configuration of the system, a magnetic coupled system with an exciter and detector modules is designed, developed and used for ground loop detection in Aditya U tokamak. A voltage signal of high frequency is injected into the system component through the exciter module and ground loop is detected when the detector module on the sub-system receives the signal of same frequency. This detection technique helps in round the clock monitoring of system insulations and loops formed in any subsystem including diagnostics. The details of this low cost ground loop detection system will be discussed in this paper.

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49/NF-28/P

DESIGN AND DEVELOPMENT OF ELECTRONICS FOR MICROWAVE DIAGNOSTIC IN ADITYA –UPGRADE

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Abstract

The Microwave diagnostics with interferometer at 100 GHz and reflectometer at 22 GHz are used for the measurement of plasma density and its fluctuations in Aditya Tokamak. For sensing of the signals, self-biased square law Schottky Barrier Diodes are used as the detectors. These diodes are waveguide mountable with outputs available through Lemo/SMA connectors. The density measurement is based on the measurement of the phase difference between the two microwave signals, one coming directly from the microwave source and the other travelling through the plasma. These two signals are mixed with a Magic tee to get the interference signal. The path of the signal coming through the plasma is very long because microwave source has been kept 5 m away from the Tokamak.

The electrical signal at the output of the detector consists of a very weak ac signal overriding a comparatively stronger dc signal. The ac signal which is of our interest is proportional to the phase shift between two microwave signals. So, it is required to amplify the composite signal to give strength to the ac signal before removing the unwanted dc component. To achieve the objective of amplifying the ac signal and removing the unwanted dc signal, output of the detector is given to a ultra-low noise ,programmable-gain Instrumentation Amplifier (IA) followed by a High-Pass RC filter, mounted on an amplifier card. The amplifier card is populated with other signal conditioning sections viz:, 4th order programmable low pass filter section implemented using sallen-key topology, opto-coupler section using analogoptocoupler HCPL2530 and differential drivers. The gain of the programmable amplifier can be set locally through the manual push-wheel switches provided on the facia panels to get the desired level of the output signal. The opto-coupler module is used to ohmically isolate the electronics and the data-acquisition system grounds. The fully differential driver is used in the output stage for driving the signal up-to the DAQ. The whole of the electronics is implemented in 3U-form with two channels in each card. The key features of the improved microwave electronics design will be fully elaborated in the paper.

62/NF-29/P

NON-ISOTHERMAL REACTION KINETIC STUDY FOR THE FORMATION OF LI_2TIO_3 BY THERMO GRAVIMETRIC MEASUREMENT

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Abstract

Reaction kinetics is the measurement that how quickly reaction occurs. It includes the investigation of how different experimental conditions can influence the speed of the chemical reaction. Thermo-gravimetric analyzer is employed to investigate the reaction kinetic parameter for the formation of Li_2TiO_3. The experiments are conducted in temperature ranging from 350 K to 1473 K under argon atmosphere in four different heating rates of 2, 5, 10, and 20 K/min. The non-isothermal kinetic data is compared with different model-free techniques such as isoconversional method of ozawa, Kissinger-Akahira-Sunose (KAS) and friedman. The average activation energy is calculated 260 KJ/mol and 260 KJ/mol with KAS and FWO method. However the calculated activation energy by friedman method 262 KJ/mol. Reaction mechanism is predicted by using malek method. It is predicted that the formation of Li2TiO3 by solid state reaction is following three dimensional diffusion mechanisms. The details of the experiments and calculations are discussed in this paper.

88/NF-30/P

RECENT STUDIES ON INERTIAL ELECTROSTATIC CONFINEMENT FUSION NEUTRON SOURCE

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Abstract

Compact neutron sources are in high demand due to its applications in cancer therapy, fusion material studies, non-invasive interrogation of illicit drugs and explosive materials. Such sources are being developed on the principle of Inertial Electrostatic Confinement Fusion (IECF). In such sources, the plasma ions are converged in a purely electrostatic field either in cylindrical or spherical geometry [1, 2]. CPP-IPR is the first institute in India to develop a cylindrical IECF device [3] and demonstrate the fusion neutrons from it. Both the hot and cold cathode discharge techniques are employed to produce the deuterium plasma inside the device. The hot cathode plasma is produced by heating the filaments whereas the cold cathode plasma is produced by the direct current discharge; maintain a higher pressure range inside the device (< 10 mTorr). Different types of discharge modes like star, jet and core modes have been observed in the case of cold cathode discharge which mainly depends upon the filling gas pressure as well as grid wire dimension. It is noticed that the star mode of operation at varying grid wire frequency corroborates to our SIMION results. Presently, the device has been operated in the voltage range of -20kV to -80kV. The emission of fusion neutrons from the device has been confirmed on employing neutron detectors such as handheld neutron monitor and bubble detector. The details of the results would be discussed in the paper.

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114/NF-31/P

PERFORMANCE ENHANCEMENT OF RIGID LN_2 CRYOGENIC TRANSFER LINES OF 80 K DISTRIBUTION SYSTEM

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Abstract

The 80 K distribution network of cryogenic facilities consists of vacuum jacketed double-walled lines, which delivered the liquid nitrogen from the liquid nitrogen storage tanks to various 80 K sub-systems from a distance of nearly 300 m in the cryo facility. There are different sizes of LN_2cryo lines e.g. DN15, DN25, DN40, and DN60. The return vapour of nitrogen collected through vent lines of different sizes outlet of respective systems. The lines are covered with cryogenic grade thermal insulation. Over years, we have observed huge frosting, condensation, LN_2 dripping in many sections of supply and return transfer lines. The probable reasons could be vacuum level degradation, leakage in weld joints of inner process line and outer jacket, Bellows leaks, thermal insulation damage etc. The initiative has been taken to improve the performance of these lines. The evacuation was done through an inbuilt vacuum port installed on transfer lines by in-house designed and fabricated puppet valve assembly. All 75 numbers of around 200 meters line sections along with vacuum barriers evacuated to vacuum order of $\leq 5 \times 10^{-3}$ mbar and pressure rise observed up to $< 10^{-2}$ mbar in 24 hours. The evacuated transfer lines have been validated by operating condition at 80 K, no condensation, ice frosting was observed. The leakage sections of supply and return transfer lines were in-house repaired. The vacuum/evacuation and repairing process in complex network of piping, accessibility in congested space and safety aspects at 12 m height were the challenges experienced during this task. In this paper, the evacuation process, detail of puppet valve set-up, in-house developed low temperature sealing of non-return valve, repairing of main 80 K outlet vent line and the final performance test will be presented.

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126/NF-32/P

CASE STUDY ON EFFECT OF STRAY CAPACITANCES AT HIGH VOLTAGE POWER SUPPLY

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Abstract

80kV, 6 MW High Voltage Power Supply (HVPS) is being used by High Power Radio Frequency devices and Neutral beam device at Institute for Plasma research (IPR). HVPS is topologically modular in which small voltage sources are added using Pulse Step Modulation (PSM) to attain high voltage output. Small voltage sources are power convertors fed by multi-secondary transformers (MST).

Multi-secondary transformer is having single primary winding and multiple isolated secondary windings wounded across the core height. Isolated secondary windings possess inter-winding stray capacitance (C_w) with adjacent windings and other stray capacitance (C_g) with other grounder parts of the transformer.

This paper discusses the effects of transformer secondary windings stray capacitances on High Voltage Power Supply during its operation. Paper also discusses simulation results and observations form HVPS.

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137/NF-33/P

SEQUENTIAL PULSE GENERATION SYSTEM FOR BETA EXPERIMENT

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Abstract

BETA (Basic Experiments in Toroidal Assembly) is a toroidal device used for studying the flow-fluctuation dynamics of toroidal system. In BETA plasma is produced for the pulse duration of around 800 ms. For better statics, several discharges are acquired and averaged to rule out the random errors in measurements. The FPGA (Field Programmable Gate Array) based trigger circuit generates sequential pulses for triggering the TF coil supply, discharge voltage and Data Acquisition (DAQ) in a given sequence. First the TF supply get triggered, then after 500 ms (to avoid ripple in TF supply) of that the discharge is triggered and then after 100 ms, the DAQ is triggered for acquiring the data, later on it triggers ECRH source in BETA. The pulse width can be adjusted as per our convenience by using offline programming technique of the system. One of the most important requirements is minimization of jitter in recurrent discharges. The jitter should be less than 1 microsecond for better averaging over multiple shots, which is really crucial for our fluctuation and confinement studies.

Sequential delay trigger pulses are generated to operate the toroidal field power supply, DAQ, microwave pulse, piezo electric gas valve etc... The output trigger pulses are buffered and can drive inductive / resistive loads of ~ 100mA. The trigger delay and pulse width of the trigger pulses can be configured to suit experimental requirements with minimum jitter. The number of trigger pulses derived from the FPGA can be expanded with in limitation of the FPGA system. The manuscript discusses the design details and implementation scheme.

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149/NF-34/P

CONTROL SYSTEM FOR PELLET INJECTION SYSTEM

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Abstract

A standalone control system based on a programmable logic controller is developed to operate the solid hydrogen pellet injection system remotely. The control system consists of a Siemens make PLC, input/output cards, isolation circuits and relays. A graphical user interface (GUI) developed in Lab VIEW software is used to control the pellet injector from a remote location. The control system ensures all system interlocks for pressure, temperature and vacuum yielding uninterrupted operation for a long period.

Solidified form of hydrogen gas or its isotopes is an efficient method of injecting fuel particles into a magnetically confined high temperature plasma device. The injector consists of Cryo-chamber, gas feed system and Differential pumping system. In addition to its designed parameters, the injector should have the provision to be operated remotely for a longer duration from a remote location. Pellet formation and ejection process is remotely controlled by successive operation of various gas feed valves, pressure and vacuum gauges. The control system ensures sequential operation of the entire pellet Injection system, co-coordinating evacuation of the all vacuum chambers, maintaining vacuum, monitoring cryo temperature, monitoring the process of pellet formation and ensuring necessary conditions for pellet injection. The operation requires continuous data archiving. The operator interface provides graphs, readings of pressure and vacuum data for judging the formation of pellet. The pellet injector with its control system is successfully integrated to the SST-1 tokomak. The detailed hardware selection, software design, development and testing results will be discussed in the paper.

152/NF-35/P

CONTROL SYSTEM OF OUT GASSING MEASUREMENT SYSTEM

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Abstract

The Out Gassing Measurement System (OGMS) of IPR provides facility to measure the out gassing rates of different materials to be used in the different vacuum conditions based on throughput method. The OGMS consists two identical vacuum chambers, which is separated by an orifice of known conductance. These chambers are evacuated usingTurbo Molecular Pumps and Sputter Ion Pump. Ion gauges and Residual Gas Analyzer are used to measure pressure and partial pressurerespectively. RTD type temperature sensors are used for measuring the temperature.

The automation of OGMS is an essential need. Otherwise the Experimentalist have to memorize full control sequence and operate different instruments as per control sequence and interlocks. The control system ensures sequential operation of the entire OGMS coordinating evacuation of the all vacuum chambers, maintaining uniform baking temperature across the whole system along with continuous data archiving.

The vacuum chambers are baked at various temperatures in controlled mode. The baking system consists of five heaters for different sectors of the vacuum chambers. The heaters are controlled in close loop comprising of temperature ramp-up, maintaining constant heating temperature and ramp- down phase. The baking control is fully automatic requiring operator to set baking temperature only and rest is controlled automatically.

Siemens PLC is used for its inherent reliability and requirement of continuous operation of the OGMS. A SCADA is developed using Lab VIEW for operator interface, trending and systemalarms. The detailed hardware development, software design and testing results will be discussed in the paper.

155/NF-36/P

TEMPERATURE AND DENSITY DEPENDENCE THERMAL PROPERTIES MEASUREMENTS OF LI_2TIO_3 PELLETS BY LASER FLASH TECHNIQUE

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Abstract

Lithium meta-titanate (Li_2TiO_3) has been considered as a tritium breeder material for Indian Lead Lithium Ceramic Breeder (LLCB) Test Blanket Module (TBM) to be tested in ITER. Li_2TiO_3 powder has been prepared by solid state reaction method. This powder is further converted to pebble shape by extrusion and spheronization method. Li_2TiO_3 pebbles will be kept inside the canisters of the LLCB TBM in the form of packed pebble bed. These pebbles will have ~ 1 mm diameter and density of 80-90% of T.D. (theoretical density). During plasma operation these pebbles will be in high temperature environment. It is very essential to have the thermal characterization of these materials including pebble bed. These thermal databases are very much required for LLCB TBM design. It is therefore necessary to evaluate the thermal diffusivity and thermal conductivity of Li_2TiO_3 material as a function of temperature and density.

In this work, required dimension of pellets have been prepared to measure the thermal diffusivity using laser flash apparatus at IPR. The Laser Flash Method had become the most popular method to measure the thermo-physical properties of materials. The measurements on Li_2TiO_3 pellets were carried out as a function of temperature (from room temperature to 800 °C) and density. Simultaneously the specific heat capacity of Li_2TiO_3 pellet is measured in this temperature range. Finally the thermal conductivity of Li_2TiO_3 has been estimated from thermal diffusivity data. The details of these measurements will be discussed in this paper.

156/NF-37/P

FPGA BASED HIGH VOLTAGE TRIGGER CIRCUIT FOR SMARTEX-C

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Abstract

Experiments on non-neutral plasmas in SMARTEX-C (**SM**all**A**spect **R**atio **T**oroidal Electron plasma **EX**periment – C) [1] are being pursued at Institute for Plasma Research. Trapping mechanism is similar to Penning-Malmberg trap which creates non-neutral plasma in cylindrical geometry. Basic trap operation is carried out in **inject-hold-dump** sequence which requires fast pulsing of potential voltage of electrodes and control sequence varying on a wide range of time scales.

Basic requirement is to trigger high current Magnetic field power supply and two electrodes i.e. injector grid and collector grid from negative potential (~ -300V to -370V) to ground and inner wall from ground to positive potential (~ 300V to 370V), when required. DC power supplies are used to create the electrostatic fields on the trapping grids. As the COTS (Commercial Off-The-Shelf) high voltage DC power supply cannot be switched at nano second time scale, fast switching in the range of 20 - 100ns of high voltages (200 - 500V) of multiple electrodes is accomplished using MOSFET, which is interface between the electrodes and DC power supply. Triggering of this power circuit and time-spans of trigger pulses are controlled using FPGA (Field Programmable Gate Array) [2]. The utility for graphical user interface (GUI) through RS232 serial communication protocol for triggering the electrodes with variable time period is developed in National Instrument's LabVIEW [2] software. Soft IP cores 32 bit IO bus & UART of Microblaze soft processor of FPGA are used to implement the logic. All the required sequential and combinational logic functions are described using VHDL, the user interface software is developed in Labview and the communication interface and command encoding is done in 'C' language for the soft processor. This report gives hardware and software description of the FPGA based high voltage trigger circuit with variable time spans along with test results.

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161/NF-38/P

STUDY OF EFFECTIVE THERMAL CONDUCTIVITY OF LITHIUM META-TITANATE AND ALUMINIUM OXIDE PEBBLE BEDS BY TRANSIENT HOT WIRE METHOD

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Abstract

The Indian Lead Lithium Ceramic Breeder (LLCB) blanket concept will be tested in ITER as a part of the TBM program. In this concept lithium meta-titanate (Li_2TiO_3) is used as the tritium breeder material in the form of packed pebble beds. The effective thermal conductivity (keff) of pebble bed is an important parameter for the design and analysis of solid breeder blanket concepts. The keff of lithium meta-titanate (Li2TiO3) pebble beds and aluminium oxide (Al2O3) pebble beds have been estimated experimentally using the developed set up based on transient hot wire techniques. The keff has been investigated at room temperature under helium gas, argon gas and in air environment. Li2TiO3 pebbles with mean diameter of 1 mm, 1.3 mm and Al2O3 pebbles with mean diameter of 1 mm, 1.5 mm were investigated. The packing fraction for both pebble beds is observed approximately 63 % after vibration packing. A clear dependence of the interstitial fluid or cover gas environment on the keff results has been observed for both the investigated materials. Highest value of keff has been measured in case of helium gas and lowest value observed in case of argon gas environment. A severe reduction of the keff is observed in air and argon gas environment. A small effect of pebbles diameter distribution on the keff results is also for both the materials. The details of the experimental set-up, its results and the influences different gases and pebble diameters on pebble bed properties will be presented in this presentation.

192/NF-39/P

DESIGN OF STANDALONE CLOSED-LOOP PIEZOELECTRIC VALVE CONTROL SYSTEM USING MICROCONTROLLER FORGAS-FEED SYSTEM IN ADITYA-UPGRADE TOKAMAK

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Abstract

Gas fueling in tokamaks is a critical parameter, for maintaining and controlling the plasma density. Normally in ADITYA Upgrade tokamak [1], plasma discharges are initiated with prefill gas pressure and later additional gas is introduce into the vessel through multiple gas puff pulses. The pre-fill gas feed is applied about 150 ms prior to the application of loop voltage. A programmable pulse generator is used for multiple gas puffs to control the fuel gas [2]. In the absence of real time density feedback at present, these gas-feed pulses are pre-fixed prior to the initiation of the discharge. The pulse width timing and voltage level, time (T) for the gas puff to start, number of pulses and the time gap between the pulses are varied with a pre-programmed gas puff according to the discharge requirements.In a typical standard plasma discharge of ADITYA Upgrade tokamak(Plasma current ~ 100 kA; discharge duration ~ 180 ms), this scheme of gas-feed pulses work quite well. However, to have a good control of the plasma density and to mitigate disruption and vessel wall loading [3], a microcontroller based circuit is designed for real time control of amplitude and delay of these pulses to drive piezoelectric valve for the gas-feed in a closed loop manner. The circuit consists of ADC, 32 bit RISC Controller, DAC and a high voltage amplifier. The circuit will continuously read the input reference signal like H-alpha, by digitizing using the ADC and an algorithm will run in real time in the microcontroller to find the proportionality constant to generate the valve voltage which eventually happens to control the amount of gas to feed in the machine.The processed data from the microcontroller is given to a DAC.The low voltage (0-5V) of this DAC is further amplified up to 100V to drive the valve. This circuit will work independently in a closed loop till the end of the plasma shot. This paper describes the salient features of the design in detail.

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201/NF-40/P

IMPLEMENTATION OF SYNCHRONOUS REFERENCE FRAME THEORY BASED SHUNT ACTIVE POWER FILTER USING DSP CONTROLLER

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Abstract

This paper conceptualizes shunt active power filter (SAPF) using synchronous-reference-frame (SRF) theory to mitigate the harmonics present in the power system. The shunt active power filter injects a suitable compensating current at a point called point of common coupling (PCC) so that the harmonics present in the line are cancelled out and sinusoidal nature of current waveforms is restored. A three phase current controlled voltage source inverter (VSI) with DC link capacitor across it is used as an active filter. Synchronous reference frame (SRF) algorithm is developed for low voltage laboratory prototype using TMS320F28335 Digital Signal Processor (DSP). The experimental test results demonstrate that the viability of the control strategy is successful in meeting the IEEE 519-1992 recommended harmonic standard limits

Keywords— Active Power Filter, DSP controller,Synchronous Reference Frame.

211/NF-41/P

STUDY OF THE EFFECT OF EXTRUDER AND SPHERONIZER SPEED AND CONCENTRATION OF PVA IN LI_2TIO_3 PEBBLES FABRICATION BY EXTRUSION-SPHERONIZATION TECHNIQUE

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Abstract

Lithium based ceramics have been considered as a tritium breeder material in the breeder blanket in fusion reactors. Indian Lead Lithium Ceramic Breeder (LLCB) blanket as a Test Blanket Module (TBM) will be tested in ITER. Li_2TiO_3 pebbles of ~1 mm diameter in the form of packed pebble bed will be kept inside the canisters of the LLCB TBM. Li_2TiO_3 powder is prepared at IPR by solid-state reaction using $LiCO_3$ and TiO_2 followed by ball milling and calcinations. XRD analysis shows the phase-purity of the synthesized Li_2TiO_3 powder. Li_2TiO_3 pebbles are prepared from this powder by extrusion &spheronization followed by high temperature sintering. PVA (Poly Vinyl Alcohol) is used as binding agent with Li_2TiO_3 powder in this method. Speed (RPM) of Extruder and Spheronizer effects the smoothness of the extrudes and the spherocity of the pebbles respectively. PVA solution is made with Demineralised (DM) water in different (W/V%) concentrations. Different concentration of PVA solution from 3 % to 10 % is used to fabricate those pebbles. Various parameters effecting the fabrication of Li_2TiO_3 pebbles and finally the optimization of these parameters and few characterizations of these pebbles will be discussed in this paper.

215/NF-42/P

STUDY ON NEUTRON EMISSION FROM AN INERTIAL ELECTROSTATIC CONFINEMENT DEVICE

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Abstract

The concept of inertial electrostatic confinement (IEC) fusion is of a particular interest for the research community due to its various near term non-electric applications as portable neutron/proton sources. The most promising applications include neutron activation analyses (NAA), neutron radiography, medical isotope production, low power ion thrusters etc. [1]. IEC is mainly a fusion concept where the lighter fuel ions (D, T) are trapped in a converging electrostatic field inside a cylindrical or spherical geometry [2]. CPP-IPR is the first institute in India to develop a cylindrical IECF device and aims to demonstrate the 2.45MeV neutrons by fusing deuterons (DD). The functional parameters of the device such as design and dimension of gridded electrodes, rating of electrical feedthrus, dimension of cylindrical chamber etc. were determined after detailed theoretical and computational analysis [2]. Deuterium plasma was produced in the device by employing two alternate discharge techniques i.e. hot and cold cathode discharges. The basic plasma parameters were measured using the Langmuir probe, Mach probe and the Optical emission spectroscope (OES) [3]. The device was coupled to the high voltage power supply (-200kV, 80mA) and was operated in the voltage range from -20kV to -80kV. On application of high voltage to the cathode grid the deuterons produced in the plasma discharge are accelerated inside the cathode region and oscillates in the negative potential well formed in between the cathode grid and chamber (anode). Thus fusion reactions occur between the counterflowing ions or between the ions and the background neutral particles. The emission of DD fusion neutrons from our cylindrical IECF device have been confirmed by employing different neutron diagnostics such as handheld neutron monitor, bubble detector, He-3 proportional counter and nuclear track detectors (CR 39). The details regarding the dependency of neutron production rate (NPR) on the neutral gas density and applied power would be presented in the paper.

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220/NF-43/P

PROTOTYPE COMPACT DATA AQUISITION SYSTEM AND ITS IMPLEMENTATION USING LABVIEW

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Abstract

A Compact Data Acquisition and Control (DAC) system is designed using USB based multifunction I/O Module (NI 6353) of National Instruments. The USB hardware module provides 31 analog input signals, 4 analog outputs and 40 digital I/Os for DAC application development. Analog inputs are used to monitor the parameters of auxiliary power supplies. Digital signals are used to control and monitor the status of auxiliary power supplies. Acquisition module is developed to acquire data for pulse mode (100-500ms) operation with 1 msec acquisition rate. Acquired data are stored in binary file and used to plot for after shot analysis. The compact DAC system can be triggered externally for remote mode operation. Analog input and output data are plotted with calibration.

User friendly GUI is developed in Lab view to operate USB hardware based DAC system. Lab view provides a user friendly platform for both the programmer as well as the end user to develop and update the applications. The logic is developed using the functions provided by Lab view in graphical programming method.

This Paper explores the features and application of the compact DAC system developed and tested. The compact DAC can be used stand alone to any system to acquire the data and can be updated for extended applications.

229/NF-44/P

WATER COOLING SYSTEM FOR SST NEUTRAL BEAM INJECTION SYSTEM: FROM CONCEPT TO ENGINEERING DESIGN

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Abstract

Steady state Superconducting Tokamak (SST-1) machine is equipped with a Neutral Beam Injector (NBI) to raise the plasma ion temperature ~ 1 keV. This injector has a capability of injecting hydrogen beam with power of 0.5 MW at 30 keV. To fulfill this requirements NBI need to extract 1 MW at 30 kV from ion source. NBI sub-systems are Neutralizer, Magnet Coil (MC), Magnet Liner (ML), Ion Dump (ID), V-Target (VT), Pre Duct Scraper (PDS), Beam Transmission Duct (BTD), Shine Through (ST). In addition to this auxiliary systems are Power Supply, Data Acquisition and Control System (DACS), Cooling Water System (CWS), Cryogenic System and Vacuum System. During operation neutral beam has to travel 7 m from exit plane of ion source to tokamak plasma center. All the above mentioned subsystems shall receive various heat load from 50 kW – 500 kW and to remove the same active cooling is provided to each subsystem for safe operation. This paper shall describe in details about NBI water cooling system from concept to engineering design. After study of heat load to each subsystem, we have finalized required water flow rate and pressure drop in each line of cooling network. Engineering design has been done and Piping Instrumentation & Design (PID) drawing also completed. Presently NBI CWS is in fabrication stage and shall be commissioned at the end of this year.

247/NF-45/P

FABRICATION OF U-BEND MHD TEST MOCKUP

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Abstract

A liquid Pb-Li MHD loop is being developed at IPR, for investigating 3D MHD flows in different types of flow geometries such as straight ducts of rectangular or circular cross section, expansions, contractions, bends, and manifolds etc. Recently a U-bend MHD test mockup along with the diagnostics such as potential pins and pressure tubes has been successfully designed, fabricated and tested at IPR. The test mockup has the outer dimension of 700mm (Pol) ×240mm (Rad) ×120mm (Tor) with the 5mm wall thickness. During the test mock fabrication, suitable welding approach has been adopted to ensure the proper electrical contact of the potential pins with the walls of the test mock up. A large number of potential pins made of SS304 rod (ϕ ~ 1.6mm) and three number of pressure tubes (ϕ ~ 8mm) made of SS316L have been welded on the test mockup for the wall electric potential and pressure measurements. Over the nine cross-sectional locations of the test mockup, total 291 numbers of potential pins have been mounted. During MHD experiment, the array of potential pins will provide electrical signals in the range of millivolts, which will be used for the MHD flow characterization. Pressure tubes mounted on the test mockup will be connected to expansion tanks for measurements of liquid metal pressure drop through cover gas pressure measurement. The MHD test mock up is now ready for assembly with the MHD loop. The details of design, fabrication and testing of the MHD test mockup will be presented.

257/NF-46/P

CHARACTERIZATION OF AN ION DEFLECTION MAGNET BY THE WIRE ORBIT METHOD

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Abstract

Ion deflection magnet (electromagnet) is used for separating un-neutralized portion of ions from the neutral beam. For the SST1-NBI system, a large electromagnet capable of producing magnetic field up to 0.2T is used for deflecting hydrogen ion beam of size 23×40 cm^2 for the ion energy range 30-50keV. Magnetic field produced by the magnet was measured for the range of applied currents (0 – 400 A) in the coils. These measurements are essential to calibrate the required currents in the coils versus the energy/momentum of the beam ions. Uniformity of the magnetic field along and across the beam path is also examined. In order to ensure the safety of the ion deflection system (magnet and ion dump), the wire orbit technique is used to visualize the trajectories of the ions in the field of the magnet. The technique of wire orbit method and the results obtained for the ion deflection magnet of the SST-1-NBI system will be presented.

262/NF-47/P

INVESTIGATION OF THE BEHAVIOR OF EFFECTIVE CHARGE OF ADITYA TOKAMAK PLASMAS

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Abstract

Accurate knowledge of the ion effective charge, Z_{eff}, is of key importance in high temperature tokamak plasma, since the value of Z_{eff} is related to bremsstruhlang radiation losses, loop voltage, etc. The Z_{eff} also gives the indication of the total impurity, which is needed to be controlled for better performance of the tokamak plasma. The visible bremsstruhlang measurement is the most widely used method in Z_{eff} determination. The diagnostics system is based on the combination of optical fiber, interference filter and photo multiplier tube (PMT) and a relatively line-free spectral region of about 2 nm around 523 nm has been selected for visible bremsstruhlang measurement. The values of Z_{eff} were analysed with respect to the plasma parameters and for the discharges produced after wall conditioning by lithium coating. It was found that Z_{eff} decreases with the increase of n_e and the incremental value of Z_{eff} is inversely proportional to the n_e^2. The values of Z_{eff} reduce to 1.7 to 2.5 ranges after the lithium coating compare to 2.0 to 3.5 before of it. This reduction arises not only due to the reduction of oxygen concentration, but also due to the reduction of metallic impurity iron inside the plasma.

264/NF-48/P

CALORIMETRY FOR SST-1 VACUUM VESSEL

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Abstract

Steady State Superconducting Tokamak (SST-1) is a medium sized Tokamak. SST-1 Vacuum Vessel (VV) is one of the sub-systems of SST-1 Tokamak. The Vacuum Vessel provides an Ultra High Vacuum (UHV) environment for in-vessel components and plasma production. SST-1 vacuum vessel is a continuous torus structure fabricated using non-magnetic SS 304L material. For easy fabrication and assembly point of view, SST-1 vacuum vessel is divided into sixteen parts, out of which eight of them are vessel sectors (VS) while the other eight are vessel modules (VM). Vessel Sector (VS) is comprised of one number of Radial Port (RP), two numbers of vertical ports (top and bottom each) and one number of vessel sector ring. Vessel Module (VM) is made up of one number of Vessel Sector and two numbers of Inter Connecting Rings (ICR) on both sides. SST-1 plasma operation needs an ultra high vacuum (UHV) inside the SST-1 vacuum vessel. In order to achieve UHV in vacuum vessel, the vessel is baked to high temperature around 150 °C for longer duration to remove water vapor and other gases which are absorbed and adsorbed. Baking of the vacuum vessel effectively reduces the net gas load due to out-gassing of the materials. Further during cool down phase and plasma operations, the vacuum chamber will be maintained at 50 °C under evacuated condition to avoid the cool down of vessel towards low temperature due to radiation loss. For baking purpose, U shaped channels of 2 mm thickness are welded on the inner surface of the vacuum vessel. Hot nitrogen gas at 250 °C is passed through these rectangular channels of the vacuum vessel for baking. K-type thermocouples are installed on the inlets and outlets of vacuum vessel sectors and on the vacuum vessel to measure the temperature of vacuum vessel. From the temperature difference between the inlet and outlet, the amount of heat transferred to the vacuum vessel is calculated. Data loggers and SCADA based software is used for temperature monitoring and data acquisition of SST-1 vacuum vessel and Plasma Facing Components (PFC). Temperature measurements of SST-1 vacuum vessel during baking and plasma operation is important, to ensure the safety of SST-1 vacuum vessel. This paper will describe about the temperature measurements and calorimetric calculations of SST-1 Vacuum Vessel and its results.

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270/NF-49/P

AUTOMATIC CAPACITANCE AND TAN DELTA TESTING FACILITY FOR INSULATION CHARACTERIZATION

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Abstract

Magnet Systems Division IPR deals with development of insulation system appropriate for superconducting and resistive magnets. For testing and characterization of developed insulation system a 12kV, 200mA Tan ∂ testing unit has been used. Tan delta testing or dissipation factor testing is an essential diagnostic method to know the healthiness of insulation and prediction of insulation life as well. It is necessary to maintain the quality of insulation as the aging of insulation occurred. By measuring the insulation of specific system periodically with Tan delta tester, it is easier to predict life and quality of the electrical insulation. A regular periodical testing of key values help in benchmarking the deterioration of the equipments, and helps to schedule preventive maintenance at appropriate times, thus preventing unwanted failures.

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271/NF-50/P

DESIGN AND TESTING OF DATAANALYSIS TOOL FOR ECRH SYSTEMS IN LABVIEW

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Abstract

Electron Cyclotron Resosnance Heating (ECRH) is one of the essential RF heating sub systems used for pre-ionization and current drive experiments in SST1. In SST-1, Gyrotronbased two ECRH systems are installed. 42 GHz gyrotron system capable of delivering 500kW RF power for 500ms and the 82.6 GHz gyrotron capable of delivering 200kW continuously for 1000 second. VME based Data acquisition and control (DAC) [1] system is installed with the gyrotron systems and is under operation with SST-1.

The new PXIe based Data acquisition and control (DAC) system is recently developed and it is commissioned as an upgradation of currently used DAC. This new PXIe based DAC[2] system is versatile and incorporates many new features which are not available in the Old DAC system.

Data analysis is an essential tool in ECRH system for its stand alone test on dummy load as well as experiments with SST1 machine. In gyrotron operation fast interlocks play a crucial role for the safety of thegyrotron tube. It takes an immediate action in real time, activates interlocks and removes the High Voltage within 10 µS and thus avoids the critical conditions during gyrotronoperation.The plot of critical signals helps in finding the interlock signal behaviour and its activation.

This paper explains the basic features of PXI DAC and the data analysis tool designed in labview 2014 and the problems faced during design and testing of different lengths of data plot. It has various features of plotting data in different categories i.e. plotting of fast acquisition signals data to decide the sequence of gyrotron interlocks happened during the gyrotron operations, conversion of main binary file into 32 .text files and all the 32 analog signals data plot in a single plot, auto update of selected important signals plot at the end of the shot.

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272/NF-51/P

ENGINEERING DESIGN & DEVELOPMENT OF LEAD LITHIUM LOOP FOR THERMO-FLUID MHD STUDIES

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Abstract

In the frame of the design and development of LLCB TBM, number of R & D activities is in progress in the area of Pb-Li technology development. Molten Pb-Li is used as a tritium breeder and also as a coolant for the internals of the TBM structure. In presence of strong plasma confining toroidal magnetic field, motion of electrically conducting Pb-Li leads to Magneto Hydro Dynamic (MHD) phenomena, as a consequence of which the flow profile of Pb-Li is significantly modified inside the Pb-Li channels of TBM. This causes additional pressure drop inside TBM and affects the heat transfer from internal structure. The detail studies of these MHD effects are of prime importance for successful design of LLCB TBM and its performance evaluation. Although, various numerical MHD codes have been developed, validated in simple flow configuration and are being used to study MHD phenomena in LLCB TBM, experimental validation of these codes in TBM relevant complex flow geometry is yet to be performed. A Pb-Li MHD experimental loop is, therefore, being developed at IPR to perform thermo-fluid MHD experiments in various LLCB TBM relevant flow configuration. MHD experiments are planned with different test sections instrumented with potential pins, thermo couples, etc. under a uniform magnetic field of ~1.4 T. The obtained experimental data will be analyzed to understand the MHD phenomena in TBM like flow configuration and also for validation of MHD codes. This paper describes the detailed process as well as engineering design of the Pb-Li MHD loop and its major components along with the plan of MHD experiments in various test mock ups.

273/NF-52/P

GUI AND CONTROL INTERFACE DESIGN IN LABVIEW FOR VME BASED DAC SYSTEM IN ECRH

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Abstract

Electron Cyclotron Resonance Heating (ECRH) is one of the essential RF heating system used for pre-ionization and current drive experiments in Aditya and SST1 tokamak. The 42 GHz gyrotron system capable of delivering 500kW RF power for 500ms has been installed for operation with Aditya and SST1 tokamak. VME based Data acquisition and control (DAC) [1] system has been installed with the gyrotron system and is under operation with SST-1. VME based DAC has GUI and control interface designed with tcl-tk and C++ on Linux operating system and control application developed for target VME hardware on VxWorks RTOS with C++.

In order to make gyrotron operation more user friendly and easy DAC up-gradation, GUI and Control interface software is upgraded with NI Labview 14.0. NI Labview is a data acquisition, measurement and control application development software. It is now used worldwide because of its robustness and versatility with selection of varieties of PXI hardware[2] for various field applications. VME DAC system is also rugged and operational, so keeping VME side control software intact, the task for Labview based front-end GUI and TCP-IP based control interface development was carried out to replace the old Tcl-tk based GUI.

Interactive Graphical User Interface (GUI) is developed on Host PC with all control and monitoring facility. The Client –Server model adopted for software development. Data Plot utility for auto update of current shot data has also been integrated for better data visualization and manipulation of data. This new Labview based GUI and control interface is versatile and incorporates many new features which were not available in the old GUI software.

This paper explains the basic features of upgraded DAC software designed in labview 2014, adopted methodology and the problems faced during design and testing.

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275/NF-53/P

POWER SUPPLY QUENCH PROTECTION SYSTEM OF TOROIDAL FIELD SUPERCONDUCTING COIL FOR SST-1

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Abstract

The quench protection (QP) system by high current power supply for superconducting magnet (SCM) has been designed, developed, integrated and tested for Toroidal field (TF) coil of Steady State Superconducting Tokamak (SST-1) machine. This protection system has been designed to protect the TF SCM, which consists of 16 D shaped identical coils connected in series at the highest operating current of 10kA with stored energy of 50MJ. The TF Power Supply (TFPS) is 12 pulse AC to DC convertor, which can ramp up the current at 5 A/s and maintains the current as required for SST1 experiment. In event of quench the current needs to brought down as fast as possible and dissipate the stored energy in the dump resistor. The TFPS receives the quench trip signal from magnet quench detection control circuit, which trips the power supply, initiates bypass operation and gives trip signal to DC circuit breaker (DCCB). The QP system has been successfully operated in event of quench during individual coil test and during SST-1 machine operation.

This paper describes the design, operation and test results of TFPS QP system during the plasma experimental campaigns of SST-1.

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278/NF-54/P

ESTIMATION OF PARTICLE CONFINEMENT TIME FOR ADITYA TOKAMAK PLASMA

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Abstract

The particle source rate plays an important role in the particle transport in the edge region of tokamak. Apart from known gas injection, the overall recycling of particles from the vacuum vessel wall and plasma peripherals along with edge plasma temperature and density determines the particle source rate in tokamaks. The particle source rate can be inferred from the ionization rate of neutral hydrogen, which can also be used to calculate the particle confinement time [1]. The ionization rate of neutral hydrogen can be estimated from the radial emissivity profile of neutral hydrogen. In this paper we present calculations of radial profile of the particle source rate in typical discharges of Aditya tokamak using the measured emissivity profile of H_α [2] which has been also modeled using DEGAS2 neutral particle transport code to find out the neutral hydrogen penetration into the plasma [3]. Using the radial profile of the source rate, the particle confinement time is derived for plasma volume within a given magnetic flux surface, $\tau_p(\rho)$, where ρ is the normalized minor radius of the flux surface. The details of calculations and comparison of results with other indirect measurements will be presented in the paper.

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283/NF-55/P

ERROR ANALYSIS IN THE SPECTROSCOPIC MEASUREMENT BY DOPPLER SHIFT SPECTROSCOPY SYSTEM FOR NEGATIVE ION BASED NEUTRAL BEAM INJECTION SYSTEM

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Abstract

A negative ion source based neutral beam Indian test facility, INTF [1] consists of a 100 keV H- RF source, under developmental stage at Institute for Plasma Research (IPR). The test facility is to validate the performance of Diagnostic Neutral Beam to be delivered to ITER [2]. A large set of diagnostics are planned to be deployed in the INTF to measure and optimize the beam performance of the 100 keV H- beam [3]. Doppler Shift Spectroscopy (DSS) diagnostics is under conceptual stage to estimate the beam divergence and stripping losses of the beam with an error less than 10% of the designed value (~10 mrad).

The divergence of the beam is estimated using the line broadening of the H_α emission radiated during the interaction of ion beam (H^-) and the background gas (H_2). The spectral broadening caused due to divergence of the beam is convolved with several spectral line broadening mechanisms. In order to derive the beam divergence from the measured line broadening, it is necessary to estimate and deconvolve them from the observed spectral broadening. During conceptualization of the DSS diagnostics set up, a detailed study on error propagation on beam divergence measurement is to be carried out, to restrict the measurement error to < 10%. A quantitative analysis on the divergence estimations is performed using the standard methodology proposed in ref [4]. In this paper, we present the results of the divergence analysis and the conceptual design of the DSS system based on these calculations.

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291/NF-56/P

ROLE OF HELIUM LEAK DETECTION IN SST-1 CRYOGENICS SYSTEM

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Abstract

Helium being precious gas, it is mandatory practice to follow proper helium leak tightness protocols before system taking into operation. Moreover, helium applications are found in temperature range of 4.5 K – 300 K. Due to viscosity and density of helium, there are at least two to three order of magnitude leak rate variation is observed at 4.5 K as compared to 300 K. The SST-1 cryo system is wide and complex in terms of its infrastructure starting from warm gas storage system to cryogenic systems. The warm gas area covers helium storage tanks at medium pressure (14 bar (a)) to high pressure (up to 150 bar (a)). Helium being very precious gas, it is mandatory to check helium leak tightness of these storage tanks on routine basis as part of quality procedures. During the overhauling of helium screw compressors, after refurbishment, the helium leak test conducted as part of acceptance. As per maintenance schedule of Oil Removal System (ORS), every 4000 hours of operation of ORS, we need to replace the filters and charcoal bed regeneration activities. After successful maintenance of ORS, it is practice to carry out helium leak tightness test at service pressure.

During recent PF coils return paths isolation tasks, helium leak test of complete cryo network within the current feeders system has been carried out. Other than this, helium flow distribution system, different low temperature characterization experimental preparation, flexible lines as well as bellows and critical components like electrical breaks are routinely checked for its leak tightness before they go for actual experiments [1]. In this paper, different methods adopted for the helium leak tightness test and severity of temperatures some of the test results will be highlighted.

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292/NF-57/P

DISCHARGE CHARACTERISTICS COMPARISONS OF ADITYA TOKAMAK PLASMA VERSUS ADITYA – U TOKAMAK PLASMA

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Abstract

ADITYA (R=75 cm, a=25 cm), a medium size air-core tokamak with a graphite circular limiter has been operation for over 2 decades. Typical discharge parameters of the ADITYA tokamak with maximum plasma current ~ 160 kA, discharge duration ~250 ms, Peak electron density (n_e) ~ 6 X 10^{19} m^{-3} and the maximum electron temperature (Te) ~700 eV has been achieved [1].After ~ 25 years of successful operation of ADITYA, it has been upgraded for having shaped plasma operation with divertor configuration to support the future Indian Fusion program [2]. After successful commissioning of ADITYA-U, the first phase plasma operations are resumed in ADITYA-U with toroidal belt Graphite limiter configuration from 1st December, 2016. During first phase operation in ADITYA-U, repeatable plasma discharges of Ip ~ 80 kA – 95 kA, duration ~ 80 – 100 ms with toroidal field B_ϕ (max.) ~1T and chord average electron density ~ 2.5 x 10^{19} m^{-3} has been obtained. Later, discharge duration has been enhanced up to ~180 ms.

As far as plasma discharge characteristics comparison is concern, following changes are noticed in ADITYA – U first phase operation as compared to ADITYA tokamak operation viz., (1) filament preionization is necessary during Pulse Discharge Cleaning (PDC) as well as main plasma discharge operation to achieve plasma breakdown in ADITYA-U. In absence of filament pre-ionization breakdown did not occur (2) Pre-filled gas pressure range enhanced from 8 x 10^{-5}torr to 2 - 3 x 10^{-4}torr (3) Requirement of higher burn through time in loop voltage shaping for properly burn out of impurities to achieve successful start-up (4) Absence of initial hard X-rays during start-up phase of ADITYA-U (5) Initial plasma current rise rate reduced from 7-9 MA/Sec to 4-5 MA/Sec. The supporting observations and possible causes of different discharge characteristics between two machines will be discussed in this paper

.

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299/NF-58/P

FAILURE ANALYSIS OF 3.0MW SODA WATER BASED DUMMY LOAD

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Abstract

ITER-India has developed a test bed capable of handling 3.0 MW/CW RF power for testing of amplifier chain in MHz frequency range [1]. The test bed consists of 12 inch transmission line components, Mis-Match Transmission Line (MMTL) system and 3MW/50 Ohm dummy load, to produce matched as well as mis-matched load condition. A soda water column inside the dummy load works as resistive element which dissipates the RF energy through Joule heating process. The unique shape of aluminum outer conductor along with soda water column provides 50 Ohm characteristic impedance at its port. The soda water is pumped inside a closed circuit through the dummy load and heat exchanger, for extracting dissipated RF energy.

During testing of Diacrode based amplifier at 1.7MW power level, an arc fault was observed inside the dummy load, which eventually damaged insulated PPH pipe and leakage of soda water column was observed. After disassembly, it was revealed that there were multiple arcing inside the load and severe damage occurred to the PPH pipe. As a part of analysis activity, 3D model of dummy load was constructed using CST Microwave Studio (MWS) and CATIA software. The conductivity of the soda water column was adjusted to achieve return loss better than -31dB over the entire frequency range of 35-65MHz, thus simulating the condition similar to experimental situation. The simulation was done for checking field patterns inside the dummy load. The maximum E-field strength observed was ~0.6kV/mm for 1.7 MW RF power level. Further simulation at 3MW level showed an increase of field strength up to ~0.8 kV/mm. The location of maximum field strength coincided with the location of arc damage observed in the PPH pipe. It was concluded that due to misalignment of soda water column with respect of outer conductor produced uneven field distribution which further lead to arc fault. The failed PPH pipe was replaced with spare tube with due attention to the co-centricity with outer conductor during assembly phase and high power operation resumed successfully.

This paper discusses in detail about the outcome of failure analysis, simulation results and repair work to bring the soda water based dummy load into operation.

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301/NF-59/P

RECENT OBSERVATIONS AND MAINTENANCE ISSUES OF OIL REMOVAL SYSTEM IN 1.3 KW @ 4.5 K HELIUM PLANT FOR SST-1

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Abstract

IPR has 1.3 kW at 4.5 K capacity helium plant to cool the superconducting magnets system of SST-1. Helium plant consists of oil flooded screw compressors to compress the helium gas at 14 bar (a). Oil removal system (ORS) is installed to remove the oil traces from helium gas and further helium gas is passed though Charcoal bed and specially designed filters to remove oil aerosol. The helium plant has on-line purifier to remove other impurities at 80 K. After 4000 hrs of continuous operation of the helium plant, the ORS filters gets saturated and it is observed that oil traces seen at purifier end, there is increase in pressure drop across purifier hence periodic maintenance of ORS and purifier filter is performed in order to ensure pure helium gas (less than 10 ppm (v)) in cold box and maintains plant health. Maintenance includes, replacing coalescer filters, regeneration of charcoal bed using hot nitrogen, and evacuation purging of helium circuit with helium gas. The performance test done before and after maintenance of helium plant.

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302/NF-60/P

TESTING OF INDIGENOUS DEVELOPED ION PUMP POWER SUPPLY

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Abstract

The indigenously developed ion pump power supply would be used for operating ion pump which would maintain appropriate vacuum inside the klystron tube. It is an important system of high power klystron tube which is used in LHCD [1] system for SST-1 [2] machine. A 5.5kV and 2mA ion pump power supply is developed and tested to validate its performance. It is tested with resistive load to measure the parameters like voltage, current, ripples, response etc. Output current is monitored on ammeter and an interlock signal in the range 0-100µA is used for activating the interlock signals.

Two interlock signals are included in the design, namely slow (<100msec) and fast (<4ms) interlocks. These interlocks generate a signal to activate protection system. Slow interlock gets activated when the output current exceeds the set limit. It generates a signal to Data acquisition and control system(DAC).Fast interlock get activated whenever output current goes beyond 1 mA .This not only generates a signal to DAC for protection but also disable the power supply(HV Output). Measurement suggests that fast interlock response time is 3.4msec. Voltage Ripple of less than 5Vpk-pk is measured for the current range between 20µA to 100µA.

The successful testing of ion pump power supply establishes that it can be used with klystron tube. The poster describes the topology of power supply and scheme used for testing. It also highlights the challenges faced during its realisation.

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303/NF-61/P

EVACUATION AND SAFETY VALVE TESTING OF LIQUID NITROGEN STORAGE TANKS AT IPR CRYO FACILITY

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Abstract

The Liquid Nitrogen (LN_2) storage and distribution system consists of three storage tanks with each has capacity of 35 m^3. These storage tanks are designed with vacuum as well as low thermal conductivity Perlite insulation. The maximum operating pressure of these tanks is 2.75 bar (g) and maximum discharge rate is about 2000 l/h with the net evaporation rate (NER) of < 1%. LN_2 distribution system has ~250 m transfer line, sub cooler Dewar, phase separator and vent lines. To reduce the evaporation rate of storage tanks and transfer line one has to periodically evacuate the annular space between outer vessel and inner vessel in order to maintain the vacuum level (< 5.0 x 10^{-2} mbar) and accordingly its NER rate. After evacuating the LN_2 storage tanks, by comparing its liquid level (filling up to 80 -90 %) in real time trends, before and after evacuation one can ensure the thermal performance in terms of NER. As per the CCOE norms, every year the safety valves mounted on the LN_2 storage tanks needs to be tested to ensure its proper operation. In this paper, we will discuss the methodology for the evacuation of LN_2 storage tanks and the procedure of the testing of safety valves as per the CCOE norms.

306/NF-62/P

DEVELOPMENT OF SOFT STARTER FOR 3-PHASE, 150KV ISOLATION TRANSFORMER OF TWIN SOURCE (TS)

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Abstract

For the galvanic isolation system of the TWIN source [1], a 3-phase, 150kVA, 415V/415V 100kV DC isolation transformer has been commissioned. The isolation transformer draws a high inrush current from the incoming line during startup, which, if not restricted, can cause false fuse or incoming breaker interruption as well acing in the upstream circuits. In order to overcome these issues, an automatic soft-starter has been designed, developed, tested and integrated with the galvanic isolation system. The soft-starter implements a power contactor (415V, 400A) and a combination of power resistors, which are automatically brought into the line for about a second at the first startup through the startup circuit, in order to soft-start the transformer. The resistors are then automatically bypassed from the line (by the startup circuit) to provide the normal operation of the transformer. The starter also implements a backup monitoring circuit, which generates a signal to forcefully trip the incoming circuit breaker and thereby protects the power resistors, in case the startup circuit fails to bypass the resistors within a designated time period. The paper will describe in detail about its design, development, testing and integration with the galvanic isolation system of TWIN source.

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[1] Design & development of electrical system for TWIN, IEEE 26th Symposium on Fusion Engineering (SOFE), (2015)

307/NF-63/P

DESIGN OF RESONANT CONVERTER BASED DC POWER SUPPLY FOR RF AMPLIFIER

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Abstract

ITER require 20 MW of RF power to a large variety of plasmas in the Ion Cyclotron frequency range for heating and driving plasma current. Nine RF sources of 2.5MW RF power level each collectively will accomplish the above requirement. Each RF source consists of SSPA, driver and end stage, above which driver and end stage amplifier are tube (Tetrode/Diacrode) based which requires auxiliary DC power source viz. filament, screen grid and control grid DC power supply. DC power supply has some stringent requirements like low stored energy, fast turn off, and low ripple value, etc.

This paper includes a detailed study of Zero Current Switching (ZCS) resonant converter based buck converter, understanding with the help of mathematical equations for various modes and simulation of the basic model. In resonant converters, LC tank circuit is used to create oscillating Voltage/Current so as to produce zero crossing. It consists of two basic cell i.e. Zero Voltage (ZV) cell and Zero Current (ZC) cell. ZV cell is used to create zero voltage across the switch and similarly, ZC cell is to create zero current through the switch. Various configurations can be achieved by incorporating these cells to basic converter unit. This paper will focus only on Zero Current Switching (ZCS) resonant converter based buck converter. This can serve the purpose of control grid and screen grid DC power supply for above requirement. IGBT switch will be used at 20 kHz so as to lower the filter requirement hence low stored energy and ripple in the output voltage. ZCS operation will also assist us in reducing EMI/EMC effect. Design of resonant tank circuit is important aspect of the converter as it forms the backbone of the complete system and basis of selection of other important parameters as well hence mathematical model analysis with the help of circuit equations for various modes have been shown as a part of selection criteria. Peak current through the switch, duty cycle, switching frequency will be the design parameters for selecting resonant tank circuit.

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309/NF-64/P

LAB SCALE DESIGN, FABRICATION OF CRYO LINE TO STUDY AND ANALYSIS TWO PHASE FLOW CHARACTERISTICS USING LIQUID NITROGEN

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Abstract

A 6-m long liquid nitrogen based cryo transfer line has been designed, developed at IPR. The liquid nitrogen experimental test setup is designed to study the thermo-hydraulic characteristics of Cryo transfer line under single phase as well as two phase flow conditions. Investigation of the thermo-hydraulic parameters in case of single phase flow of cryogen is always easy in experimentation but it is real challenge to deal with the two phase flow of cryogen due to unavailibity of mass flow measurements (direct) under two phase flow conditions. The test design of experimental setup consists of: The nitrogen supply system, liquid nitrogen transfer line, instrumentation for pressure, temperature and single phase flow measurements. The liquid nitrogen transfer line is a vacuum jacketed stainless steel line, which transfers liquid nitrogen from the supply to the application. A 2.1 kW rated heater is installed within vacuum jacket of cryo line, to study pressure drop variation at various heat loads and its effect on quality at the outlet.

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312/NF-65/P

APPLICATION OF HIGH TEMPERATURE CALCINATION IN PHASE PURIFICATION OF $SrCe_{0.9}Y_{0.1}O_{3-\delta}$ SOLID STATE PROTON CONDUCTING CERAMIC FOR DEVELOPMENT OF ELECTROCHEMICAL BASED HYDROGEN ISOTOPE SENSOR

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Abstract

Online measurement of hydrogen isotope concentration in liquid lead lithium (Pb-Li) is one of the most important tasks for Tritium Extraction System (TES) of Lead Lithium Ceramic Breeder (LLCB) Test Blanket Module (TBM). Though hydrogen isotope sensors based on permeation have been reported for this, they get corroded in the presence of liquid Pb-Li. This corrosion reduces the permeation flux significantly with time. So, they have to be replaced very often, which is a big limitation. However,solidstateproton conducting electrolyte basedhydrogen isotope sensors, which have high chemical and physical durability in liquid Pb-Li at elevated temperatures,need to be developed for measuring hydrogen isotope concentration in liquid Pb-Li.

This work describes in detail the synthesis of $SrCe_{0.9}Y_{0.1}O_{3-\delta}$ (SCY) ceramicthrough solid state chemical reaction. SCY ceramic is a potential solid state proton conducting electrolyte. Disc shaped pelletsof SCY can be used inelectrochemical based hydrogen isotope sensors as a solid electrolyte, which separates reference and working electrodes. Disc shaped pellets of different diameterand thicknesses from SCY ceramic powderhave been prepared for this purpose. Effect of calcination at higher temperaturein phase purification with XRD analysis of the prepared SCY ceramic has been discussed in detail. This work also describes other challenges involved in developing electrochemical based hydrogen isotope sensor.

327/NF-66/P

DESIGN AND SIMULATION STUDY ON 60 MHZ ROD TYPE RADIO FREQUENCY QUADRUPOLE ACCELERATOR AT IPR

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Abstract

A Radio Frequency Quadrupoles (RFQ) [1] is considered to be the most suitable linear accelerator for the acceleration of low energy, low q/A beams due to its advantages of simultaneous focusing, bunching and acceleration that can be achieving by suitable variation of the modulation of rods/vanes along the length of the RFQ, in a single structure. They are widely used as injectors in linear accelerators and synchrotrons, stand-alone accelerators in some applications like ion-implantations, Ion –Irradiation etc. Being capable of producing high particle flux, RFQ is also useful for providing a close simulation to natural space radiation environment and helps in the some test methods e.g., ionizing radiation (also called total dose) test and dose rate induced latch-up tests along with mitigation of the electronic component's failure on the subassembly and assembly

At IPR, a project has been planned to characterize Fusion Grade material properties using Ion-Irradiation through Radio Frequency Quadrupoleaccelerator. Ion Irradiation is presently preferred for material studies as it rarely requires more than several tens of hours to reach damage levels of 1-100 dpa range and provides safer environment than neutron irradiation along with many other advantages [2].

Rod type RFQ structures [3], where the rods most importantly act as a pair of transmission lines has advantage of substantially reducing the cavity size than its counterparts, even for low frequencies of few tens of megahertz.

At IPR, a 4.2 m long rod Type RFQ has been designed at 60 MHz frequency for accelerating 50 KeV protons to 1 MeV energy @5 mA beam current with 97% transmission efficiency for a vane voltage of 95 kV and characteristic radius of 1.64 cm. A six cell radial marching section has been designed to match the DC beam from ECR ion source to time varying structure of RFQ in the beginning. 12 posts have been used to achieve a resonating frequency of 59.6 MHz in the 4.2 m long cavity. In this paper we will focus on the electrical model used for the integral and distribution parameter analysis on basis of which geometrical parameters are selected to achieve resonant frequency and to improve the RF properties of RFQ such as

intrinsic quality factor and shunt impedance to reduce the power consumption and measure of longitudinal flatness of inter-electrode voltage. We will also discuss the numerical simulations that have been carried out for the cavity using CST Microwave studio (MWS). These issues will be discussed along with the design of 60 MHz Rod type RFQ.

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330/NF-67/P

ASSEMBLY & INSTALLATION OF MW LEVEL RF AMPLIFIER BASED ON TETRODE TECHNOLOGY

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Abstract

The Ion Cyclotron Heating and Current Drive (IC H&CD) system is expected to play an important role for heating & driving current of ITER plasmas [1]. The same system will also be used for wall conditioning at low power level. The IC H&CD power source is design to couple 20 MW RF power into the plasma. India is responsible to deliver nine number of RF Sources, each having 2.5 MW/CW RF power handling capability with load VSWR 2:1 in the frequency range 35-65 MHz or 3.0 MW/CW with load VSWR 1.5:1 in the frequency range 40–55 MHz, with 25% duty cycle. Since no high power vacuum tube exists as per ITER requirement, each RF source is a combination of two amplifier chains capable to deliver 1.5MW RF power. An R&D program [2], using Diacrode (TH628) &Tetrode (4CM2500KG) technologies was launched for the qualification of final stage tube and associated critical components for the ITER application. In this R &D program single chain experimentation at 1.5MW/CW/35-65 MHz/ VSWR 2:1 is considered.

A chain of 1.5MW/CW amplifiers using Tetrode technology is developed for the R&D program, which consists of three cascaded amplifiers i.e. pre-driver, driver and final stage amplifiers, auxiliary power supplies, transmission line components and dedicated control system. ITER-India has developed a complete test facility with all the required infrastructure and associated auxiliary systems to conduct comprehensive testing of such amplifiers. After successful assembly and integration, high power RF test has been initiated at ITER-India test facility. Encouraging results obtained so far are 1.5MW/2000s/36MHz with 2MHz bandwidth at 1dB point, 1.7MW/3600s/36MHz and 1MW/2000s at 40, 45, 55, 60 and 64MHz with 2MHz BW on matched load. Further high power test is under progress. This paper describes the assembly, integration and high power test results of the tetrode based amplifier chain at ITER-India test facility.

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336/NF-68/P

ELASTIC MODULUS AND HARDNESS MEASUREMENT OF LITHIUM TITANATE PEBBLES USING NANO INDENTATION TECHNIQUE.

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Abstract

Lithium titanate (Li_2TiO_3) is a candidate material for tritium breeder for Indian LLCB. Characterization of the physical properties of the Li_2TiO_3 pebbles is essential in order to produce the qualified pebbles for LLCB TBM be tested in ITER.There are numerous characterizations for the lithium titanate pebbles, i.e., porosity measurement, crush strength of the pebbles, thermal properties, density etc. Among these characterizations, estimation of elastic modulus of the single pebble as well as pebble bed is plays an important role in assessing the overall properties of the lithium titanate pebbles
.
Nano indentation is a powerful technique to quantitatively measure the indentation modulus of localized microstructures, interfaces, small surface features, and thin films. During a nano indentation test, a probe of a well-known geometry is pressed into the surface of the material as the applied force and resulting indenter displacement is continuously measured. The acquired force-displacement curve is the nanoscale mechanical fingerprint of the material and provides a highly sensitive measurement of the probe/sample contact stiffness, from which the indentation modulus can be quantitatively calculated.

Elastic modulus values for single pebble as well as for pebbles bed will provide input for experimental set up and simulations for further investigation of behavior of lithium ceramic pebbles under fusion environment.Hence, this characterization can be used to validate or benchmark the sustainability of lithium ceramic pebbles for fusion application.

337/NF-69/P

DEVELOPMENTOFARDUINOBASEDFAULTDETECTIONSYSTEMFOR ROBIN

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Abstract

ROBIN, the first step in the Indian R&D program on negative ion beams is currently in advanced operational phase. The beam phase operations are being conducted in surface mode.

In surface mode, metallic Cesium (Cs) vapor is injected into the source which lowers the work-function of the plasma grid (plasma facing grid) and enhances the negative ion production. To reduce the impurities (Cs contamination) into the source continuous pumping of the source was implemented. The Turbo Molecular Pumping (TMP) station is operated continuously which is supported by UPS system to avoid the TMP shutdown in case of power failure. However sometimes in case of power failure incomer MCB of the TMP/UPS trips and when power is restored TMP doesn't switch to utility (normal) power, hence manual interruption is needed, moreover UPS battery is exhausted in few hours and corrective actions are needed, otherwise vacuum condition of the source deteriorates which lead to source contamination. To communicate with the responsible person; SMS based system is developed and tested successfully.

For Detecting and notifying power failure of Mains system, Arduino based fault detection system is developed. Arduino UNO board is interfaced with GSM SIM 800 Module through serial communication. This System continuously detects voltage level of input mains power at Arduino and triggers the GSM module to send a SMS to experimentalists on the event of power failure for further action.

In this paper, we present the overall scheme used for interfacing UPS system to Arduino and GSM system.

339/NF-70/P

MULTIMEGAWATT-MULTIAMPERE NEUTRAL BEAM TEST FACILITY AT IPR

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Abstract

Neutral beams have played an important role in supporting the plasma operations in tokamaks as auxiliary plasma heating and current drive devices in addition to assisting plasma rotation and plasma diagnostics. With the world of tokamaks moving towards large fusion devices with higher plasma densities and with operations expected in severe nuclear environments, the requirements from neutral beam systems are approaching challenging proportions in terms of design, material, manufacturing and operation to deliver several tens of megawatt power and survive the desired periods of operation with minimal maintenance. The design aspects of such systems cover extensive physics and thermomechanical calculations related to beam optics, heat load estimations estimation of the cooling requirements and study of the component behavior under estimated power loads, ~ 1 – 10 MW/m^2. In addition the aspects of material and process development are of prime importance to manufacture components with stringent tolerances and also survive the life time of the machine operations with minimal damage due to limited maintenance opportunities for reasons mentioned above.

An effort towards development of such a neutral beam facility is underway at IPR. The facility, which covers all the aspects mentioned above, is aimed at establishing 100 keV 60 A H beams corresponding to a current density 35 mA/cm^2. The beam production and acceleration is achieved using a Cesiated 8 driver based RF negative ion source having an extraction plane of ~ 1.8 m x 0.6 m. The extractor and accelerator system is a 1280 beamlet 3 grid system designed to extract, accelerate and focus the beams at 21 m. In addition to the ion source are the critical design and manufacturing of beam line components which include the neutralizer, the electrostatic residual ion dump and the calorimeter to diagnose the beams. The experience gained in the design, manufacturing and establishing the desired beam properties could be of interest to several areas of beam development on other devices from the national perspective. The presentation shall discuss these areas of physics and engineering design of the planned beam line, its present status and the programmatic approach under

consideration towards establishing the beam. The planned facility is also expected to contribute to the operational data base for ITER in terms of the expected power in the plasma from diagnostic beam line for He ash determination.

340/NF-71/P

EXPERIMENTAL STUDY ON CRITICAL LENGTH OF ELECTRICALLY EXPLODING WIRE

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Abstract

Electrically exploding wires (EEW) find applications in diversified fields like high energy density physics, nano-particle generation, pulsed power systems, bridge wire detonators etc.. The applications are based upon their phenomenal characteristics at particular range of experimental parameters [1]. Present studies are carried out to characterize experimental parameters for efficient radiation emission from EEW [2]. One such factor so called "critical length" which is the length of wire below which it gets overheated. In turn, if overheating factor is more than one, temperature attained by exploded wire plasma is also higher as needed for most such applications. Below this value of wire-length, ionisation will be initiated immediately after vaporization without any current pause.

In the present work, experiments are reported to obtain critical length of such wires. The experiments have been carried out in air at atmospheric pressures with enamelled copper wire of 233 micron diameter. Capacitor bank, with 2μF total capacitance and operated at 16 kV, has been discharged through single copper wires of varying lengths (1.7 cm-8.5 cm) and shots repeated many times to generate reliable results. Voltage across wire and current in the circuit has been recorded using resistive voltage divider and Rogowsky coil respectively. It is observed that dwell period is non-zero for lengths greater than 4.5 cm.. This value is seen to be differing from that expected based on empirical relations proposed by Kotovet. al.[3]. This may imply that critical length is system specific and thus more investigations are necessary to determine relation between critical length and experimental parameters.

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341/NF-72/P

EFFECT OF STRESS SHIELD CONFIGURATION ON HIGH VOLTAGE OPERATION OF PROTOTYPE HV BUSHING

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Abstract

Prototype High Voltage Bushing (PHVB) is an established system [1,2] designed to validate insulator based configuration of HV bushing of Diagnostic Neutral Beam (DNB) injector and to ensure its operational performance in high vacuum, high voltage environment.

As PHVB is designed to operate at high voltage, stress shields are provided at different locations for uniform electric field distribution and to protect the insulators during HV breakdown. These shields were designed after several iterations by FE analysis to get optimum electric field at various regions of PHVB. Experimental verification of the design is considered necessary to validate the modelled stress shields for various shields parameters e.g. design, dimensions, surface roughness, manufacturing process etc. impact the efficiency of voltage holding.

To carry out this study, two types of stress shields are used for the experiment. Electrostatic analysis was performed in ANSYS to obtain typical stress values at different locations of PHVB like, ceramic surface, triple point in vacuum, metal in vacuum and air etc for both the cases. Based on the analysis results, the shields were designed and fabricated by two different process parameters and tested for high voltage, keeping other operating parameters similar.

First shield was fabricated by hot spinning method with high precision for the dimensions and surface roughness (0.1-0.4 µm). Maximum voltage holdingup to 60 kV (20% higher than rated voltage) was achieved. Also, no breakdown was observed during 50 kV operation up to 3600s using this shield. However, the second shield was fabricated using sheet welding process. The shield design was considered very simple and easily manufacturable. Operation up to 60 kV was performed using this shield however, several breakdowns were observed during long pulse.

The experimentally obtained results were co-related with analysis results obtained by FEA to ensure operating electric stresses. Configuration of electric stress shields, FE analysis results for operating conditions and experimental results obtained from their operational performance shall be presented.

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342/NF-73/P

ANALYSIS OF MULTIPLE MAGNETOHYDODYNAMIC MODES IN ADITYA-UPGRADE TOKAMAK

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Abstract

ADITYA-Upgrade tokamak is an air-core, mid-sized (R = 75 cm, a = 25 cm) ohmically heated tokamak equipped with two garlands of 16 Mirnov coils located at two different toroidal locations to study the Magnetohydodynamic (MHD) phenomena. Extensive frequency spectral analysis of the poloidal magnetic field fluctuation ($\dot{B}\theta$), in several hundreds of discharges of Aditya-U tokamak, revealed presence/co-existence of multiple bands MHD modes (with frequency ~ 5-50 kHz), during the current flat top in a good number of discharges. It has also been observed that the same modes are present in frequency spectrum of Soft X-Ray and microwave interferometer signals. The lowest frequency lies in range of 5-10 kHz and the second band lies in 10-20 kHz frequency range, the third 15-30 kHz range and so on. A distinct feature of these modes is that the 2nd band has exactly twice the frequency of the 1st Band, and the third band is exactly thrice the frequency of the 1st band. Also the power of these modes decrease with increase in their frequency. In this paper we will present the identification and characteristics of these multiple MHD modes and probable reason for their existence.

345/NF-74/P

SOLENOID VALVE BASED GAS FEED SYSTEM FOR VARIABLE PRESSURE IN ALTERNATE ARRANGEMENT OF MASS FLOW CONTROLLER

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Abstract

Gas feed system is important pre requisite for Plasma generation in any ion source. There are many way to establish Gas Feed System (GFS) by Mass Flow Controller (MFC) based, Solenoid Valve (SV) based etc. MFC based Gas feed system is installed in ROBIN Experimental Facility at IPR. MFC is electronic device and it is observed malfunctioning during ROBIN experimental campaign due to RF radiation. To overcome from RF radiation problem, such alternate system is needed which can operate in radiation environment, require less electronics and easy to operate. So Solenoid valve based Gas Feed System idea introduced.

In prototype development of solenoid valve based gas feed system control logic is required to control the solenoid valves of gas feed system. Gas feed system is used to supply H2 and N2 for the plasma production. The gas feed system is combination of five valves among four is used to feed the gas at required pressure and one is used for puff. This system is remotely controlled which is designed by Siemens PLC. The pressure can be varied from 0.1 Pa to 1.5 Pa by four valves combination logic. A Boolean logic is used to implement this system. In this type of gas feed system each of the solenoid valves must be calibrate for a fix pressure value. As stated above out of four valves the first valve is calibrated to 0.1 Pa, second valve is calibrated to 0.2 Pa, third valve is calibrated to 0.4 and fourth valve is calibrated to .8 Pa to achieve pressure from 0.1 Pa to 1.5 Pa. By on/off controlling the proper solenoid valve, a desired pressure can be achieved.

This paper discusses in detail about the development and validation of solenoid valve based gas feed system.

347/NF-75/P

SURFACE MODIFICATION STUDY OF ZIRCONIUM ON EXPOSURE TO FUSION GRADE PLASMA IN AN 11.5 kJ PLASMA FOCUS DEVICE

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Abstract

In continuation of our investigation [1] on effect of fusion grade plasma produced in an existing MEPF-12 (11.5 kJ, 40 μF, 24 kV) plasma focus (PF) facility on different materials, likely to be used in future fusion reactors, we have reported here the study on Zirconium (Zr) metal. The PF devices have been widely used to simulate the behavior of materials in fusion reactor environment. Intense flux of pulsed ions, pulsed plasma streams along with fusion neutrons produced in plasma focus device have been used to irradiate materials and study their surface damage characteristics. Zirconium (Zr) either in alloy or in pure form is envisaged to be used in many components of the nuclear fusion reactor and has been used in fission reactors due to its high corrosion resistance, low neuron absorption cross section and high thermal conductivity. It is thus important to know the behavior of Zr material in fusion environment.

In the present work, the Zr sample in disc (2 mm thick, 10 mm diameter) form was exposed to twenty shots of plasma focus operated at 4 mbar deuterium gas filling pressure and 11.5 kJ bank energy. The samples were placed at a distance of 6 cm from the tip of the anode in the MEPF-12 PF device. The emissions from the device comprise of deuterium ions in wide energy range (a few keV to several hundreds of keV), high temperature plasma (in general a few keV) and neutrons of 2.45 MeV energy produced due to D(D,^{3}He)n fusion reactions. The typical ion fluence at sample position was measured to be close to 10^{14} ions/cm^2 with an average energy of around 100 keV, while the neutron fluence at sample position was nearly10^6 neutrons/cm^2. The PF device having stainless steel anode and tungsten inserted anode were used in irradiation study. The irradiated samples were characterized using various techniques (XRD, EDX, SEM and surface profilometer). The SEM images of irradiated samples reveal that the defects like blisters, cracks are formed over the Zr sample. The XRD profiles suggest thermal stress in the sample due to transient heating and then rapid cooling. The EDX spectra indicate changes in elemental composition of the surface layer of the sample after irradiation. A comparative analysis of surface damage characteristics of irradiated sample along with the virgin sample shall be presented along with comparison with a few important samples reported [1] earlier.

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349/NF-76/P

EXPERIMENTAL MEASUREMENT OF BEAM EMITTANCE OF ACCELERATOR BASED 14-MEV NEURON GENERATOR

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Abstract

Institute for plasma research has indigenously developed accelerator based 14-MeV neutron generator. It has a 2.45 GHz, 2 kW Electron cyclotron resonance (ECR) ion source for producing D+ ion. 500 µA ion beam is extracted with 10 kV extraction voltage from ECR ion source and it is further accelerated up to 300 keV. 14-MeV Neutron is produced by hitting accelerated deuterium beam to stationary water cooled tritium target.

The performance of the neutron generator depends on ion beam parameters in which beam emittance is very important. There are some instruments are available in the market which directly measures it but these are expensive. This paper presents experimental techniques using common beamline components and related calculation to measure beam emittance. This arrangement uses variable focusing voltage of Einzel lens and one beam profile monitor [1-4] .These results are very useful to characterize the neutron source and improvement of ion beam stability.

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354/NF-77/P

DEVELOPMENT OF LAB SCALE FAST GAS INJECTION SYSTEM FOR SST-1 TOKAMAK

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Abstract

The plasma density control plays an important role in tokamak operation. The factors that influence plasma density in a tokamak device are working gas injection, pumping, ionization rate and the recycle coefficient representing the wall conditions. Among these factors, gas injection is relatively convenient to be controlled. Hence, the most frequently adopted method to control the plasma density is to control the fast gas injection [1]. The fast gas injection system consists of a density measurement subsystem, a feedback control subsystem and a gas puffing subsystem. Gas puffing subsystem comprised of Piezo valve, Pressure sensor and suitable controller. Piezo valve having response time of 1-2 ms feeds the gas inside vacuum chamber in direct proportion to applied voltage. Pressure sensor provides the fast feedback of quantity of gas fed into vacuum chamber. FPGA based controller is used to generate required fast pulses which is fed & control through software based PID controller implemented using Labview.

This paper describes the design and experimental work carried out towards the development of Fast Gas Injection System for SST-1 tokamak. Laboratory based test setup was successfully established for Fast Gas Injection System that can feed predefined quantity of gas in a controlled manner into vacuum chamber. Further, this FGIS system will be implemented in SST-1 tokamak environment with online density feedback signal.

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359/NF-78/P

DUCTILE TO BRITTLE TRANSITION TEMPERATURE STUDIES OF IN-RAFMS

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Abstract

Reduced Activation Ferritic martensitic steel (RAMFS) have potential for its application to structural material for Tritium breeding module (TBM) in ITER. Indian specific Reduced activation ferritic martensitic steel IN-RAFMS have developed for these requirement. Welding technology requirement have been developed for the Indian LLCB TBM. During Electron beam welding Technology development it has been found that Ductile to brittle transition temperature of IN-RAFMS is higher then the base metal so for that a parametric study have been carried out to lower the DBTT of RAFMS.DBTT is one of basic property for qualification of any new material & also for functional validity of material at various sub zero temperature. Electron Beam weldpads were prepared in desired number with different heat input & welding parameters. Sub-size charpy specimens were tested at different subzero temperature & qualification criteria was decided based on RCC-MR.

360/NF-79/P

ESTIMATIONS OF CAPACITANCE REQUIRED FOR THE MATCHING NETWORK OF ROBIN

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Abstract

ROBIN [1] is an inductively coupled, single driver RF (1MHz, 100kW) based negative ion source system in which RF power is used to generate plasma. In order to transfer maximum amount of RF power to the ion source, a RF matching network is used to match the load impedance (Ion source Exciter impedance) with the impedance of the RF generator [2]. Thematchingnetworkconsists of a high frequency transformer and set of tunable& fixed capacitors connected on both primary and secondary terminals of the transformer. The capacitors connected on the secondary of the transformer are in series, which nullifies the reactive part of the load impedance and the capacitors connected on the primary of the transformer are in parallel, which serves to match the resistive part of the load impedance. In the present operational scenario of ROBIN, there is a need to optimize the matching capacitance requirement in order to achieve maximum RF power transfer to the plasma beyond 60kW. As it is difficult to estimate the exciter impedance of the ion source, calculations have been done based on the available experiment data of ROBIN at various combinations of source pressure & RF power for exciter impedance estimation, which is then used to estimate the capacitance required to transfer maximum RF power to the ion source, using the SMITH charts.

The paper describes about themethodology and the estimated tuning capacitance for the ROBIN matching network in order to transfer maximum power in the load based on the available experimental data of ROBIN.

References:

[1]**"RF-plasma source commissioning in Indian negative ion facility"** by M.J. Singh, et al. AIP Conf. Proc. 1390 (2011) 604-613
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364/NF-80/P

MANUFACTURING OF LARGE SIZE RF BASED -VE ION SOURCE WITH 8 DRIVERS -CHALLENGES AND LEARNINGS-

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Abstract

Radio Frequency (RF) Ion Source for ITER Diagnostic Neutral Beam (DNB) system, is an 8 driver based ion source, where the desired plasma density is produced by inductive coupling of RF power. The electrostatic accelerator is a multi-aperture 3 grid systems (separated by post insulator) providing a net extraction area of 0.2 m^2. A total of 800 kW of RF power uniformly distributed over 8 drivers shall be used to produce and accelerate H- ion beams at 100 kV. The expected accelerated current from the source is 60 A. The duty cycle for beam extraction and acceleration is 3 Sec ON / 20 Sec OFF with 5 Hz modulation during the ON period.

According to the ITER component classification, Ion Source and accelerator falls under the category of Quality Class 1(QC1) and actively water cooled components are Vacuum Quality Class 1A (VQC1A). This classification implies for (1) development of the welding technique of a special kind which allows the full penetration weld with 100% volumetrically examinable joint (2) welding of dissimilar material transition, which otherwise being done by brazing technique (3) deep drilling over the length of ~2m with max. drift of 0.5mm (3) milling of closely spaced cooling channels (4) manufacturing of high purity ceramic components with threads (5) use of material with special restriction on cobalt contents (6) voltage holding capacity of 140kV (7) assessment of each material being used from the perspective of its nuclear and vacuum compatibility.

Apart from this, the functionality of the Beam Source (focusing of beam at ~20m distance) demands overall alignment of components in the range of +/- 0.2mm over the grid plane of 2m x 1m. To meet this requirement, higher degree of manufacturing tolerances have been imposed on the individual components (in the range of few tens of microns), especially for accelerator components like grid segment, post insulators, support frame and mounting flanges. Each of the involved manufacturing activities (e.g milling, stress releasing, electro-deposition, electro-polishing, fixture design, handling protocols) have its own effect on the

overall accuracies and therefore, the overall process have to be optimized to meet the end targets.

The present paper describes the experience of developing a manufacturing design to meet the above mentioned requirements, feasibility assessment, prototyping carried out, parallel experiments in support of manufacturing and realization of sub-components along with their quality inspections activities performed. Additionally, paper also presents to the observations in terms of deviations and non-conformities encountered, as a part of learning for the future components.

372/NF-81/P

STUDY OF MORPHOLOGICAL CHANGES AND DEFECTS IN ION IRRADIATED TUNGSTEN FOILS

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Abstract

Tungsten is one of the potential material proposed to be used for the first wall of plasma facing component (PFC) in future fusion devices. In such devices, high energy neutron produced by D-T reaction bombarded on the first wall of PFC create defects as well as surface modifications. In the absence of 14 MeV energy and high flux neutron source, ion beam irradiation can be used as a surrogate irradiation for studying defects and morphological changes in tungsten. During ion irradiation, various dynamic processes occur in the target material thereby changing its structural, microstructural and topographical properties. In the present work, tungsten foils were studied for morphological and resistivity changes before and after ion irradiation.

Mechanically polished pristine and annealed (1838 K) tungsten foils of thickness 100 µm were irradiated with boron, gold, deuterium and helium ions of energies 10 MeV, 80 MeV, 100 keV and 250 keV respectively. Also, sequential ion irradiation of Au+D, Au+He and Au+He+D were performed in order to see the effect of D and He behavior in Au irradiated tungsten. The surface and morphological studies were done with high resolution scanning electron microscope (FESEM). SEM studies revealed the bubble formation and other surface morphological changes of tungsten foils due to gaseous ion irradiation. Four probe DC resistivity measurements were performed in a temperature range of 30 K to 300 K to study the overall defects in tungsten foils before and after irradiation. The correlation between Residual Resistivity Ratio (RRR) and the defects in the samples will be presented.

374/NF-82/P

RF MEASUREMENTS ON THE INDIGENOUSLY DEVELOPED 63.5MM CORRUGATED WAVEGUIDE PROTOTYPE FOR ITER-INDIA GYROTRON TEST FACILITY (IIGTF)

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Abstract

In the electron cyclotron resonance heating (ECRH) system, Gyrotron sources are away from the ports used for power injection to tokamak. As a result, long distance transmission lines with high power capability and very low attenuation are needed to transmit the beams. Corrugated waveguides are widely employed as transmission lines to transmit high-power microwaves for ECRH systems including various other applications viz., plasma diagnostics, radar, materials heating, and dynamic nuclear polarization (DNP) nuclear magnetic resonance (NMR) spectroscopy, etc. The power is transferred by coupling the output RF beam from a gyrotron to the fundamental HE_{11} mode of an over moded corrugated waveguide. Such corrugated waveguides are proven to have low loss, high power capability and large bandwidths for transmitting HE_{11} mode [1].

ITER-India, the Indian domestic agency for ITER project, has the responsibility to supply a set of two, high power (1MW), long pulse (3600 s) Gyrotron sources at a frequency of 170 GHz to ITER for Electron Cyclotron Heating & Current Drive applications [2]. ITER-India is establishing an ITER-India Gyrotron Test Facility (IIGTF) for testing 1MW class Gyrotrons as per ITER requirements. As a part of prototype developments for the IIGTF, an activity on indigenous development of prototype corrugated waveguide for 170GHz microwave power has been taken up. The mechanical fabrication of the corrugated waveguide sections from aluminum has been completed successfully. The initial results of the fabrication of a 63.5 mm diameter, 300 mm length, were already presented [3]. The corrugation dimensions have been verified using profile projector, which is found to be well within the required specifications.

The other methodology to validate the fabrication of the corrugations is through RF characteristics of the developed corrugated waveguide sections. The insertion loss measurement of the fabricated waveguide section is being carried using a low power D-band RF source BWO (backward wave oscillator) and 63.5mm mode converters. The return loss or the reflections will also be measured using a Vector Network Analyzer (VNA).

This paper presents the objective, test set up and test results/observations in detail.

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376/NF-83/P

DEVELOPMENT OF PROTOTYPE COLLECTOR COIL SWEEPING POWER SUPPLY FOR ITER-INDIA GYROTRON TEST FACILITY (IIGTF)

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Abstract

ITER-India is establishing a Gyrotron test facility (IIGTF) for testing 1MW class Gyrotrons as per ITER requirements (1MW, 170GHz, 3600sec) [1]. Considering the efficiency of Gyrotron, only about ~50% of input electrical energy supplied to the Gyrotron is converted to RF, while rest of it is dissipated in the forms of heat on the collector walls. Since the cross section of electron beam is very small, it results in very high heat flux on the collector walls. Despite of having an active water cooling, this heat flux if sustained at a location can go beyond thermal capability of the collector walls. In order to reduce this high heat flux, the electron beam is swept over the surface of the collector walls using collector magnet coils which are excited by an alternating current (~40A peak) with triangular waveforms (< 10Hz).

These magnet coils which are to be swept by an alternating current have very high time constants (200ms) when compared to the time period of desired operating frequency (100ms). In addition to this, the power supply has to sweep the current linearly (in both rise and fall) through the collector coils. These specifications require a source which can produce bi-polar voltages across magnet terminals and which can inject/extract the energy linearly at desired frequencies and waveforms. The COTS power supplies have faster response time (~10-50ms) for a resistive load but for high inductive loads this would be high (~400ms).

In order to achieve these specifications an H-bridge topology (four Switch Bridge) was employed and simulated in MATLAB® with satisfactory results. The same concept is being verified with laboratory prototype considering scaled down parameters. In order to drive the switches in bridge topology, a modular and rugged driver circuit were explored. This power supply also requires a centralized controller which can monitor, control and ensure safe operation.

This paper deals with the design, simulation results, analysis, implementation, and prototype results of the collector coil sweeping power supply.

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382/NF-84/P

DEVELOPMENT OF DATA ACQUISITION SYSTEM AND SIGNAL CONDITIONING FOR T TYPE THERMOCOUPLES FOR CRYOCOOLER EXPERIMENT OF INDIAN TEST FACILITY

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Abstract

Indian Test Facility (INTF) is currently under development at IPR to characterize the ion and neutral Beam produced from the 100 keV/60A Beam Source for application in the Diagnostics Neutral Beam (DNB) for ITER. For achieving operational parameters an installed pumping of 1.2 x 10^6 l/s is required to ensure low loss of ions due to stripping and low re-ionisation loss.

In order to qualify Helium section of the Cryopump and experimentally verify, a Cryocooler based experiment has been undertaken.

For the experiment cryogenic sensors such as Silicon Based Diodes (SBD) and T type thermocouples were selected to obtain information regarding temperature profile of the surface. It was important for the experiment that data from these sensors is monitored and acquired for post analysis.

T type thermocouple is made of copper-constantan material and is suited for measurements in the −200 to 350 °C range and as such offers low cost alternative to SBD sensors. For measuring signal from T type Thermocouple in grounded configuration, custom signal conditioning circuits were developed and interfaced with the data acquisition system. The temperature signals from T type TC were deduced by a 9th order polynomial linearization in LabView. The signals were digitized using a PLC platform and integrated to LabVIEW with OPC (OLE for Process control) server. SBD sensors were interfaced using lakeshore monitor for conditioning and acquisition. At the presentation layer of the system both these senor types were read and integrated using LabView based software. In total 16 sensors are parts of the experimental system. Continuous acquisition was done for durations up to 8 hrs of experimental duration on daily basis.

In this paper we present the overall scheme used for sensor interfacing with the data acquisition system and methodology for measuring the temperature signals for cryogenic temperature ranges.

383/NF-85/P

DEVELOPMENT OF WATER COOLING DISTRIBUTION SYSTEM FOR ITER-INDIA GYROTRON TEST FACILITY

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Abstract

ITER-India, the Indian domestic agency for ITER has the responsibility to supply 2 high power Gyrotron RF Sources (1MW, 170GHz, 3600sec) for Electron Cyclotron Heating & Current Drive (EC H&CD) system on ITER [1]. To facilitate the integrated system testing of Mega Watt class Gyrotron RF sources, ITER-India is developing a Gyrotron Test Facility (IIGTF). As these Gyrotron RF sources would be operating at high power and long pulse, there will be significant thermal heat loads across various components of the Gyrotron system, which needs to be removed by means of active cooling. The water cooling distribution system for this test facility has been designed to provide and maintain necessary flow rates, temperature, pressure and quality of water as per the Gyrotron source requirements. The water cooling distribution system for this test facility is designed in such a way that it can accommodate the design specific cooling requirements of the different Gyrotron manufacturers.

Currently, single Gyrotron operation scenario is considered in the IIGTF, which requires ~2700 LPM of water at inlet pressure of 6 Bar through 22 cooling circuits to extract 2.5 MW of thermal load in the system. As the number of independent cooling circuits are more and their respective requirements are different, the components are grouped according to their pressure drop and flow rate specifications. Additionally, two booster pumps are considered in 2 groups to cater to the pressure drop requirements. Since most of the components of Gyrotron System are rated for low pressure, additional Pressure Reducing Valves (PRV) are considered in respective groups that can meet the required flow parameters of individual components. The design has also been verified with a flow analysis to ensure the flow balance at the rated specifications.

Based on this design, development of water cooling system has been initiated through local industry and the fabrication is ongoing. During project execution, necessary design changes, aspects related to quality control have been implemented. This paper presents system overview, requirements, design concept, design changes, test plan and status in detail.

References:

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385/NF-86/P

PHASE FORMATION OF ER_2O_3 COATING IN REACTIVE SPUTTER DEPOSITION AND ITS EFFECTS

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Abstract

One of the most promising hydrogen isotope barrier and electrical insulation coatings for the applications in some sub-systems of nuclear fusion research reactor designs is that of Er_2O_3 (erbia). Considering harsh environment of such reactor, structural and microstructural stability of such coatings in large range of temperature is vital. The polymorphs of erbia are reported in cubic, monoclinic and hexagonal phases depending on the formation temperature and pressure. Cubic is the most stable phase among these as it remains cubic with temperature up to 2327 C. Hence, with an objective of obtaining cubic phase coating, it is important to study the evolution of structural phases under the adopted deposition process.

Systematic erbia deposition experiments are performed through magnetron sputtering of erbium by argon plasma in presence of controlled oxygen, commonly known as reactive sputter coating process. The structural phases and microstructure of the deposited films are studied using X-Ray Diffraction (XRD), Grazing Incidence Diffraction (GID), Scanning Electron Microscope (SEM) and Atomic Force Microscope (AFM). The variation in these properties is correlated with the variation in process parameters such as, temperature, oxygen proportion, post annealing, buffer metallic layer deposition, etc. This helps in deriving important understanding on evolution of cubic and monoclinic phases and their effect on microstructure and intactness of coating. The electrical resistivity of the coatings is also studied in conjunction with the phase formation pattern. The details of the same will be presented in this paper.

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390/NF-87/P

DESIGN AND DEVELOPMENT OF PROTOTYPE RF POWER MEASUREMENT SYSTEM USING 8X1 RF MULTIPLEXER SWITCH AND ANALOG DE-MULTIPLEXER

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Abstract

A 3.7GHz, 2MW, CW high power lower hybrid current drive (LHCD) system [1] is employed to drive and sustain plasma current in a super-conducting steady-state tokamak (SST-1) [2]. To cater this task, RF power from four 3.7GHz, 500kW klystrons, is divided and fed to the SST-1 with 64 waveguides and grill antenna. Forward and reflected power in each such waveguide is measured with dual directional coupler and Schottky detector diode. Alike every semiconductor devices, no such two Schottky diodes have exactly identical I-V characteristics. Thus, even if there is equal amount of RF power in each waveguide, one will be having different detector outputs. This causes absolute as well as relative measurement error. Initially, the prototype is designed for an 8 channels power measurement. Later it will be expanded to 128 channels.

If we can use single Schottky diode to measure power from the multiple waveguides, relative measurement error can be reduced. To achieve this, RF power from 8 different waveguides is fed to the 8x1 multiplexer switch. Each channel is switched for predefined 125 micro-seconds to get time-division multiplexed (TDM) RF output. This TDM RF output is then fed to Schottky detector to get TDM analog output signal. The TDM analog signal is then de-multiplexed using analog switch to get individual analog output for each corresponding RF input channel.

Prototype RF power measurement system using 8x1 RF multiplexer switch and analog de-multiplexer is successfully designed and tested. Designing of prototype and test results is discussed in this paper.

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392/NF-88/P

AN ANALYSIS OF CONTROL SCHEME AND TEST RESULTS OF FAST FEEDBACK POWER SUPPLY

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Abstract

Real time Plasma Position Control is an essential for obtaining long duration plasma in tokamaks. For that purpose four external coils has been installed in toroidal direction. Magnetic field of these coils interact with the plasma and tries to keep it radially stable in vacuum vessel to avoid direct contact of plasma to wall of tokamak. A fast feedback power supply has been installed in Aditya Tokamakwhich is able to set the appropriate current in either direction and current magnitude in external coils on the fast scale.

In this paper, an analysis of control scheme and testing of Fast Feedback Power Supply (FFPS) has been described. FFPS is IGBT based H-bridge inverter programmable power supply. It has Digital Signal Processor (DSP) based controller which take care of real time plasma position error signal. With the help of magnetic probe diagnostics actual position of plasma can be obtained. Deviation of actual position from the desired position refers as the position error signal. Position error signal can be either in current or in voltage signal. By using the position error signal and the predefined reference signal, processor of FFPS generate an appropriate PWM signals for the IGBTs. According to switching of IGBTs, current generated in four external coils which shifts the plasma position in radial directions to minimize the position error. It has feature of settable gain for the input signal and settable time duration for the output current.FFPS can generate bi-directional current up to 2000A at 250V. It has been observed that FFPS respond reliably up to 200 Hz input signal.

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393/NF-89/P

DESIGN OF DC POWER SUPPLY FOR SOLID STATE POWER AMPLIFIER

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Abstract

ITER-India is developing Solid State Power Amplifier (SSPA) of 12 kW in the frequency range 35 MHz- 65 MHz. The design comprises of multiple RF amplifier modules with each module capable of delivering 1800 W power output. Low Voltage High Current DC Power Supply is required to bias amplifier modules.

Nominal Rating of DC Power Supply is derived to be 65 V and 320 A. Twelve pulse parallel rectifier followed by buck converter topology is selected. Design is modular and numbers of modules are optimized to minimize losses and voltage drop. MOSFET switch will be used at 100 kHz so as to lower the filter requirement hence compact modules and lower ripple in the output voltage. Thermal analysis has been carried out to select suitable heat sinks for rectifier and chopper section. Calculation of system efficiency has been done to compare conventional buck and synchronous buck converter.

This paper describes about the Power Supply requirement, protection system & interlocks and design & simulation of proposed topology.

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395/NF-90/P

PROCESS DESIGN OF CRYOGENIC DISTILLATION COLUMN FOR HYDROGEN ISOTOPE SEPARATION SYSTEM

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Abstract

Hydrogen Isotope Separation is one of the key processes in the fuel cycle loop of a fusion reactor. Cryogenic distillation is a promising method for a hydrogen Isotope Separation System (ISS) and will be used in ITER too. ISS separates different hydrogen isotopologues, from which Deuterium and Tritium are used for fuelling the fusion reactor.

The pure form of each isotope can be separated and recovered in a cryogenic distillation column cascade.This distillation exploits different boiling points of the hydrogen isotopologues (ranging in the cryogenic temperature20 to 25 K). Distillation processes are based on the relative volatility notion, which is a comparative measure of the vapour pressure of the components within a mixture. In most of the cases, distillation is carried out in a tray column or in a packed column. Tray columns are preferred for high ratios of liquid flow rate to vapour flow rate. However, packed columns are a practical solution in several situations, like, low pressure drop separation, handling of corrosive chemicals, or in the case of small column diameter.

In this work, an equilibrium-based dynamic model has been presented for binary mixture of hydrogen and deuterium.Design of the packed column for binary componentsincludes selection of appropriate column and determining number of stages at different reflux ratio, column sizing, condenser and reboiler heat load for specific reflux ratio for known feed compositions.

397/NF-91/P

CONCEPTUAL DESIGN OF TRITIUM ACCOUNTANCY SYSTEM FOR LLCB TBM

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Abstract

Lead Lithium Ceramic Breeder (LLCB) Test Blanket Module(TBM) will be tested in ITER for performance evaluation of high grade of heat extraction and tritium breeding. The bred tritium in the breeder materials is extracted and recovered by Tritium Extraction System (TES), whereas tritium permeated from breeder materials to helium coolants, viz.,primary coolant and secondary coolant, is recovered by Coolant Purification System (CPS). This recovered tritium has to be accounted before transferring it to tritium plant (i.e., ITER inner fuel). This tritium accountancy is performed by Tritium Accountancy System (TAS). In addition to tritium accountancy, TAS also provides necessary data for the validation of design and modelling tools.In this work, we have presented conceptual design of TAS. It also describesoperational philosophy, process parameters, process flow diagram, and interface details with ITER tritium plant.

399/NF-92/P

CONCEPTUAL DESIGN OF ADITYA-UPGRADE BAKING CONTROL SYSTEM

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Abstract

ADITYA tokamak has been upgraded in the diverter configured ADITYA-U tokamak. The ADITYA upgrade vacuum vessel consists of two electrically isolated semi torus. The vacuum vessel baking is one the effective method for removing water, volatile hydrocarbons and hydrogen from vessel walls. The vessel needs to be baked at various temperatures in controlled manner. The baking system consists of fifty heaters for different sectors of the vacuum vessel. The heaters shall be controlled in close loop comprising of temperature ramp-up from room temperature, maintaining constant heating temperature (~ 150°C) and ramp- down to room temperature phase.

Baking control system has been there in manual, semi automatic forms for long time in Aditya Tokamak. Main requirements during Aditya Upgrade are: the system must be automatic, integrated, rugged, reliable, small form factor and cost effective. The automatic control is elaborated as fully automatic requiring operator to set the baking temperature only, rest of the parameters (viz. ramp up time, steady baking time and ramp down time, intermediate temperature set points) are calculated and implemented by the system. The rugged & reliability demand the system must be available in operation throughout Aditya operation phase requiring minimalistic maintenance. Baking system using normal auto transformer and individual stand alone PID controllers make system large in size and disintegrated requiring tedious wiring loops, setting individual set points.

A PLC is chosen for its inherent reliability and requirement of continuous operation of the Aditya Baking control system. A SCADA shall be developed using National Instrument (NI) Lab VIEW for operator interface, trending and system alarms. The detailed hardware concept, software design and prototype testing results will be discussed in the paper.

400/NF-93/P

3D EDDY CURRENT ANALYSIS IN SST-1 START-UP USING FINITE ELEMENT METHOD

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Abstract

During the plasma startup phase, high eddy currents induced in the surrounding structure generate error fields that can disturb the plasma formation in tokamaks [1,2,3,4] and hence it necessitates a detailed analysis. This paper describes the numerical calculation of eddy currents that circulate in the vacuum vessel and cryostat structure and their effect on the magnetic null in SST-1 tokamak using 3-dimensional finite element model. A commercial software *ComsolMultiphysics* [5] is used for this purpose. The analysis show that the induced eddy current generates high error fields which are not negligible and necessities correction. Fairly good matching is observed when simulated loop voltages are compared with that of experimental measurements. The analysis suggests that a precise study of eddy currents is necessary for designing any superconducting tokamak. Also, with this work, it is shown and suggested that the magnetic null distortion due to high eddy currents can be compensated using radial coils inside the vacuum vessel with appropriate current.

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402/NF-94/P

UP GRADATION OF VME BASED DATA ACQUISITION FOR SST-1 SUPERCONDUCTING MAGNETS

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Abstract

SST-1 magnet system consists of sixteen Toroidal Field (TF) coils and nine Poloidal Field (PF) superconducting coils along with a pair of vertical field coils and air core ohmic transformer. These magnets are instrumented with various cryogenic compatible sensors and voltage taps for its monitoring, operation, protection, and control during different machine operational scenarios like cryogenic cool down, current charging cycles including ramp up, flat top, plasma breakdown, dumping/ramp down and warm up. A VME hardware based data acquisition system has been developed for data monitoring, acquisition and control of magnet operation. A java platform based client and server utility has been developed for this data acquisition system. Upgradation of this java software utility has been carried out with enhance features, fast operating performance and new tools additions. Upgradation features are includes larger data file sizes, highlights of critical data indicators, new file generation, online mass flow calculations etc. This poster describes basis hardware details, Upgradation of previous software utility, testing and troubleshooting during software development.

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404/NF-95/P

UPGRADATION AND TESTING OF SIGNAL CONDITIONING ELECTRONICS FOR SST-1 MAGNETS

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Abstract

The magnet system of the SST-1 tokamak at the Institute for Plasma Research, Gandhinagar, India, consists of sixteen Toroidal field and nine poloidal field Superconducting coils together with a pair of resistive PF coils, an air core ohmic transformer and a pair of vertical field coils for its various magnetic field requirements. Various cryogenic compatible sensors and voltage taps are installed in those magnets for its monitoring, operation, protection, and control during different machine operational scenarios like cryogenic cool down, Magnet current charging cycles including ramp up, flat top, plasma breakdown, dumping/ramp down and Cryogenic warm up.

The signal conditioning electronics has been developed under in-house program to cater the need of various cryogenic compatible sensors and voltage taps installed on magnets and design carry all the necessary measures to counter various EMI/RFI interference and measure low amplitude signal in high common mode electromagnetic voltage pickup environment. One or more modification in card can serve for signal conditioning of different sensors for temperature, displacement and Hall probes. It uses inbuilt excitation (current/voltage) module for catering different sensors' excitation needs. Review and modification was carried out in excitation modules to counter errors in temperature at RT condition which is dominated by excitation errors. Further testing for offset and excitation in cards were carried out to quantify the errors due to earlier mentioned factors. This poster gives overview of the Magnet signal conditioning Electronics hardware, testing of signal conditioning electronics with VME based Data Acquisition hardware and the measures taken to counter combined errors due to Electronics and VME hardware after long time running experience in SST-1 cryogenic cool down campaigns.

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405/NF-96/P

PROTOTYPE DEVELOPMENT OF LIP SEAL BY LASER BEAM WELDING

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Abstract

Lip Seals are used for high vacuum sealing purpose in vacuum vessel and other mechanical component & devices; and becomes more promising for the systems which has the requirement of regular maintenance. Laser Welding has been considered for the lip seal welding, considering the attributes of laser welding like; small spot diameter, low concentrated heat input and high precision. Initiated with the finalization of welding parameter optimization and the parametric study to understand the effect of welding set-up variables (like air gap, plate and beam misalignment) on the weld quality, and which defines the limits/tolerances for the set-up variables. With the requirement of set-up variables, a clamping tool was designed, fabricated and tested in coordination with the robotic arm mounted on the laser welding head to get the required weld with the penetration of 3mm and the acceptable weld quality. Taking this welding set-up (clamping tool with robotic laser welding head), welding of scaled size (3m*1.5m) of DNB Vessel rectangular configuration lip seal and actual size (1m length and 1.2 m diameter) of High voltage bushing elliptical configuration lip seal was demonstrated. Destructive and non-destructive examination was done to qualify the weld joints. Helium leak test of the lip seal joints has also carried out to ascertain the tightness of the welds, and achieved the leak rate in the range of E-10 Pa.m3/sec.

The paper presents the methodology adopted for the welding demonstration of the large size lip seals of non-circular configurations. The paper shall cover the developmental experience in terms of practical/experimental problems encountered and their resolution during welding. Sample preparation and performance of testing and qualification study conducted for the weld joints. It shall also present the design development of the clamping tool, which includes different concepts, boundary conditions and their analysis results.

410/NF-97/P

QUENCH DETECTION ELECTRONICS TESTING PROTOCOL FOR SST-1 MAGNETS

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Abstract

Quench Detection (QD) system consisting 204 signal channels has been successfully installed and working well during plasma experiment of SST-1 Tokamak. QD system requires testing, validation and maintenance in every SST-1 campaign for batter reliability and maintainability of the system. Standalone test of each channel of the system is essential for hard-ware validation. The standard Testing Protocol follow in every campaign which validate each section of QD electronics as well as voltage tap signal cables which are routed inside the cryostat and then extended outside of the SST-1 machine up-to the magnet control room. Fiber link for Quench signal transmission to the SST-1 magnet power supply is also test and validate before every plasma campaign. Precise instrument used as a dummy source of quench signal and for manual quench generation to test the each channel and Master Quench Logic. Each signal Integrated with the magnet DAQ system, signal observed at 1Hz and 50Hz configuration to validate the logging data, compare with actual and previous test data.

This paper describes the testing protocol follow in every campaign to validate functionality of QD electronics, limitation of testing, test results and overall integration of the quench detection system for SST-1 magnet.

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411/NF-98/P

DEVELOPMENT OF FLEXIBLE 12 INCH BELLOW TYPE TRANSMISSION LINE

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Abstract

India has developed 1.5MW test bed to test RF amplifier, 12 inch Transmission line components, Gas Barrier and Dummy load. A number of high power transmission line components are required for connecting various stages of RF source. 12 inch transmission line components are part of the end stage of the RF source where two RF chains 1.5MW/CW/3600sec will be combined to get an output power of 2.5 MW at VSWR 2:1 and 3.0MW at VSWR 1.5:1. The installation of 12 inch coaxial transmission lines between amplifier and dummy load as per layout is difficult due to the standard fabrication length of these transmission lines. To bridge the gap in order of 10-30 mm in horizontal and vertical direction during installation, flexible 12 inch coaxial transmission line is required.

To achieve this flexibility, we have developed bellow type 12 inch coaxial transmission line. It consists of mainly a bellow, an outer Aluminum conductor, an inner ETP copper conductor, slotted inner conductor joint, double layer of finger contacts and Teflon support disk. This double plied bellow is made up of SS-304 and has ply thickness as 0.50 mm, no. of convolution as 7 and pitch of convolution as 22mm. The bellow will hold air pressurization inside the flexible transmission line at MW level RF power.

This paper provides the design & simulation, fabrication, assembly, installation and commissioning of the 12 inch bellow type transmission line along with RF test results at 1.7 MW for 3600 seconds duration.

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415/NF-99/P

DEVELOPMENT OF FIELD SIMULATOR TO TEST & QUALIFY THE GYROTRON LOCAL CONTROL UNIT FOR ITER-INDIA GYROTRON TEST FACILITY

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Abstract

High power RF sources such as a Gyrotron system are operated at required output parameter by using various auxiliary power supplies, High voltage power supplies, auxiliary services and a dedicated Local Control Unit (LCU) [1]. These sub-systems must be operated in synchronous and safe way to control the gyrotron output parameters. The LCU performs remote, synchronous and safe operation of the all the gyrotron sub-systems. Broadly the LCU functions are operational control, data acquisition, protection and safety of the gyrotron system. At ITER-India gyrotron Test Facility (IIGTF) a local control unit (LCU) is being developed to operate the complete gyrotron system [2]. The major functions of the LCU are implemented by developing required logic on COTS Controller (PLC &PXIe system). A LabVIEW based graphical user interface (GUI) is developed facilitating the operator to set the parameters of the controller and which finally operate the complete system. For some of the critical & fast protection function a FPGA based hardwired system will be used. Since the operating environment is very harsh, a signal conditioning unit (E/O and O/E convertor) will be used for interfacing field signals to LCU.

Considering the above design and operation aspects, it is very important to perform integrated testing & qualification of the LCU components, before using it for the actual gyrotron operation. This will also improve the reliability and safety of overall system. As various gyrotron sub-systems are under development & procurement phase at IIGTF, a gyrotron field simulator is under development that will perform the role of gyrotron field sub-systems and can be considered as test bench to qualify the LCU functionality. Most of the auxiliary power supplies have serial interface for control, and hardwire interface for monitoring and protection, while H.V.P.S has a dedicated hardwire interface with LCU. To simulate the behavior of the auxiliary power supplies having serial interface, an 8-port USB-Serial convertor module is procured. The module will be programmed to simulate the power supplies signals, and will be used to test the sequential & interface logic with LCU. The H.V.P.S signals will be simulated using Real time PXIe controller. Also the glue logic developed in PXIe-FPGA module for fast control and interlock functions will be tested using field simulator. A LabVIEW based GUI will be designed to operate the field simulator. The LCU components will be arranged in cubical as per final configuration, while the field

simulator hardware will be arranged in another cubical that will be replaced with actual sub-system during the gyrotron operation.

This paper presents the design, development and various features of the field simulator. It also discuss LCU functionality test cases & results obtained using field simulator

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423/NF-100/P

SOFTWARE DEVELOPMENT FOR NB ION SOURCE POWER SUPPIES OPERATION USING PXI SYSTEM

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Abstract

A Neutral Beam Injector (NBI) is leading heating system for SST-1 Tokamak. It is designed to inject 1.7MW power to tokamak plasma. To generate this beam power, various power supplies are utilized for the plasma generation and NBI operation. Here, filament based ion source is powered by heater power supplies to heat the filaments, discharge power supplies for the plasma generation and Regulated High Voltage Power Supply (RHVPS) for the beam extraction. Filament and discharge power supplies are floated at acceleration voltage (~55kV). It is essential to operate these power supplies smoothly in noisy environment.

This paper describes the software development activity for the smooth and reliable operation of various NB ion source power supplies. This software is developed in LabVIEW which works on a PXI based hardware platform. This newly developed advanced system can be an ideal replacement for an existing VME based control system, by which a better and efficient operation with better supports will be achieved.

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431/NF-101/P

HELIUM LEAK TESTING OF BASE SECTION FACTORY WELD JOINTS FOR ITER CRYOSTAT

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Abstract

ITER Cryostat is a large stainless steel vessel providing vacuum environment to ITER Machine components.It weighs ~ 3500 t and measures up to ~29 meters in diameter and ~29 meters in height. For the entire vessel, material of construction is Dual marked SS 304/304L and thickness varies from 25 to 190 mm. Cryostat consist No. of subassemblies, cutouts, penetrations due to road transportation constraints at ITER site and various interfacing component. This results in large number of weld joints to join these subassemblies to fabricate the subassemblies.

The Design, manufacturing, inspection and NDE of the cryostat is being carried out as per ASME Section VIII Division 2 with supplementary requirement of ITER Vacuum Handbook. Cryostat is VQC (Vacuum Quality Class) 2 Component, therefore, in addition to the NDE as per ASME Section VIII Div 2, Helium Leak testing is mandatory to ensure the leak Tightness as per Vacuum Handbook. Acceptance Criteria of Leakage rate is 1X 10^{-9} Pa/m^3/s for each Vacuum Boundary Weld Joints.

The main challenge is to test the weld joints in Vacuum mode because of the critical leakage rate acceptance criteria. Vacuum mode needs confined space for creating vacuum for the test. Hence, in order to create the confined space for individual joints, customized vacuum cups have been developed. Cryostat consist weld joints having various type of geometrical configurations, vacuum cups of different types were developed to suit the weld profile, its geometry and accessibility. All vacuum cups were validated on Mockup weld joints prior to implementation on actual weld joints. ~550 m of Base Section Weld joints were Helium Leak Tested with the various Types of Cups and found satisfactory.

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[2] ITER Vacuum Handbook RDB1_05, V 2.3
[3] EN13185

436/NF-102/P

DEVELOPMENT OF OUTGASSING TESTING FACILITY FOR ITER CRYOSTAT MATERIALS

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Abstract

The Cryostat is a cylindrical vacuum vessel of ~29m diameter, ~29 m height and 50mm thickness and weights ~3200 Tons. The material of Cryostat is dual marked stainless steel 304/304L. ITER vacuum handbook asks for outgassing requirement for Cryostat materials.

For maintaining high vacuum environments, outgassing plays an important role. Outgassing is a surface phenomenon which directly proportionate to extent of cleanliness, surface roughness and temperature of material. For most solid materials, the method of manufacturing and preparation can reduce the level of outgassing significantly.

There are various established methods for the measurement of out-gassing rate in Laboratories. In Cryostat, **Dynamic Flow Method** has been used. In this method coupon is pumped through a known conductance and the pressure difference across this conductance is measured.

Various manufacturing processes shall be involved in the fabrication of Cryostat. Outgassing tests has been performed on represented coupons that was subject to the same manufacturingprocesses as used for the Cryostat and has been performed at room temperature.

A testing facility has been developed for outgassing testing. Total 9 coupons of plate and figgings materials with different combinations for manufacturing process were tested and found satisfactory.

For Cryostat, maximum steady state outgassing rate (for all impurities except water and hydrogen) measured at 20^{o} C shall be < $\mathbf{10^{-7} Pa.m^{3}s^{-1}m^{-2}}$. Study on measurement of out-gassing of Cryostat surface has been done and process has established

Reference:

1. ITER Vacuum Handbook: Appendix 17
2. Mandatory Appendix : CON-II-CR-APB1_06 – Vacuum Requirements, Surface Treatment And Baking

437/NF-103/P

ACCELERATED JOINING PROCESS FOR PFC COUPON MATERIALS IN GLEEBLE 3800 SYSTEM

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Abstract

The accelerated joining process is an interesting technique for the joining of similar or dissimilar materials in fusion research. This technique has also been adopted in the fabrication of the Plasma facing component [1-2]. Joining of Plasma Facing materials (PFMs) with the heat sink (CuCrZr) and structural materials (SS316L) is generally performed by the suitable joining techniques such as vacuum brazing, welding or diffusion bonding approach.

In this paper, we adopted the accelerated joining techniques such as vacuum brazing and diffusion bonding for the development the joining of the Plasma Facing component (PFC). Joining of tungsten material to Steel have been prepared using vacuum brazing and diffusion bonding using suitable filler material in Gleeble 3800 system. Samples were undergone for ultrasonic test to check the quality of the joints. Metallography studies of the joints have also been conducted. To assess the life of the joints, the thermal cyclic test has been performed on the selected samples. The experimental methodology and characterization results will be presented in the paper.

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441/NF-104/P

THERMAL ANALYSES OF CONDUCTION COOLED AND SOLID NITROGEN COOLED NB_3SN MAGNET

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Abstract

Thermal analyses of a laboratory scale Nb_3Sn magnet is carried out using FEA software in conduction cooling and solid nitrogen cooling mode. A pulse tube cryo-cooler of capacity 1 W at 4K was employed as cooling source to the coil. The coil is composed of insulated Nb_3Sn strand (Bronze route) of 1.2 mm diameter. The strand is wound over a copper mandrel which is thermally anchored to the second stage of the cold head unit of the cryo-cooler via a copper plate of 10 mm thickness. Cryo-compatible cyanate ester resin was used for impregnation of the coil. Symmetric boundary condition is used for the analyses. In the present work, the axial and radial temperature distribution of the coil winding pack are carried out considering both steady state heat load (conduction, residual gas conduction and radiation) and dynamic Joule heat load. The temperature distribution across the coil winding pack for conduction cooling and solid nitrogen cooling is compared

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452/NF-105/P

TEST SETUP FOR PRESSURE DROP AND FLOW MEASUREMENT FOR CABLE IN CONDUIT CONDUCTOR

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Abstract

Stable operations of superconducting magnets depend critically on the balance of heat deposition rate versus heat extraction rate by the cryo-coolant. Thus, the mass flow rate of the coolant in case of force-flow cooled superconducting magnet with Cable-In-Conduit-Conductor (CICC) construction becomes an important factor for the optimum stability of such magnets. The data of flow and pressure drop characteristic are critical parameters to determine the heat load in superconducting magnets and their operations. A test set-up has been developed and established to measure the pressure drop, flow and discharge coefficient for CICCs, transfer lines etc. This paper presents principal components used to develop test setup including its instrumentation. This test setup is installed and validated with 1 meter length superconducting CICC.

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455/NF-106/P

UPDATES OF MAGNET SYSTEM DIVISION ACTIVITIES AT IPR

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Abstract

Magnet system has initiated various activities for new development as well as maintenance and operation of existing systems. SST-1 related activities consist of thermal hydraulic study of superconducting TF and PF coils at RT, 200 K, 100 K and 80 K. Superconductivity of PF coils, Operation of TF coils at 1.5 T and error field measurements at RT and at low temperature. Technological initiative comprises of various conductor fabrication, heat treatment of Nb_3Sn strands, sub cables and development of high temperature superconducting cables for future Tokamaks. Laboratory level validation tests on Low Tc and high Tc superconductors have also been initiated. Achievements of magnet systems in last few months will be presented in this paper.

464/NF-107/P

EXPERIMENTAL AND SIMULATION STUDY ON FILLING MECHANISM OF LI_2TIO_3 PEBBLE FOR LLCB TBM

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Abstract

India is developing lead lithium ceramic breeder (LLCB) test blanket module (TBM) for fusion blanket design to absorb the energy from the fusion neutrons produced by plasma, tritium breeding performance. It consists of different ancillary systems, such as cooling purification system (CPS), Lead-Lithium Cooling System (LLCS), First Wall Cooling Systems (FWCS) and Tritium Extraction System (TES). Breeder in fusion blankets are sintered block and pebble bed. Due to some uncertainty and lack of accurate prediction of thermal conductance, the pebble bed has been used as the tritium breeders and neutron multipliers. The Ceramic Breeder (CB) consists of lithium titanate (Li_2TiO_3) in the form of packed pebble bed and lead lithium (PbLi) eutectic as multiplier, breeder and coolant. The tritium produced in CB zones extracted by low-pressure purge gas helium. In order to extract tritium produced in CB zones,a good packing density of Li_2TiO_3pebbles is require in pebble bed. So an efficient packing mechanism is required for the filling the Li_2TiO_3 in CB zones by restricting the vibration and pouring by some inclination.The experiment was conducted initially with a mock-up of (100×20×100) mm with an unimodal pebble size of 1 mm diameter.To implement the collision physics of granular media into computer codes we employed molecular dynamics simulations for simplification of granular cluster. As we have considered the grains as spherical pebbles, particular elastic and adhesion forces and the various friction forces are included. We implemented our algorithm in LIGGGHTS (LAMMPS improved for general granular and granular heat transfer simulations) which are latter discussed

465/NF-108/P

MANUFACTURING ASPECTS FOR LONG LENGTH SUPERCONDUCTING CABLE IN CONDUIT CONDUCTORS

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Abstract

Magnet System Division (MSD) is engaged in development of various manufacturing technology critical for fabrication of fusion relevant superconducting magnets using a cable-in-conduit-conductor (CICC). The manufacturing of CICC involves twisting of superconducting strands in required cabling configuration which is then inserted into jacket material for further shaping and sizing operation. The critical manufacturing parameters in each stage such as cabling, insertion, sizing and testing during fabrication of long length CICC is discussed in this paper. The effect on manufacturing methodology due to various design parameters to be achieved for sound performance of CICC during their operation is discussed in this paper. The typical test plan for quality assurance during manufacturing of long CICCs is presented with emphasis on operating requirement (vacuum and cryogenic) of superconducting CICC. Finally, the lesson learned during indigenous manufacturing of long length NbTiand Nb_3Sn based CICC at MSD as well as worldwide experiences gained in ongoing activities for CICC development is summarized in this paper.

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468/NF-109/P

DEVELOPMENT OF INSULATION SYSTEMS FOR VARIOUS MAGNETS AT MAGNET SYSTEM DIVISION

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Abstract

Magnet Systems Division (MSD) at Institute for Plasma Research, is engaged in the development of appropriate insulation system for various types of magnets considering their design requirements such as superconducting magnets and high temperature resistive magnet. The development of these insulation systems involves basic kinetic studies of resin system for the formulation of proper curing time, optimization of vacuum pressure impregnation process as well as electrical characterization and mechanical characterization. MSD has various facilities for the basic study of curing kinetics and rheological behavior of resin system like Differential Scanning Calorimeter (DSC), Thermogravimetric Analyzer (TGA), Dynamic Mechanical Analyzer (DMA) and Brookfield viscometer. Cayante ester based insulation system has been developed for high temperature application coil operating up to high temperature (~350^{0}C) as well as for cryogenic temperature application like superconducting coils operating at -269^{0}C. Both resins are cayante ester based but they have different properties like viscosity, curing temperature etc. The activation energy for both high temperature (Make - PT-30 Lonza) and low temperature (Make - AroCy L-10 Huntsman) cyanate ester based resins has been evaluated with DSC. It is found to be 67.13 KJ/mol and 64.26 KJ/mol respectively using Kissinger method. The glass transition temperature of cured resin for both types of cayante ester was determined with DMA as~393^{0}C and~260^{0}C. Both Insulations system have been characterized for their electrical and mechanical properties at room temperature as well as at their application temperature. This paper elaborates methodology for sample preparation, vacuum impregnation process for of lab scale samples, test procedures followed for mechanical and electrical characterization and their results.

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470/NF-110/P

INVESTIGATION OF THERMAL PERFORMANCES OF VARIOUS CRYOSTATS FOR LOW TEMPERATURE EXPERIMENTS

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Abstract

Magnet System Division (MSD) has multiple cryostats for the test of superconducting material and magnet at various magnetic fields and temperatures. The cryostat design and thermal load estimation are essential to estimate the use of cryogen liquids and performance of cryostat for long duration operation and testing of superconducting materials. To improve the performance of cryostats, estimation of thermal loads and proposal for modification in the existing cryostats,finite element analysis is carried out to analyze them using commercially available software such as ANSYS. The simulations approach has been adopted with the appropriate material models to minimize the trials and to investigate the effect of various operating parameters for the optimization of the thermal performance of various cryostats. Basic analytical calculations have been performed to calculate the total heat load and liquid helium consumption (LHe) in the cryostat. Optimization of the thermal performance of two types of cryostats i.e. cryostat for gyrotron cavity magnet and cryostat for testing of superconducting strands / sample in self-field has been performed by considering 'conduction path length' as a critical parameter with the help of FEA and analytical results. To estimate the LHe consumption in the gyrotron cryostat, sixteen different cases have been investigated by considering four different temperatures of top plate of Inner Vacuum Chamber (IVC) i.e 70 K, 77 K, 80 K, 85 K and four different conduction path lengths On the basis of the analytical results, FEA of proposed model of cryostat for gyrotron cavity magnet has been carried out with appropriate mesh sensitive analysis. Similarly, optimization of thermal performance of Self-field cryostat has been carried out by optimizing numbers of baffles and their positions in LHe chamber to optimize the convection and radiation heat load.

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476/NF-111/P

DESIGN OF TEST KITS FOR THE RF CHARACTERIZATION OF THE PAM ANTENNA OF LHCD SYSTEM FOR ADITYA-UPGRADE TOKAMAK

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Abstract

The Lower Hybrid Current Drive (LHCD) system [1] of the ADITYA- Upgrade tokamak will employ a Passive Active Multijunction (PAM) antenna [2] [3] to launch 250 kW of RF power at 3.7 GHz to drive plasma current non inductively in the tokamak. To evaluate the RF performance of the designed PAM antenna, it is characterized with the help of VNA measurements. The performance of the PAM antenna is mainly decided by the integrated performance of the entire antenna (with a differential phase shift of 270^{o} and equal power distribution between each of the output waveguides) and the performance of mode convertor, which transforms input TE_{10} mode to TE_{30} mode (with a mode purity of 98.5% at the output).

The input of PAM antenna is fed by standard WR 284 rectangular waveguide and the same can be connected to VNA through waveguide to co-ax adapter. However, the output of the PAM antenna comprises of a 4 x 3 matrix (4 toroidally and 3 poloidally) of non-standard rectangular waveguides each having a cross-section of 76 mm x 12 mm. Also, the output profile of the antenna has a curvature of radius 250 mm in the poloidal direction. This non-planar and non-standard arrangement of the output section makes it difficult to connect the second port of the VNA. To facilitate it, a test kit has been designed to make compatible connections with the complex output profile of the PAM antenna, keeping the criticality and the accuracy of the RF measurements intact. The testing kits involve bends, transformers, loads et cetera to match the impedance of the transmission line. A separate set of bends have been designed along with transitions to standard rectangular WR 284 waveguides for the testing of mode convertors.

This poster thus reports the design and analysis of these testing kits. Also, the test results of PAM antenna obtained by using these test kits would also be presented and discussed in this poster.

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482/NF-112/P

ADSORPTION CHARACTERISTIC OF DIFFERENT TYPES OF CHARCOALS AT CRYOGENIC TEMPERATURE

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Abstract

A comparative study on gas adsorption characteristic of different types of activated carbons such as granules, pellets, cloths and globules is performed by analyzing their adsorption isotherm at Liquid Nitrogen (L-N_2) and liquid Helium (L-He) temperature. The adsorption capacity or the porosity of these carbons are quantified in terms of their BET surface area, pore diameter and pore volume. In experimental results, it has been found that the BET surface area of these material ranges from 800 m^2/gm to 3000 m^2/gm. The pore size distribution of these materials largely peaked at a value < 10 A^o, which clearly indicates microporous characteristics of these activated carbons. Also, it has been observed that the gas retention capacity of these samples is related to their pore volume distribution. From the tested samples, it has been found that the activated carbon cloth has the higher adsorption capacity in comparison to other samples.

The adsorption analysis is performed by using the adsorption test facility (ATF) established at IPR. It consists of a standard micropore analyzer and a GM cryocooler based extended cooling unit for sample testing at L-N_2 and L-Hetemperature, respectively. This study is aimed at selecting a right activated carbon for the cryo adsorption cryopump development program and other industrial applications. A detailed adsorption study of these samples will be presented.

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491/NF-113/P

DEVELOPMENT OF COBALT FERRITE FOR HIGH FREQUENCY MICROWAVE CIRCULATORS

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Abstract

Cobalt ferrite possess a high saturation magnetization and therefore is a promising candidate for magnetic recording devices, Microwave circulator etc. In current report, we prepare cobalt ferrite by sol-gel auto combustion technique, and graphene oxide by hummer's modified method. We use ultra-sonication method for synthesis of nanocomposite. XRD analysis of cobalt ferrite show the phases corresponding to the reported values of cobalt ferrite and the crystallite size is below 100 nm. UV Visible analysis shows that the band gap decreases with calcination temperature and a large decrease in band gap is observed in cobalt ferrite graphene oxide nanocomposite studies the optical property of cobalt ferrite and graphene oxide. Vibrating Sample Magnetometer show the saturation magnetization of cobalt ferrite to be 46.95 emu/gram.
The electrical properties of the sample is studied by using Hioki 3532-50 LCR HiTESTER.

140/NF-114/P

MODIFICATION IN POTENTIAL WELL OF AN INERTIAL ELECTROSTATIC CONFINEMENT DEVICE

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Abstract

The Inertial Electrostatic Confinement (IEC) is basically a fusion concept where the lighter fuel ions (D, T) are trapped in a converging electrostatic field inside a cylindrical or spherical geometry [1]. A cylindrical IEC device is currently under operation at CPP-IPR. The device houses a cylindrical gridded cathode for confining deuterium ions and thus producing 2.45 MeV neutrons. The neutron production rate from the device depends not only on the ion density in the central core of the gridded cathode but also on the applied potential [2].

Deuterium plasma is produced inside the device by making use of both hot and cold cathode discharges. The plasma characteristics such as electron temperature (kT_e), plasma density (n_i), plasma potential (V_p) and the ion flow velocity were measured using the Langmuir probe, emissive probe, Mach probe and the Optical emission spectroscope (OES). On application of high voltage to the cathode grid the ions produced in the hot cathode discharge were accelerated inside the cathode region and oscillates in the negative potential well formed in between the cathode grid and chamber (anode). We have noticed that the ion oscillates in the fundamental mode of frequency as well as in higher harmonics. The observation of oscillating ions in higher harmonics predicts the modification of potential well structure which in turn affects the ion density profile [3]. Therefore, we have experimentally verified the modification in potential and ion density profiles on application of negative voltage to cathode grid. The detailed results will be presented in the paper.

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133/NF-116/P

ETHERNET BASED PARAMETER SETTING AND CONTROL FOR SOFT XRAY ELECTRONICS

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Abstract

Various diagnostics are situated on and around the Plasma vessel for the measurement of plasma parameters where signal conditioning of the signals emanating from different types of detectors is required before feeding them to the data acquisition system. The importance of the diagnostics electronics can be underlined from the fact that every diagnostic signal passes through the front-end electronics and the plasma shot operation criticality depends on acquiring of these signals with high level of integrity and reliability. The diagnostic signal varies from shot to shot and differs for different experiment. Sometimes signals are needed to be strengthened and some time they need to be reduced. Signal parameters can be changed manually or remotely. Manual adjustment is always tedious and time consuming. The tokamak environment is complex and hazardous. Remote parameter setting is one of the best solutions. These circumstances inspire us to develop an Ethernet based controller card which will sit with the signal conditioning card and can be accessed remotely from PC connected on LAN. The controller card designed is implemented to set gain, bias and channel shutdown of each Soft X-ray signal conditioning modules.

Soft X-ray is one of the important diagnostic for plasma temperature measurement which is placed on radial port very near to the vessel. The current signals coming from the x-ray detector array are in the range of 10-1000 nA The detector array need 0v to +15v or -15v to 0v bias voltage depending upon common cathode or common anode configuration. There is provision for variable bias on the controller card. Parameters setting are done remotely through virtual instrument, Labview. The poster will present hardware and software design in detail.

112/NF-117/P

APPLICATION OF FUNCTION PARAMETRIZATION FOR RADIAL PLASMA POSITION CALIBRATION IN ADITYA-U

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Abstract

Calibration experiments to simulate the movement of plasma channel in tokamak ADITYA-U in the horizontal direction (i.e., in-board and out-board movement), are carried out by setting up current carrying conductor inside the vacuum vessel. This conductor is energized with a known current (through a capacitor bank system) and the response at various magnetic pickup coils is recorded. For various radial position of this conductor and for known current, the pickup coil response database is generated. Function parameterization method (FP) is utilized to generate an input-output relation (regression function), in which the input is magnetic pickup coil's signal and the output is the location of conductor. In the real situation, conductor is replaced by the plasma channel and hence, the radial movement of this channel would be directly known from the regression function obtained from FP. Detailed analysis of FP along with the error estimates would be presented in this paper.

274/NF-118/P

SOFTWARE DEVELOPMENT ENVIRONMENT FOR CONTROL AND DATA ACQUISITION SYSTEMS

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Abstract

Software Development Environment (SDE) provides an infrastructure which helps in housing various applications of software and maintains their different versions. The SDE also helps in providing collaborative development platform for the software applications. The SDE includes the role-based issues tracking system to report, assign and resolve the various bugs/ technical issues during and after development.

The paper describes understanding of basic terminology of SDE, defining the various requirements targeted for control & data acquisition systems and studies the various features of available open source packages in the market. The paper also summarizes the selected packages, its features, configurations and installation details. The SDE can further be enrichedin future with short/long term backup and restore solution for the software repository and other data.

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338/NF-120/P

DEVELOPMENT, IMPLEMENTATION AND REMOTE OPERATION OF TWIN SOURCE VACUUM SYSTEM THROUGH TS-DACS

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Abstract

Twin Source (TS) experimental setup is a stepping stone towards ITER based Diagnostic Neutral Beam (DNB) source from existing single driver based ROBIN experimental setup in IPR, India. The control system consists of (i) Master control system (S7 400PLC) (ii) Remote I/O (ET200S) for vacuum and cryogenics. Depending upon the need of isolation to avoid ground loop and noise immunity, fiber optics PROFINET communication is used between Master control system and remote I/O station. For the development of control core program, Siemens step 7 tools and for SCADA function(Supervision, Alarm and Archiving) CODAC core system 4.0 is used. For the data acquisition, National Instruments (NI) PXIe system and NI 6259 digitizer cards have been considered. The LabView real time software has been used for real time data acquisition application.

The vacuum system of twin source requires to maintain a base level vacuum of nearly 10-6 mbar inside vacuum chamber prior to operation, which would be obtained by turbo-molecular pumps (TMP) with a pumping capacity of 5000l/s. Currently two nos. of TMP each having a pumping capacity of 2500l/s have been installed in parallel and tested with vacuum vessel. TMPs have been connected to vessel over DN 500 port with a Tee – shaped adapter having ISO 500 F to ISO 320 F transition. Over these two ISO 320F ports the two TMPs are mounted along with Gate valves. TMPs have been operated in REMOTE mode via DACS and several operational safety interlocks were tested. These interlocks essentially prevents TMP to start unless chamber pressure is less than 0.1 mbar and prevents gate valve to open if chamber pressure is more than 2 mbar. There are approximately 45 control and 5 acquisition channels interfaced with TS-DACS of the vacuum subsystem of twin source. All interlocks have been implemented for safety of multiple and simultaneous functioning of TMPs. The remote operation of vacuum system with multiple TMPs has been performed successfully.

This paper discusses in detail about development, successful implementation and remote operation of vacuum system through a twin source data acquisition and control system (TS-DACS.

185/NF-121/P

DESIGN OF A 3.7 GHZ OSCILLATOR FOR THE SOLID STATE DRIVE OF THE LHCD SYSTEM

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Abstract

The LHCD System is commissioned on the SST- 1 tokamak for the current drive. It has a capability to generate power of 2 MW CW at 3.7 GHz and deliver the power to the tokamak via a grill antenna through a phased array of waveguides. The system relies on 4 Klystrons (TH-2103D) each generating 500 kW CW power. The klystrons act as an amplifier providing a gain of 40 dB with a bandwidth of 10 MHz and amplify the input power provided by a solid state driver. The klystron requires a supply of 65 kV and 20A for its operation and has to be extensively conditioned before it can be operated even for obtaining lower power levels.

As such there is a requirement of a compact, low cost source which can give an output of 50W to 1kW at 3.7 GHz with a very narrow bandwidth. This can be achieved by the use of solid state devices (transistors). However the power handling of a solid state device is limited (1 kW). Higher power levels can be achieved by using many such solid state devices in parallel and then combining each of their output power. An effort to build such a modular device through which we can obtain variable output power (50W to 1kW CW) at 3.7 GHz has been initiated.

This paper describes the design of oscillator for such a system. The oscillator is based on bipolar junction transistor BFR360F. Linear and non-linear analysis has been performed on the design to ascertain its performance. The oscillator delivered a power of 20 mW at 3.7 GHz.

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368/NF-122/P

DESIGN OF TEST JIG FOR CENTRALIZED INTERLOCK & PROTECTION MODULE OF ITER-INDIA GYROTRON TEST FACILITY

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Abstract

Fast Interlock and protection system plays very crucial role in ensuring the safe and reliable operation of High power RF sources such as a Gyrotron system. Critical Protection Interlocks are generally implemented using hardwired components and are required to have a response time as fast as < 10 μs [1]. In this context, an Industrial grade prototype Centralized Interlock and Protection Module (CIM) based on ITER-India design has been developed successfully with the help of local industry [2]. The CIM system consist of two types of modules; one is analog and the second is digital. 14 numbers of the analog channels are integrated in 7 modules (called as ACIM) which has 2 analog channels per module. The optical signals (10 inputs and 11 outputs) and 14 TTL outputs of ACIM modules which are connected through the backplane, are integrated in the single digital module (called DCIM module). To simulate and verify the performance of the complete CIM system simultaneously, many dummy input signals with different types (analog, digital and optical signals) are required. In this context, a dummy digital test module has been developed indigenously to cater the DCIM input/output optical signal requirements (12 Transmitters & 12 receiver channels). To cater 7 ACIM module testing requirements simultaneously, it is planned to design and develop a Test Jig module indigenously. The main objective of this test jig is to simulate and verify the performance of the developed sub-systems mainly Centralized interlock module/signal conditioning modules etc.

The test jig consists of digital potentiometers to generate required DC output voltage (±10V with 20mV resolution), Direct Digital Synthesizer (DDS) based programmable waveform generator ICs for sinewave/triangle wave/square wave generation, cascaded Programmable Instrumentation Amplifiers (PGA) to provide required gain for each DDS output signal and finally high speed buffers to drive the require loads. A combination of 32 Bit Microcontroller (TMS320 series) and Complex Programmable Logic Device (CPLD, XC95216) is chosen for controlling these specified functions (viz digital potentiometers, DDS waveform generators, PGAs etc.) using a direct data latching method (Input / Output expansion). This design has both operational modes: local/ remote mode. For remote operation, a LabVIEW^{TM} based Graphical User Interface (GUI) will be developed to operate this test jig from a remote PC

through RS232/LAN interface. For the local mode operation, a 7” TFT LCD panel will be used to control and selection of the specified parameters through the local GUI of TFT LCD panel. Embedded programming will be done using KEIL C51 and Xilinx ISE tools. A detailed engineering design has been completed and development process is in advance stage. This paper presents the complete requirements, approach, detailed design concept and current status of Test Jig in detail.

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[2] V. RATHOD et al., Fusion Eng. Des., **112**, 897-905 (2016).

379/NF-123/P

DATA ACQUISITION SYSTEM FOR COOLING WATER SYSTEM OF ITER-INDIA GYROTRON TEST FACILITY

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Abstract

ITER-India has planned to setup a Gyrotron Test Facility (IIGTF) for establishing the integrated system performance of Gyrotron. IIGTF would be having a High power mm wave Test Gyrotron (1MW at 170GHz), a Transmission Line test set, Dummy load, High voltage and Auxiliary power supplies, water cooling connections, Gyrotron diagnostics, crowbar Protection systems, and Local Control Unit to operate the Gyrotron system[1]. As these Gyrotron RF sources would be operating at high power load and pulse, there will be significant thermal heat loads across various components of the Gyrotron source, which needs to be removed by means of active water cooling system. The cooling water distribution system for this test facility is designed to provide and maintain necessary flow rates, temperature, & pressure across various components and quality of water as per the Gyrotron RF source requirements.

This cooling water distribution system requires various instruments (such as water flowrate sensors, temperature sensors, pressure sensors) for the accurate measurement of cooling parameters. For these cooling parameters, the online monitoring, data acquisition and slow protection functions are implemented using Programmable logic controller (PLC) [2]. These cooling parameters consists of 24 temperature signals, 10 pressure signals and 23 flowrate signals originating from 24 RTD (Resistance Temperature Detectors), 10 Pressure sensors and 23 flowrate sensors respectively. The selection and choice of instruments also depends on many factors such as maximum allowed pressure drops across instruments, straight run requirements, interface scheme with PLC and the power supply requirements. Accordingly, optimum configuration of PLC is carried out with sufficient I/O modules for interface with these instruments and application logic for PLC is developed in STEP-7 using Ladder and SCL programming language. The parameters are then transferred to Labview by means of OPC server to display on common Graphical User Interface.

This paper presents the detail design of Data acquisition system of the cooling parameters using Programmable logic controller (PLC) and Graphical User Interface (GUI) developed in Labview.

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384/NF-124/P

IN-SITU MONITORING OF DYNAMIC WORK FUNCTION IN CONDITIONS RELEVANT TO NEGATIVE HYDROGEN ION SOURCES

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Abstract

Cesium seeded negative hydrogen ion sources are major components of neutral beam injection systems for heating/current drive and diagnostics of fusion plasmas. The yield of negative ions has a direct correlation with the work function of the converter surface. Work function plays a key role in determining the ion source performance. Hence a dedicated experimental setup is being developed for an on-line measurement of dynamic work function under vacuum and plasma conditions relevant to ion sources.

The method used to measure the work function is based on Fowler's theory, which is a prominent non-invasive technique to determine the absolute work function of the metal surface based on photoelectric effect. The evaluation procedure relies on the correlation of the photocurrent with incident photon energy which depends on the surface work function. For the experimental implementation of the Fowler method, a rotating multiple lasers along with compact photocurrent capturing unit is being used for an accurate and precise measurement of the work function. This poster presents the description of the experimental setup and its development so far.

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473/NF-126/P

DEVELOPMENT OF PICKLING AND PASSIVATION PROCESS FOR XM-19(UNS S20910) FASTENERS FOR IWS BLOCK ASSEMBLY

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Abstract

Fasteners of XM-19 material were developed for the IWS block assemblies for the ITER Vacuum Vessel. Total quantity of fasteners required for the IWS block assembly is around 89000. Fasteners are manufactured from chromium-manganese-nickel austenitic stainless steel type XM-19, UNS S20910 bars. Different types and sizes of fasteners of M30, M24, M20 bolts, cap screws and nuts are developed. Normally XM-19 possesses strength and corrosion resistance that is higher than stainless steel grades 316, 316/316L, 317, and 317/317L. Manufacturing of fasteners follows various stages for example from raw material part off to hot forging, head, height turning, UT inspection, drilling & tapping, thread rolling and slotting, solution annealing, LPT, pickling and passivation, and finally visual inspection. Fasteners are typical components of an IWS block assembly as without this pre assembly and assembly of blocks is not possible. IWS plates of different shapes and sizes are assembled together from three plates to maximum ten plate's assembly with the help of two lateral bolts. Upper brackets and lower brackets are assembled with the help of cap screws to poloidal ribs and support ribs.

During the initial manufacturing of fasteners pickling and passivation was carried out as per ISO 16048:2003.As per the ISO standard first degreasing is done, chemical used is techniclean SF(2-4%), temperature is 60-80 degree Celsius and soaking time is 20 to 30 minute, then water rinsing and pickling is done, chemical used is HNO3(10 to 15%) at ambient temperature for 10-15 minute after that water rinsing and then passivation is done, chemical used is HNO3 + Na2Cr2 O7, concentration is 20-50 %(HNO3) and 3-5 g/l (Na2Cr2O7), temperature is 40-50 degree Celsius and soaking time is 20-30 minutes and finally drying. The main drawback of this standard is there is no testing after pickling and passivation. Also fasteners were of grey color. As such presence of iron particles was not detected during visual inspection. When ferroxyl test were performed on these fasteners after certain duration the results confirmed presence of iron particles.

So we developed pickling and passivation process for XM-19 fasteners following ASTM A380/A380M standard. The standard refers to the cleaning, descaling and passivation of stainless steels of different grades. Also the concentration mentioned in the standard is very

broad spectrum and time duration for soaking etc. is mentioned as necessary. We performed a number of combinations by changing the percentage of HNO_3, HF, $Na_2Cr_2O_7$, temperature, time duration etc.

This paper will explain as how different parameters of pickling and passivation were considered to optimize the process of pickling and passivation of fasteners along with the various test to make sure that no iron particles are present on the surface of the XM-19 fasteners.

190/NF-127/P

PRELIMINARY MECHANICAL DESIGN OF THE VACUUM BOUNDARY AND IN-VACUUM COMPONENTS OF RFX-MOD2 MACHINE

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Abstract

Reversed Field pinch Experiment (RFX-mod) has proven its potentiality by achieving important experimental results in both reverse field pinch and tokamak configurations. The Vacuum Vessel of RFX-mod is closely surrounded by a passive stabilizing shell to give plasma stabilization against magnetohydrodynamic (MHD) modes. Study shows that highly resistive vacuum vessel of RFX machine causes an electromagnetic torques on the rotation of plasma dynamo modes [1]. The machine upgrade is proposed with removal of present vacuum vessel considering compatibility with the as-built experiment [2].

The mechanical modifications of the vacuum boundary and in-vacuum components of RFX-mod are presented here. The vacuum boundary is designed at the toroidal assembly joints by developing different sealing solutions compatible with the stringent requirements of the present components. New supporting rings are designed to support the stabilizing shell. The stabilizing shell has to perform as structural component in addition to passive stabilization of plasma MHD. The stabilizing shell will provide support to First Wall tiles and withstand structural, thermal and electromagnetic loads. The proposed component design and modifications of the torus assembly are supported by thermo-mechanical analyses undertaken by developing 3D models in ANSYS environment considering different load combinations.

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197/NF-128/P

HEAT TRANSFER ANALYSIS OF ZNO-WATER NANOFLUID FOR NUCLEAR APPLICATION

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Abstract

The thermal conductivity of traditional heat transfer fluids is inherently low. Metals or Metal oxide in ultra-fine form have orders of magnitudes higher thermal conductivity of those of fluids. So it is a need to understand the fundamental behavior of the metals or metal oxides nanoparticles in base fluids. ZnO is a semiconductor but has a wide range of application. It has high refractive index, high thermal conductivity, binding, antibacterial and UV-protection properties. ZnO nanoparticles are prepared by high energy planetary ball milling of ZnO powders with BPR 10:1 at 300 rpm for different milling time. It was observed from XRD and TEM that the size of the particles is in the range of 20nm-30nm. These nanoparticles are used to make nanofluid by mixing them with water at different volume fraction of solute. The stability of the nanofluids was observed for several days. The zeta potential of the nanoparticles was observed. The nanofluids behavior was studied in terms of viscosity, density and thermal conductivity. It was observed that the surface charge of a nanoparticle plays a crucial role for nanofluids preparation and stability. The volume fraction of ZnO nanoparticle plays a very crucial role in thermal conductivity. The viscosity ratio of nanofluids increases with increase in concentration. The thermal conductivity of nanofluid is observed for different size nanoparticles. In this study the thermal conductivity and viscosity will be discussed in details with experimental and theoretical models. The application of ZnO based nanofluids will be very much useful in nuclear fusion.

355/NF-129/P

OVERVIEW OF HIGH PRESSURE, HIGH TEMPERATURE HELIUM COOLING SYSTEM−AN ATTRACTIVE COOLANT FOR FUSION BLANKETS

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Abstract

Helium is an attractive coolant for fusion reactors because it is chemically and neutronically inert and can be used directly for gas turbine cycle power conversion. Additionally, among the three coolants – water, liquid metal and helium− considered for future fusion machines helium is superior from safety considerations.

The TBM Program in ITER foresees the operation of six TBMs, located in 3 dedicated ITER equatorial ports, with their own ancillary systems (e.g., coolant, Tritium extraction, Instrumentation & Control, maintenance) to form six Test Blanket Systems (TBSs). Among the six TBMs proposed for testing in ITER, First wall of the five TBMs are cooled by high pressure, high temperature helium gas and only one TBM is cooled by water. India is developing lead-lithium cooled ceramic breeder (LLCB) test blanket module (TBM) along with associated systems for testing in ITER. In LLCB TBM, Pb-Li eutectic alloy is used as multiplier, breeder, and coolant for the ceramic breeder (CB) zones. The Pb-Li velocity is moderate enough that such that the heat generated within and the heat transferred from ceramic breeders are extracted effectively. The outer box structure of LLCB TBM is cooled by high pressure, high temperature (8 MPa, 300–500 ◦C) helium gas named as First wall helium cooling system (FWHCS). The Pb-Li system is also cooled by another helium system named as lead-lithium helium cooling system (LLHCS) through a liquid-metal helium heat exchanger outside of TBM.

This paper discusses the features of helium as coolants for breeding blankets and process parameters, process flow diagram & operation and control scheme of a typical helium cooling systems used for cooling the Breeding blanket in ITER. It will presents briefly the process details of some of the major experimental helium cooling facilities build globally for testing of breeding blanket related technologies. It will also highlight the process details and main features of the Experimental Helium Cooling Loop (EHCL) being developed at IPR.

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434/NF-130/P

DEVELOPMENT AND SIMULATION OF VISUAL SERVO CONTROLLER FOR REMOTE HANDLING SYSTEMS

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Abstract

Remote Handling (RH) or robotic system are controlled using a feedback control loop that monitors and compares the instantaneous position or velocity value with the desired value. Though the control system is closed loop, the kinematic chain is still an open loop as no information is provided to the control system regarding the present position of the robot tool (TCP) with respect to the desired position or target object. For tokamak RH systems which are long and cantilevered, inherent structural deformations or minor errors in assembly can cause the position of the TCP to vary than the anticipated position by the controller. This can be rectified by providing photometric information to the control system using camera feedback. Visual servo is field in robotics where computer vision data is used in the servo loop to control the motion of a robot.

This paper presents the development and testing of a visual-servo controller for 6-axis tokamak relevant Articulated Robotic Inspection Arm (ARIA). The control loop is implemented using Robot Operating System (ROS). The controller subscribes the images of the tiles from a pre-calibrated camera mounted on the robotic system. Feature details of the tile edges are extracted from the images to determine the coordinates of the tile with respect to the TCP of the robot. The controller computes the instantaneous joint velocity using an approximate interaction matrix and error in the present and desired features. The velocity skew matrix is published to the joint controllers for actuating ARIA robot. The developed controller is tested in a virtual reality model that simulates the ARIA robot within a tokamak environment for tile replacement. Results show that a good convergence of the joint trajectories and smooth alignment of the tool with respect to the tile.

366/NF-132/P

GENERATION AND DE-CONFINEMENT OF RUNAWAY ELECTRONS IN THE ADITYA TOKAMAK

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Abstract

Energetic electrons are generated in a tokamak under specific conditions. The presence of such energetic electrons, called Runaway Electrons (RE), pose serious threat to the reliable operation of ITER-like future tokamaks. Uncontrolled RE beam may cause serious damage to the Plasma Facing Components (PFCs) and the tokamak vessel. This marks the importance of RE studies for fusion-based energy generation.

An elementary ‘zero-dimensional’ model has been adapted to understand the conversion of plasma current into runaway current during the current quench. Runaway current profile has been calculated using this model in COMPASS and ADITYA tokamaks, assuming that plasma current comprises of Ohmic current and the current carried by the runaway electrons. Calculation of runaway density from the solutions of drift-kinetic equations was also foreseen.

Runaway deconfinement during magnetic reconnection has also been presented in this poster. In particular, study between the runaway deconfinement measured through hard x-ray spectroscopy and the frequency of rotation of magnetic islands has also been investigated.

76/PD-01/P

C-R MODEL FOR AR-O_2 MIXTURE PLASMA USING RELIABLE FINE STRUCTURE CROSS SECTIONS

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Abstract

The trace addition of reactive molecular gases (RMG) in inert gas plasma provides reactive species/radicals that are required for plasma processing and plays a prime role in many application e.g. etching, surface modification and sterilization. Recently, Jogi *et. al.* [1] have reported the OES measurements of Ar/O_2 (0-5%) gas mixture plasma in 40 MHz RF discharge at 2 Torr pressure. In the light of this measurement a Collisional radiative (CR) model has been developed by incorporating all relevance populating and depopulating possesses occurring in the Ar/O_2 mixture plasma. In the present study we have extended our earlier CR model [2] for pure argon plasma in the light of our recent work on Cs-H_2 plasma modeling [3].

The model includes various atomic processes i.e. electron impact excitation and ionization, radiative population transfer in addition to quenching of Ar* with O_2. Since electron impact collision processes plays a vital role, a complete data set of relativistic electron impact fine structure excitation cross sections calculated by relativistic distorted wave (RDW) theory [4] has been incorporated in the model. Moreover, as we are dealing with medium pressure (2Torr) radiation trapping for 1s (resonance) levels is very high. We have included the trapping *via.* escape factors in the present model. Diagnostics have been done by optimizing the normalized intensities obtained from this model with the OES measured intensities [1] for different transitions between fine structure levels. We found that electron temperature increases (0.9 to 1.8eV) with the increase of O2 fraction (0-5%). The population densities of Ar 1s fine structure states are also investigated from this model and compared with the measurements [1] at different O_2 fractions. All the details of C-R models along with the results will be presented in the conference.

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78/PD-02/P

FINE-STRUCTURE RESOLVED C-R MODEL FOR THE DIAGNOSTIC OF ARGON-NITROGEN PLASMA

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Abstract

In the present work, we consider the diagnostics of Ar/N_2 mixture plasma at low temperature and propose a collision radiative model. The required optical emission spectroscopy (OES) measurements are used from Lock et al [1]. The trace addition of N_2 in inert gas plasmas provides reactive species/radicals such as NO; N_2(A) which play significant role in many applications such as thin film deposition, material modification, etching, and lighting etc. In low temperature plasma conditions, the electron impact excitation and de-excitation are dominant populating and depopulating channels. Therefore the reliability of the model highly depends solely on the use of cross sections for these processes. For this purpose, we extend our earlier collisional radiative (CR) model for pure argon plasma [2] where we used accurate fully relativistic distorted wave (RDW) cross-sections

The CR model we developed for argon-nitrogen plasma is composed of coupled particle balance equations of excited states by incorporating various atomic processes i.e. electron impact excitation and ionization as well as other processes such as radiative population transfer and quenching by N_2 etc.. The solution of these coupled equations provide the population of all the levels upto 3*p* (Paschen notation) states as a function of plasma parameters (electron temperature, density, gas temperature etc.) for various N_2 fraction. The excited state population is directly linked to the emission intensity of the line originating from the corresponding state and by optimizing the measured line-intensity [3] with the modeled values, the required information of plasma parameters are then obtained. All the details of CR models along with the results will be presented in the conference.

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236/PD-03/P

INVESTIGATION OF MICROWAVE RADIATION FROM A COMPRESSED BEAM OF IONS USING GENERALIZED PLANCK'S RADIATION LAW

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Abstract

An ion-beam compressed by an external electric force is characterized by a unique non-equilibrium distribution function. This is a special case of Tsallis distribution [1] with entropy index q=2, which allows the system to possess appreciably low thermal energy. The thermal radiation by such compressed ion-beam has been investigated. The system being non extensive, Planck's law of radiation [2] has been modified using Tsallis thermostatistics [3]. The average energy of radiation has been derived by introducing the non extensive partition function in the statistical relation of internal energy. The spectral energy density, spectral radiation and total radiation power have also been computed. It is seen that a microwave radiation will be emitted by the compressed ion-beam. The fusion energy gain Q (ratio of the output fusion power to the power consumed by the system) according to the proposed scheme [4] using compressed ion beam by electric field will not change significantly as the radiated power is very small.

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263/PD-04/P

IDENTIFICATION AND SIMULATION OF SPECTRAL MOLECULAR BANDS OF NITROGEN PRESENT IN RF PLASMAS

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Abstract

Optical emission in the wavelength range of 300 nm to 900 nm has been recorded from RF produced plasma using a miniature spectrometer (USB4J01222). The plasma is primarily produced in hydrogen through applying of radio frequency (RF) power of ~ 60 – 100 W at 13.56 MHz. To study the nitrogen molecular spectral bands, a small amount of air is released into the plasma purposefully. Intense molecule spectral bands of N_2 ($B_3\prod_g - A^3 \sum_u^+$) has been observed. Three bands are identified as Δv= 4, 3 and 2 transitions of Nitrogen first positive system in the wavelength ranges of 560 – 620 nm (Δv =4), 620 – 690 nm (Δv = *3*) and 690 – 780 nm (Δv = 2) respectively. After identifying the vibrational bands, the vibrational temperature of Nitrogen molecules has been estimated using the Boltzmann plot method. Further, the vibrational band spectra corresponding to above mentioned transitions from Nitrogen molecules are simulated using a code in MATLAB, developed in-house. The simulated spectra has been fitted to the experimentally recorded ones to estimate the temperature by iterating with different temperature values. The full width at half maxima (FWHM) of each vibrational spectrum is estimated by folding the instrumental width with the available rotational spectral lines within one vibrational spectrum. The best fit simulated spectra to the experimental spectra gives the temperature. The temperature estimated using this method matches fairly well with those estimated through Boltzmann plot method.

329/PD-05/P

ALGORITHM DEVELOPMENT FOR TOMOGRAPHIC STUDY OF HELICON PLASMA

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Abstract

Optical Emission Tomography (OET) is a passive diagnostic technique to study the plasma dynamics noninvasively. This is a standard technique which provides the spatial profile of the spectral line radiations emitted by the plasma. The emission profile is obtained from the inversion of the line of sight integral of emissivity i.e. brightness, measured with a proper detection system. Suitable analysis of emission profile gives many valuable information of plasma such as plasma density, temperature, ion velocity distribution etcetera [1]. Most of the laboratory plasma systems have restricted viewing access and hence the tomography measurement, in general, constitutes an under-determined and ill-conditioned inversion problem. Taking care of these aspects, a tomography code has been developed based on maximum entropy concept to reconstruct the 2D emissivity profile of the optical emissions in helicon plasma. The maximum entropy concept evolves from the Bayesian statistics and provides a consistent description of probabilistic inferences, yielding the most probable and least biased solution in conformity with available noisy data and other prior knowledge [2]. The code has been tested with known functions representing MHD phenomena in plasma with and without noise and gives very consistent results. The present OET system will be installed in the permanent magnet based Helicon source being developed in IPR to study the plasma dynamics in the RF driver [3].

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343/PD-06/P

ESTIMATION OF EMISSIVITY OF FE^{14+} AND FE^{15+} VUV SPECTRAL LINES RELEVANT TO ADITYA-U TOKAMAK PLASMA

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Abstract

High temperature tokamak plasma mainly contains low-Z impurities like oxygen, carbon and medium-Z impurity such as iron. These impurity ions are present due to sputtering and desorption processes involving surfaces in contact with the edge plasma. These surfaces include divertor plates, limiters, vacuum vessel walls and radio frequency antennas. Presence of such spectrum of impurities leads to enhanced energy loss, fuel dilution and overall degradation of plasma properties. Thus the studies of the behavior of impurities and their transport in the plasma are becoming very important. In Aditya tokamak, VUV spectra from impurities were regularly monitored using a VUV survey spectrometer having operation in the spectral range of 10-180 nm, which covers the important lines of partially ionized low and medium-*Z* impurities and also emissions from higher excited states of highly ionized low-Z impurities. One of the approach to study impurity transport inside the tokamak plasma is to compare the experimental spectral intensities with one obtained by modelling the spectral line emissions using impurity transport code, such as STRAHL [1]. To perform such studies, Photon Emissivity Coefficient (PEC) values for the spectral emissions of impurity ions are required.

In this work, initially PEC values of O^{4+} emission at 650.024 nm has been generated through a user developed code using the fundamental atomic structure data, relevant reaction rates of various atomic processes, and generalized collisional-radiative (GCR) model code for PEC calculation available in ADAS database [2]. This has been compared with existing PEC values data available in the ADAS database to understand the details calculation procedure and relevant atomic physics. Later the PEC's of Fe^{14+} at 28.42 nm and Fe^{15+} at 33.5 nm & 36.0 nm have been obtained for studying the iron impurity transport in Aditya-U tokamak plasma. In this study, details on the PEC data generation and simulation of Fe^{14+} and Fe^{15+} spectral emissions will be discussed.

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440/PD-07/P

DESIGN OF AN X MODE REFLECTOMETRY SYSTEM TO MEASURE EDGE PLASMA DENSITY DURING LOWER HYBRID WAVE COUPLING IN ADITYA -U TOKAMAK

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Abstract

To study the coupling of lower hybrid power, a new PAM antenna [1] is being developed for LHCD system of Aditya –U Tokamak [2]. A reflectometry system is planned to study edge plasma density profile in front of PAM antenna. In a reflectometry system a microwave beam is sent in to the plasma and it reflected back from plasma cut off surfaces, then reflected signal is compared with the launching wave to extract the phase information. From the phase information one can extract the plasma density profile [3]. A swept frequency X mode refletometer for ADITYA U Tokamak is designed to measure edge density profile. The system is considered to operate between 26 and 36 GHz at sweep time of 100 micro second and will cover a density range of approximately 10^{17} to 5 x10^{18} m^{-3} at 0.75 to 1.5 Tesla. Depending upon the operational scenario and the physical constraints of port size dual sectorial E plane horn antenna has been designed to launch and receive microwave signal. The details of the reflectometry system components focusing on the sectorial E plan horn antenna design and mounting is described in this paper [4]. Along with this the density profile reconstruction technique from phase information based on Bottollier-Curtet algorithm [5] is also presented.

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10/PD-08/P

ELECTRICAL CHARACTERIZATION OF AN ATMOSPHERIC PRESSURE PLASMA JET

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Abstract

The recent years have witnessed the remarkable application of non-thermal plasma because of its promise in poisonous gas treatment, disinfection, surface processing and decomposition of volatile organic compounds. However, producing non thermal plasma is complicated, mostly because it necessitates high power supply, vacuum chamber equipment etc.

The present research has been conducted using Ar/O2 gas at 3.7 kV, 27 kHz, sine wave as an excitation source. The discharge has been characterized by electrical methods. The electrical properties of discharge have been studied by means of voltage and current measurement to determine electron density. Moreover, the energy consumption in the discharge has been carried out through Lissajous Figures. The electron density in the discharge was measured by power balance method.

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15/PD-09 /P

ELECTRICAL CHARACTERIZATION OF ATMOSPHERIC PRESSURE DIELECTRIC BARRIER DISCHARGE

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Abstract

The electrical characteristics of a dielectric barrier discharges (DBD) in atmospheric pressure air and argon gas has been studied experimentally and numerically. The discharge was generated by applying high voltage power supply in the range of (0-20) kV operating at a frequency of 27 kHz. The DBD system consists of a parabolic electrode of brass with an axial hole of diameter 3.5 mm above a disc electrode covered with dielectric material (glass) of thickness 1.1mm. The discharge was characterized by measuring current and voltage using a high frequency digital oscilloscope. The effect of electrode gap spacing on the discharge behavior was investigated. The energy dissipated per discharge cycle was calculated from the Q-V Lissajous figure. The experimental results were compared with the results obtained from the numerical simulation of the discharge performed using Matlab Simulink.

Keywords: Dielectric barrier discharge, Q-V Lissajous figure, Numerical simulation, High voltage

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71/PD-10/P

UPGRADATION OF TANGENTIAL FAR-INFRARED INTERFEROMETER FOR POLARIMETRY MEASUREMENT IN SST-1

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Abstract

This paper presents the upgradation of tangential view of Far-infrared (FIR) interferometer in SST-1 tokamak for polarimetry measurement. A multi-channel FIR interferometer has been developed for plasma density measurement in SST-1. It consists of six tangential viewing chords with fan beam geometryto coverthe plasma cross section at mid plane (R=0.9 m to R=1.3 m)[1]. The density measurement by interferometry is vibration sensitive and susceptible to fringe jump errors. Therefore, interferometry diagnostics has been augmented for plasma polarimetry to check and correct theerrors that might haveoccurred in theinterferometry measurements. In plasma polarimetry, a linearly polarized beam propagating in the direction of magnetic field experiences Faraday rotation[2]. Various polarimetry techniques are available for measuring the Faraday rotation angle[3]. In the present work the Faraday rotation angle is deduced from the intensity measurement of two orthogonally polarized components of wave electric field before and after the plasma shot. One of the orthogonal components is deduced from already implemented probing arms of tangential view interferometer by inserting polarizing optics along the beam path. Further theseinterferometry probing arms are beingaugmentedto measure the other orthogonally polarized component. The Faraday rotation measurement by tangential polarimetry givesthe product of pathintegratedelectron plasma density (n_e)and parallel component of toroidal magnetic field ($B_{\parallel}$)[3],[4]. As $B_{\parallel}$is known, plasma density is deduced from the measurement of Faraday rotation.

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77/PD-11/P

POWER DIVISION AND MIXING IN MULTICHANNEL FAR-INFRARED INTERFEROMETER FOR SST-1

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Abstract

This paper presents the power division scheme for multi-channel Far-infrared (FIR) Laser Interferometer for SST-1 tokamak. The interferometer consists of one vertical chord at R = 1.075m and six tangential chords covering entire plasma cross section, R=0.9 m to R=1.3 m, at mid-plane for measuring electron plasma density [1]. An optically pumped 118.8µm twin methanol (Edinburgh Instruments Ltd.) laser is being used as the radiation source for both vertical and tangential viewing. The laser has been kept in a climate controlled clean room lab adjoining SST-1 hall.The FIR laser beams are propagated ~ 16 m from the laser lab up to SST-1 tokamakhall using oversized dielectric waveguides[2]. The waveguided transport ends at the interferometer support structure assembly near the tokamak and the beams are, then, transported in free space. The main beamsare split into beamlets for multichannel viewing using beam splitters. This paper presents the detailed power division scheme,for probe as well as reference beam, to divide power equally in all the channels. The scheme decides thepower division ratio of the beam splitters used. Two types of beam splitters are being used in SST-1 FIR interferometer: (i) Crystal Quartz Beam Splitters and (ii) Mesh Beam Splitters. Crystal Quartz is transparent to both visible and FIRwavelength[3], hence, ispreferred over long propagation path due to the ease of alignment. They are used to split plasma probe beams which travel ~3 m upto next optics (i.e, corner cube reflectors mounted on vessel wall) and total ~6 m from beam splitter back to the detectors.Mesh beam splitters are relatively cheap but cannot be used for alignment with visible beams. Therefore, they are being usedfor splitting the reference beam where the beam propagation length is short and can be done using liquidcrystal sheets.The thickness of Crystal Quartz beamsplitters decides the ratio of reflected and transmitted power. The required thickness has been calculated for the powerdivision scheme using Fresnel's equations [4].Mesh parameter i.e., transparency of the mesh, decides the ratio of reflected and transmitted power.Therefore, the mesh parameter has been decided according to the power division scheme.The probe beams and

reference beams are finally mixed using 50 : 50 mesh beam combiners and detected by Schottky Barrier Diode (SBD) mixers. Considering power division scheme and power losses along beam paths, power reaching each detector ~3 mW. The optical arrangement for experimental realization of power division and mixing scheme of FIR interferometer has also been presented.

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103/PD-12/P

RE-VAMPING OF PLC CONTROL SYSTEM FOR NBI CRYOGENICS SUB-SYSTEMS SIGNALS

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Abstract

NBI PLC System is the central control and data acquisition system for the NBI Sub-Systems such as External Vacuum System, Gas Feed System, Cooling Water System, Cryogenics System and Interlock System. PLC System handles more than 100 analog signals and around 140 digital signals. NBI Cryogenics System can be classified as the following sub-systems: External Cryogenics Distribution System (ECDS), Internal Cryogenics Distribution System (ICDS), LHe plant PLC System and Gas Storage with Compressor System. All these cryogenics sub-systems interface with NBI PLC System. The paper describes the re-vamping of the signals and interface for PLC System. It also describes the re-designing of the instrumentation for the cryogenics sub-systems and the isolation card details used.

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121/PD-13/P

A NON-INVASIVE METHOD OF ESTIMATING COLLISION FREQUENCY IN 13.56 MHZ CAPACITIVE COUPLED ARGON DISCHARGE

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Abstract

Collision frequency is an important plasma parameter as it relates to different derived parameters in the discharge such as mobility, diffusion, plasma conductivity etc. Being an intrinsic property of plasma, collision frequency can also be used as a controlling and monitoring plasma parameter [1], hence it can be useful in industrial plasmas. Usually collision frequency is measured by sophisticated techniques like spectroscopy and electrical probes. These methods are useful, however they are difficult to implement in industrial plasma systems due to significantly high (~ 1 kV) oscillation in plasma potential [2]. Since probes are intrusive and also strongly perturbing in magnetized plasma, therefore they are forbidden to use in process plasma tools. Thus the non-invasive method demonstrated here can be useful in such applications.

In this paper an attempt has been made to determine the collision frequency, non-invasively in a magnetized 13.56 MHz CCP discharge. This has been achieved by deriving an analytical model which relates the bulk plasma reactance with the collision frequency. The bulk reactance of the plasma has been experimentally obtained from the phase and amplitude measurement of rf voltage and current in conjunction with the estimated sheath reactance and stray capacitance of the discharge circuit. A qualitative discussion has been presented to explain the effects of transverse magnetic field on discharge characteristics. The proposed method provides a non-invasive means to determine collision frequency in capacitive discharges. The collision frequency gives an insight in to the qualitative behavior of the discharge.

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135/PD-14/P

ELECTRIC PROBE ANALYSIS OF LOW TEMPERATURE HELIUM PLASMA

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Abstract

Low temperature helium plasma produced in laboratory devices is an alternative to hydrogen discharges due to safety issues, in view of conducting systematic high plasma heat flux studies on material surfaces for Tokamak applications. The lighter atoms of helium can be conveniently magnetized at modest magnetic fields in the range of 20 – 30 mT. Electric probes provide useful information about the state of this plasma. However its performance must be validated when the discharge is operated under magnetic field. In this paper we emphasize on understanding the behavior of helium plasma by electric probe methods. In particular, electron energy distribution function (EEDF) measurements have been obtained in dc helium plasma under varying conditions. Electron temperature; density and plasma potential have been evaluated using single Langmuir probe characteristics. A SCILAB based mathematical tool has been developed to fit raw I (V) characteristic using optimization algorithm gives the various plasma parameters. Electron Energy Distribution Function (EEDF) is obtained for helium plasma under magnetic field. Plasma parameters obtained from the EEDF has been compared with characteristics in argon. A qualitative discussion is given to explain the overall behavior of EEDF under the influence of magnetic field.

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142/PD-15/P

RF POWER MEASUREMENT BY PHASE CALIBRATION TECHNIQUE FOR A MAGNETIZED CCP DISCHARGE

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Abstract

RF power/phase measurement is an important tool for non-invasive diagnostics of the RF discharge. From these, useful information about the discharge characteristics and can be obtained. The electrical footprints can be combined in to a feedback control system to optimize the discharge process. However, direct measurement of RF power is not straightforward due to losses in the transmission lines and phase-shifts introduced due to external measuring instruments circuits. This results in significant difference in the power read from on-board power meter with the consideration of lossless matching system [1].

In this work, RF power measurement has been performed by phase calibration in a magnetized parallel plate capacitive coupled Argon discharge. The RF power delivered to the plasma is measured by inferring the phase between the RF voltage and current waveforms measured by the commercially available voltage and current probe. Accurate phase measurements are done, by introducing a constant calibrating factor for the measuring instruments, which is obtained by comparing the phase between the voltage and current waveforms in the DSO (Digital Storage Oscilloscope) with the load characterization of a VNA (Vector Network Analyzer).

The RF power measurements based on the above method are compared with the onboard power meter of the RF generator and are found to be significantly different during high reflected powers, while agreement has been found with the on-board reading for good matching conditions. The obtained discharge characteristics have been qualitatively discussed.

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162/PD-16/P

CHARACTERIZATION OF THE PROTOTYPE MICHELSON INTERFEROMETER FOR THE ITER ECE DIAGNOSTIC SYSTEM

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Abstract

The Electron Cyclotron Emission Diagnostic system in ITER will be used to determine the electron temperature profile evolution, electron temperature fluctuations, the runaway electron spectrum, and the radiated power in the electron cyclotron frequency range (70-1000 GHz). These measurements will be used for advanced real time plasma control (eg. steering the electron cyclotron heating beams), and physics studies.

Considering the ITER requirements, ultra-wide band (70 – 1000 GHz) ECE radiation measurement for the estimation of the ECE radiated power loss will require the transmission lines as well as a radiation measurement instrument with 10 – 20 ms time resolution and 5 – 10 GHz frequency resolution. The transmission line and the radiation measurement instrument need to be evacuated to avoid water vapor absorption in this frequency range. The calibration of the total system including transmission line and the radiation measurement instrument is required for the ECE radiation measurement. To transmit the low power calibration signals over the frequency range 70 to 1000 GHz with low attenuation over a long distance of 40 – 50 meters is main challenge. Michelson interferometer with high throughput and a fast (10 - 20 ms) continuous mechanical scanning mechanism for the moving mirror in low vacuum is required for these measurements. The development of the Michelson interferometer with fast scanning mechanism in the low vacuum is another challenge.

Therefore to meet these challenging requirements, a prototype Michelson interferometer with fast scanning in the vacuumwas designed and developed for various measurements of the components to be used in the ECE diagnostics system. The developed Michelson interferometer has good time resolution of 10 ms with scanning length of 15 mm that gives frequency resolution of 10 GHz and detectable power measurement dynamic range is 29 dB with very low Noise Equivalent Power of 2×10^{-12} W/Hz$^{1/2}$.

The paper/presentation will provide the details of desired parameters and its characterization to ensure that target parameters are achieved.

169/PD-17/P

A NOVEL ROGOWSKI COIL FOR THE DETECTION OF PULSED CURRENTS ASSOCIATED WITH HIGH FREQUENCY ELECTROMAGNETIC WAVES IN A PLASMA

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Abstract

A novel Rogowski coil for the detection of pulsed currents associated with high frequency electromagnetic waves in a plasma has been developed in our laboratory. The currents (100 kHz - 5 MHz), as low as 10 mA/cm^2 are associated with linear whistler waves[1]. Whistler waves are the normal modes of the electron magnetohydrodynamics regime[2] and are characterized by spatial scale lengths between electron and ion Larmour radii $r_{Le} << L << r_{Li}$, and temporal scale lengths $\omega_{ce} >> \omega >> \omega_{ci}$. Whistler waves exhibit complex topologies and force free nature as revealed by the work carried out by number of researchers over the years[3]. In all previous laboratory studies, magnetic field has been measured using B-dot probes and **J** fields were constructed numerically using Curl $\mathbf{B}=\mu_0\mathbf{J}$. No independent measurements of **J** have been carried out to confirm the force free nature of the fields. The Rogowski coil developed in our laboratory is wound using thin Kapton coated copper wires on a vacuum compatible ceramic disc of cross-section 1 mm × 1 mm. The coil major radius is approximately 5 mm allowing minimal perturbation of the plasma, yet being able to measure currents at several points over the spatial scale lengths (~ few cms) of the electromagnetic perturbations. Moreover, the novel bifiliar design helps reject the electrostatic pickup at the probe tip itself.

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172/PD-18/P

LIFE ENHANCEMENT OF ISRO LASER GYRO BY PLASMA PROCESSING

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Abstract

Laser Gyro (ILG) finds wide applications in Launch vehicle, satellites, missiles, aircrafts and ships etc. as it provides high accuracy, resolution in measurement of inertial rate with wide dynamic range capability. For satellite application there is a demand for long life. But the gas contamination of the He-Ne gain plasma is the major limiting factors for Laser Gyro life time. Studies suggest that among the various gases Hydrogen (Mostly hydroxides formed during fabrication or material ageing) is the primary source of contamination for which gain reduction is most [1]. Approximately 800 ppm (V/V) of Hydrogen can reduce the gain completely.

Dielectric barrier capacitive coupled radio frequency active gas plasma has been developed to produce cleaner cavities in much less time and at lower cost. This technique involves the coupling of RF energy in to a gas filled Laser cavities to generate active plasma to clean entire Laser cavity. An in-situ diagnostic tool optical emission spectrometer (OES) has been inducted in the study to analyze the effectiveness of plasma coupling and in-situ monitoring of the plasma for effectiveness of cleaning with various gaseous systems. It is also very useful tool for optimization of coupling energy as well as understanding the plasma chemistry during the processing. The plasma is initiated in a laser tube of internal diameter 4 mm, length of 33 mm and volume of 7cc. The 40.68 MHz RF generator with 40±2 W power is used. The plasma is analyzed using an Ava spec 2048 spectrometer with diffraction gratings with 600 and 1200 lines/mm. The spectral resolution in the wavelength range 400–950 nm was 0.4–0.7 nm. Helium, Neon, Argon, air and oxygen used as active gases for plasma processing.

Various gases plasma at specific PD (PD optimized based on the diameter, mean free path and ionization characteristics of atom) has been used. The plasma has been analyzed for removing primarily Hydrogen contamination by in-situ monitoring of H_2 characteristic peak at 656 nm (2p to 3d & Aik-6.381E+07/s) using OES. Above studies show that oxygen plasma at 20 mbar*mm

found to be to be very efficient to remove H_2 contamination completely from the Laser cavity. From the spectroscopic peaks and electronic transitions referred from NIIST data, it shows that atomic transitions at 777 (3s to 3p & 3.697E+07/s), is responsible for removing H_2 from the system by forming water molecule ($H_2$0+ peak at 615.8 nm), by chemically reacting with hydroxyl radical by free radical mechanism [2]. By this process H_2 can be reduced to < 1 ppm. Further the oxygen rich Laser cavities made ultra clean by Neon isotope plasma processing also in-situ monitored by OES.

By in-situ utilizing of OES, the technological process has been optimized for achieving ultra clean laser cavities for filling He Ne gas. By this process about 100 sensors has been filled with no sign of gas contamination (He-Ne plasma analyzed by OES with different time period) for about 7 years of operation. Hence the life has improved significantly from about few months to many years.

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188/PD-19/P

COMPARATIVE STUDY OF PLASMA PARAMETERS BY USING MOVABLE LANGMUIR SINGLE AND DOUBLE PROBE IN ARC PLASMA FOR DIFFERENT MATERIALS OF ELECTRODES

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Abstract

Plasma is produced by arc discharge between two electrodes and is characterized by using a movable Langmuir probe. It is a simple way to measure plasma parameters such as electron temperature, electron density, ion density, Debye length, plasma frequency, floating potential, etc. A movable Langmuir single probe technique has a reference point since it is biased with reference to any one electrodes of the plasma producing system. In some situations, such as radio frequency discharges, a reference point is not available to bias the movable single probe. Hence a single probe technique is not applicable and that is why the movable double probe technique is more appropriate. In this method, each probe is biased with respect to one another. When the two probes in a vertical plane are biased with a potential and allowed to move through arc plasma, depending on the magnitude of biasing potential charges are collected by the probes and corresponding current flowing to the probe circuit is estimated. We use electrodes of different materials such as Copper, Iron, Brass etc. The obtained values of plasma parameters for different materials will be helpful to understand the various characteristic of produced plasma in laboratory, which has various applications such as gaseous discharge, plasma torch, sputtering, surface modification as well as fusion process.

227/PD-20/P

ESTIMATION OF PLASMA COLUMN POSITIONIN ADITYA-U TOKAMAK USING MIRNOVCOILS

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Abstract

Due to several forces acting on the plasma column in a tokamak, the plasma column tends to move horizontally and/or vertically leading to many adverse events including termination of plasma. The movement of plasma column is stabilised using equilibrium magnetic fields (vertical magnetic fields). The required magnitude of the equilibrium field depends on the plasma parameters. Thedynamical variation of the plasma parameters throughout the discharge demands appropriate alterations of magnitude of equilibrium magnetic field in real time during the discharge to obtain a stable plasma column position inside the tokamak.To determine the appropriate magnitude of this equilibrium magnetic field, accurate measurement of plasma column position throughout the discharge with good temporal resolution is a necessity.

Among different estimation methods of plasma column location, the plasma position estimation using poloidal garland of magnetic probes (Mirnov coils) is extensively used in many tokamaks and is being proposed to measure the plasma position in Aditya-U tokamak. The Aditya-U has two Mirnov probes garlands, each of them has 16 magnetic probes,distributed at equal angular separation in poloidal plane.Both the garlands are installed at two different toroidal locations inside vacuum vessel at opposite positions.To estimate the plasma column position using these Mirnov coils, the first task is to calibrate these coils. Forcalibrating these coils, the plasma current centroid is simulated by passing current through a toroidal conductor placed at different locations inside the Aditya-U vacuum vessel. Due to the current in the conductor, the magnetic field picked-up by the coils of both the Mirnov garlands has been recorded. By analysing the recorded data the position of the conductor is determined and matched with its actual location. The detail calibration procedure, analysis of calibration data based on numerical code and the plasma position estimation based on analysis for ADITYA-U will be discuss in this paper.

228/PD-21/P

STUDY OF IMPURITY RADIATED POWER DURING NEONGAS PUFF

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Abstract

Impurity radiation behaviour and power balance has been studied for plasma discharges with neon gas puff in tokamak Aditya. Impurity radiation is measured by 20 elements AXUV photo diode array and installed on the top port of Aditya. Impurities like carbon, oxygen and Iron have major contribution in the radiation measurements. The total radiated power(line, bremsstrahlung) in the range UV, VUV, SOFT X-RAY REGION of the plasma measured from top port is 20% to 40 % of the input power and 10% IR radiated power with the IR imaging system is also contributed.In power balancing, input ohmic power (P_{OH}), power Loss (P_{RAD}), diamagnetic energy (W_{DIA}) and confinement time were taken. Diamagnetic energy (W_{DIA})was measured by a set of two loops, namely diamagnetic loop and compensating loop mounted in poloidal plane inside the vacuum vessel.P_{RAD} was measured by AXUV photo diodes. Confinement time was calculated using alcator scaling formula $3.8x10^{-21}$ n_e a^2.We observed that radiated power in the detector viewing outer edge (toward outboard) is more than the inner edge detector after neon gas puff. The detailed discussion is given in the paper.

232/PD-22/P

TIME RESOLVED DENSITY AND TEMPERATURE MEASUREMENT IN PULSED DC ANODIC GLOW PLASMA

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Abstract

The time dependent density and temperature phenomena have been investigated in an unmagnetized anodic glow plasma (fire ball). By applying high DC potential to the anode and cathode, intense plasma is formed near the anode. The discharge has been pulsed at a frequency of 3 KHz and Duty cycle of 50%, which leads to a modulation in the density and temperature inside the fireball. The temporal behaviour of n_e (t) and T_e (t) adjacent to the fireball has been investigated using triple probe and a hairpin probe. The results show a sharp density peak in the beginning of the pulse 'on' phase and the results are correlated with discharge current and the voltage. This type of power modulated (pulsed plasma) is potentially useful in the plasma material processing particularly for low ion energy modification of polymer surfaces substrates [1] [2] [3].

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239/PD-23/P

STUDY OF RADIO FREQUENCY REACTIVE MAGNETRON SPUTTERING DISCHARGE FOR DEPOSITION OF CORROSION RESISTANT TITANIUM OXIDE THIN FILM

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Abstract

The discharge characteristics have been studied in reactive environment of argon and oxygen gases in radio frequency (rf) magnetron discharge for optimal deposition of titanium oxide thin film. The variation of discharge characteristics such as electron temperature, electron density as well as dc self-bias have been studied at varying oxygen pressure but at constant argon pressure and applied power. Using optical emission spectroscopy, the variations of oxygen, argon, sputtered titanium lines and its molecular form and the titanium oxide band have been studied under different oxygen pressures. The metallic, transition and reactive modes of the discharge are characterized by observing the intensity of different species under different conditions. Typical deposition conditions have been optimized in the transition region of the reactive sputtering discharge where it has been observed that the intensity of atomic titanium line diminishes and the titanium oxide band becomes most prominent. Titanium oxide films have been deposited and its properties like corrosion resistance, adhesion, crystalline phases and optical properties have been studied. These films can be used as corrosion resistant film on bell metal.

248/PD-24/

ON ANALYSIS OF CHARGE EXCHANGE NEUTRAL PARTICLE ANALYZER MEASUREMENTS IN THE ADITYA TOKAMAK

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Abstract

Core-ion temperature, Ti0, measurements have routinely been carried out by the energy analysis of passive Charge Exchange (CX) neutrals escaping out of the ADITYA-tokamak (R/a=75cm/25cm) plasma using a 45° parallel plate electrostatic energy analyzer. The temporal evolutions of peak ion temperature in the core regime typically found to be Ti0~80 eV to 150 eV as estimated by analyzing the energetic CX-neutral counts obtained on four energy cannels using *Channeltrons* of multi-channel data acquisition system for circular limiter, *ohmically* heated plasma discharges. The maximum error in the Ti0 measurements comes out to be ΔTi0/Ti0~0.25. Ratio of ion temperature to the electron temperature (Ti/Te) is found to be in the range of ~0.3 to 0.4 for set of plasma discharges investigated herein. Several plasma discharges having similar plasma parameters are investigated for the ADITYA tokamak, which provides an estimate for the neutral hydrogen (H0) density in the core regime and its evolution with time. Effect of Ion cyclotron radio frequency heating (ICRH) on Ti0 is observed and reported here, which shows additional increase of Ti0 up to 60% for the set of plasma discharges investigated herein. Experimental observations of the CX-neutral counts at each energy channels are compared with the calculated CX-neutral energy spectrum using a simple slab model. Using the modeling results, local energy loss rate profile for the CX-particle flux leaking out of plasma has also been reported and compared with total CX-neutral power loss from the plasma based on experimental results. Temporal evolution of the total CX-power loss from the tokamak plasma during current flat top is also estimated and typically found to be around 3% of input ohmic power.

254/PD-25/P

PASCHEN CURVE, A NOVEL DIAGNOSTIC APPROACH TO VERIFY SUSTAINABILITY OF NON-THERMAL PLASMAS

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Abstract

Experimental
Gas discharges in plasma atmosphere are known to consist of a collection of different particles, mainly electrons, ions, neutral atoms and molecules. So the formation of plasmas in DBD systems and its sustainability are the main responsibilities of this piece of research work. The present need is to characterize the plasmas and optimization of the designed and fabricated plasma system under variable conditions. One of most important issue is the electrical breakdown of gases and to find the point of electrical breakdown of some volatile organic pollutants. Those are Benzene, toluene, xylene, chlorobenzene, dichlorobenzene, nitrobenzene, methylene chloride etc. Self-sustainability of DBD-plasmas are explained for different VOCs under different experimental conditions taking helium and argon as carrier gases in terms of Paschen's curves. It explains the breakdown voltage as a function of the electrode spacing or gas gap (d), operating pressure (p), and gas composition. The breakdown voltage is a function of the product of the pressure (p) and the inter-electrode distance (pd). It is verified that as the nature of substituent group changes, it varies the breakdown voltage and glow discharge zone following Townsend breakdown curve depending upon electron density of the system. The breakdown voltage is also interpreted as function bond dissociation energy.

258/PD-26/P

CALIBRATION OF SINE AND COSINE ROGOWSKI COILS

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Abstract

ADITYA-Upgrade tokamak is a medium sized air core tokamak with major radius of 0.75 m and minor radius of 0.25 m, which was recently upgraded from limiter to limiter-divertor configuration. Plasma position measurement and its control is imperative for successful operation of a tokamak. Plasma position is a measure of the displacement of the centroid of current carrying plasma column. Various diagnostics like Mirnov coils, External magnetic probes, Soft X-ray, etc. exist for the determination of plasma position. Sine or cosine coil is a modified form of a Rogowski coil in which the number of turns per unit length vary sinusoidally or cosinusoidally [1, 2]. The output of sine and cosine coil is proportional to the change in current and the vertical and horizontal displacement of the current centroid respectively. Further, since this diagnostic comprises of a single coil, the analysis becomes much easier as compared to other magnetic diagnostics. A pair of sine/cosine coils have been designed, fabricated and installed on ADITYA-U tokamak. After installation, these coils are calibrated in-situ using a single turn current carrying conductor placed inside the vacuum vessel, which mimics the plasma current. Current pulses of different magnitudes and pulse widths are applied to the conductor to observe the time response of the Cosine/Sine Coils. The considerations for design parameters for both the coils, their fabrication and installation procedure along with the calibration experiment, data analysis and the results will be discussed in this paper.

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286/PD-27/P

MODELINGOF AN OPTICAL CAVITY USING FINESSE

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Abstract

An optical cavity is an ultra-sensitive detection arrangement having diverse application. The cavity finds its application in laser spectroscopy [1], nonlinear optical devices[2], optical frequency metrology for precision measurement[3] and cavity quantum electrodynamics[4], besides its importance in laser physics where the photons can be amplified with or without a gain medium. Accuracy in measurements using an optical cavity can be increased only if the pair of mirrors constituting the cavity is properly aligned and precision locked. For all such measurements, the optical cavity is usually locked to the fundamental mode. The locking becomes a challenge if the cavity setup is exposed to vibration. In this paper, with the help of modeling the locking of an optical cavity using a feedback control loop is implemented.

Control loop is based on Pound-Drever-Hall (PDH)[5] technique which will lock and stabilize the optical cavity to the fundamental optical mode. To test the stability of the cavity, randomly generated mechanical vibration will be induced on the experimental setup which will try to unlock the optical cavity. These mechanical vibrations actually mimic the ambient noise or signals which try to detune the cavity from the fundamental mode. The detuning is compensatedexperimentally using a PDH control system. Modelling of the control loop is performed using the software Frequency domain INterferomEter Simulation Software (FINESSE)[6].

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287/PD-28/P

DEVELOPMENT OF VACUUM EQUIPMENT INTERFACE USING PYTHON FOR MONITORING AND CONTROL

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Abstract

A computer based interface was developed using Python[1] to operate and control a turbo-molecular pump (TMP) remotely. RS-232 was used to communicate between the pump controller and the computer. The interface was carried out using pyserialmodule[2] of Python which would detect and connect the equipment. Command strings from RS-232 consist of 8 bit data including the parity bits which are formatted and send from python. Parameters like voltage, current, speed of the pump, temperature of the pump bearing etc. can be read using this interface. Combination of Python modules were used to display, plot and store data received through the interface. The features of interface developed using Python was also validated using commercially available software like LabView and custom made T-plus software [3] of the pump manufacturer. The performance of this Python based interface was found to be highly satisfactory. With a slight alteration in protocol strings, such interface module can be used for controlling pumps of any make.

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294/PD-29/P

FABRICATION AND CHARACTERIZATION OF TRANSMISSION LINE FOR ITER ECE DIAGNOSTICS

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Abstract

The ITER ECE Diagnostics will be used to measure the electron cyclotron radiation in the frequency range 70-1000GHz. By analyzing the measured radiation, one can determine the electron plasma temperature with good spatial and temporal resolution. The ITER ECE system consists of front end optics including in-situ calibration sources, set of transmission lines (TLs), and ECE instruments like radiometers and Michelson interferometers.

For ITER ECE system, a broadband (70-1000GHz) TL system is required to transmit the ECE radiation and also the low power (~ few nW) thermal radiation (from calibration source) from tokamak vessel to ECE instruments which are placed ~ 43m away with attenuation not exceeding 15 dB and 22 dB in the frequency range of 70-400GHz and 400-1000GHz respectively. This is a challenging requirement and plays a vital role in the performance of ITER ECE transmission line. Different types of waveguides such as circular smooth walled, corrugated and rectangular waveguide are being assessed for acceptable level of transmission losses.

A prototype transmission line (TL) was designed and fabricated indigenously. The prototype TL consists of smooth walled circular waveguide straight sections (2 meters), 90-degree Miter bends, and pump-out tee and vacuum compatible waveguide joints based on metallic seal. The important criterion for fabricating waveguide components is the minimal geometrical imperfections like axial misalignment or offsets, axial tilts and variation in the diameter of the waveguide. These imperfections induce mode conversion losses in the TL system. The attenuation of the prototype TL system has been measured in the frequency range 70-1000GHz using a black body source and Michelson interferometer (70-1000GHz). The presentation will provide the details of waveguide components design and tolerance in the fabricated components along with the measurement results of the waveguide components.

294/PD-29/P

DESIGN AND DEVELOPMENT OF ICRH DIAGNOSTICS ON ADITYA-U TOKAMAK

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Abstract

The use of RF waves in various frequency ranges for auxiliary heating in most of the tokamaks is well established and a considerable amount of work has been done in this field world-wide. During ICRF heating a small amount of RF power is locally deposited at the edge. This changes the local plasma parameters and plasma wall interaction enhances. There exist possibilities of parasitic excitation of local modes and surface modes. Knowledge of edge plasma parameters is important for proper coupling of RF power from antenna to plasma and for proper tuning of antenna impedance. Studies of RF wave plasma interactions at the plasma edge therefore is of great interest. Proper diagnostics are needed to analyse edge plasma behaviour during Tokamak shots[1].

Some plasma edge diagnostics, used in most of the tokamaks like JET, Asdex-U,Tore Supra are 2π bolometer, Langmuir probes, Spectrometer, Charge Exchange diagnostic and Reflectometer [2].Few diagnostics have been developed for Aditya-U tokamak.Langmuir probes are to be used to measure edge plasma density and temperature. Loop probes and dipole probes have been developed to measure RF magnetic field and RF electric field.The probes are mounted in a probeholder above the ICRH antenna and movable in the SOL region by 50mm.These diagnostics are tested in the standalone mode for UHV compatibility.The diagnostics will be installed soon on Aditya-U tokamak. Some of the experimental results obtained from Langmuir and loop probes in Aditya tokamak during ICRH experiments are presented in the following paper.

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296/PD-31/P

ITER CXRS-PEDESTAL DIAGNOSTIC: PERFORMANCE ASSESSMENT USING SOS CODE

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Abstract

Charge eXchange Recombination Spectroscopy (CXRS) diagnostics has a primary role for measurements of ion temperature, plasma rotation and impurity density for ITER advance plasma control and physics studies. Measurement requirements for these parameters in the pedestal region (r/a=0.85 -1.0) need to be achieved by suitable design of the detection system. To measure the charge exchange impurity (He, Be, Ne, Ar, C) emission simultaneously, a broad wavelength spectroscopic system is needed along with high spectral resolution to measure the wavelength shift for velocity measurements. With the help of simulation of spectra (SOS) code [1], one can predict the impurity density profile and associated relative errors for a given input spectroscopic system specifications.

Preliminary performance assessment has been carried out using simulation of spectra (SOS) code. The impurity signal intensity, velocity and edge ion temperature profile, SNR, error profile estimated in the pedestal region for several ITER scenarios. The required inputs (total transmission, etendue, dispersion) of the light collection optics and spectroscopic system play a key role to meet the accuracy requirements as per ITER measurement requirements. Optical design tool ZEMAX [2], is used to study & optimize the transmission losses by attentive selection of optical components used for light collection, emitted from the interaction zone of the Diagnostic Neutral Beam (DNB) & plasma in the pedestal region. This paper will discuss the impact of the collection optics and spectroscopic system input parameters on estimated, impurities signal levels, temperature profiles, and velocity profiles for different ITER scenarios.

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319/PD-32/P

INVESTIGATION ON METAMATERIAL LENS ANTENNA DESIGN FOR FUSION PLASMA DIAGNOSTICS

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Abstract

The ability to control the propagation of millimeter waves through a magnetically confined plasma is a greater challenge in plasma research. Electron cyclotron emission (ECE) is one of the principal application in the detection of the electron temperature profile[1]. In order to image the best spatial resolution of the electron temperature, electron density and its fluctuation in the plasma, a highly and efficiently focusing diagnostic material element should be placed inside the tokamak, whose focal length increases with frequency and that can receive the radiation through it to focus it on the imaging surface.Metamaterials are artificially engineered structures that are known for their unusual material property, exhibit reverse chromatic aberration (RCA) [2], a frequency dependence phenomenon that enhances the focusing ability of a transmitter for a longer distance, opposite to what is normally encountered in natural materials. In [3], the proposed work explains the art of imagingantenna arrays from 100 GHz to 220 GHz for ECE detection at higher fields.The quality of ECE detection inside the DIII-D tokamak has been successfully improved by incorporating an optic element exhibiting RCA is discussed in[4]. In our proposed research, ECE from the plasma is reflected off through ametamaterial lens, placed on the low-field side of the tokamak, after which it is received by anEH horn antenna placed at higher field side at a distance of 1-2 meter replacing the plane mirrors which were previously used with a metamaterial lens would enable higher imaging. Moreover, moving the metamaterial lens near around the tokamak would result in change of foci that affect the changes in the toroidal field strength.

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320/PD-33/P

CONCEPTUAL DESIGN OF A NIR SPECTROMETER FOR ADITYA-U TOKAMAK

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Abstract

A new spectroscopic system detecting spectral emission in the near infrared (800 - 2300 nm) region of electromagnetic spectra is proposed for Aditya-U tokamak. The measurements will provide information that can be used for machine protection, plasma control and performance evaluation. Three experimental measurements are mainly proposed using the system. First is the spectral survey for Paschen H line series and low-Z impurity monitoring. The second one is to provide a validated background emission for divertor Thomson scattering experiments wherein blackbody radiation, bremsstrahlung, recombination and impurity lines contribute largely to the background noise. The third is the measurement of Br9/Paα intensity ratio which is sensitive to the temperature and hence serve as temperature diagnostic in the SOL and near-wall region of Aditya tokamak.

For designing the system, the signal estimation for the Paα line for existing plasma parameters of Aditya tokamak has been carried out. This is based on the measured values of temperature and density measurements available and also using simulations using DEGAS2 code []. Since the dark current levels of the commercially available detectors in the NIR range is significantly high (10 ke$^-$/p/s), signal estimation is one of the important factor in designing of the system. Theoretical estimation of the line and bremsstrahlung emission for the Paα line using the atomic data from the ADAS database has been done [2]. These are found to be ~10^{11} and 10^9 photons cm^{-2} s^{-1} for $n_e = 5\times10^{18}$ m^{-3}, T_e=1 eV and n_n=1×10^{17} m^{-3} respectively. The intensity estimates are well above the dark current levels of the detector. The design and selection of the spectroscopic system comprising of the spectrometer, grating, detector and the collection optics has been carried out based on the requirements of the experiments planned. The details of conceptual design of the overall system capable of measuring spectral emission in NIR range from Aditya-U tokamak will be presented in this paper.

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323/PD-34/P

X-RAY CRYSTAL SPECTROMETER FOR ADITYA-U TOKAMAK

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Abstract

A high resolution X-ray Crystal Spectrometer is designed, developed and fabricated for ADITYA-U Tokamak [1, 2] to measure ion temperature and plasma rotation velocity using Doppler broadening and Doppler shift of spectral line radiations emitted from tokamak plasma respectively. Detailed studies of impurity transport in typical discharges of ADITYA-U tokamak will be carried out using the spectrometer. It will also provide information about the core plasma parameters. The spectrometer consists of a cylindrically bent Si crystal and two dimension CCD detector to measure Ar XVII line emission at 3.9494 Å viewing the plasma tangentially in the toroidal plane of the vacuum vessel. A very thin Beryllium foil is used to avoid radiations in other wavelengths. The diagnostic has a tangential angle of 26° with respect to the toroidal direction in the magnetic axis and will be directly mounted on one of the radial ports of ADITYA-U. The crystal, foil and the CCD detector need to be put under ultra-high vacuum to detect X-ray radiation from the plasma. Due to the very complex geometry of the tokamak system and space limitation, the spectrometer system was subjected to stringent design restrictions. The spectrometer contains three major parts, the collection arm, crystal housing and detection arm. The engineering design has been optimized after adequately addressing issues related to port geometry, machine accessibility etc. In this paper we present the complete conceptual and engineering design of the spectrometer.

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325/PD-35/P

SPECTROSCOPY DIAGNOSTIC FOR MEASUREMENT OF PLASMA ROTATION ON ADITYA-U TOKAMAK

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Abstract

A high resolution spectroscopic diagnostic has been designed and developed for the measurement of plasma rotation and impurity ion temperature from emission of various ionisation stages of carbon impurity ion from ADITYA-U[1-2] Tokamak plasma. The diagnostic comprises of a high resolution 1m *f/8.7* Czerny Turner spectrometer equipped with 1800g/mm grating and coupled to a CCD camera. An array of nine 400 μm core fibers are lined onto the entrance slit to carry out measurement from at least eight lines of sight inside the plasma to find out spatial profile of the spectral emission from carbon. For this purpose the selected carbon emission lines are at 229.69, 227.09 and 529.01 nm from C^{2+}, C^{4+}, and C^{5+}, respectively. To measure the toroidal rotation velocity profile, one front end collections optic based on optical fiber and lens has been developed. This is having the lines of sight viewing the plasma along toroidal direction from a tangential view port of Aditya-U tokamak. Initial measurements to capture above mentioned spectral lines, experiment were carried out in the first phase of ADITYA-U operation using a 0.5m *f/6.5* spectrometer equipped with 1200g/mm grating along with CCD camera. In this presentation, the details on the development of the diagnostics and initial result will be discussed.

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326/PD-36/P

CALIBRATION OF MICHELSON INTERFEROMETER DIAGNOSTICS AND MEASUREMENTS WITH MONOCHROMATIC SOURCE

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Abstract

Michelson interferometer diagnostic is capable of measuring the spectrum of the electron cyclotron emission in a wide spectral range (70-500 GHz). The Michelson interferometer is calibrated with hot-cold technique and the sensitivity of the diagnostics is decided by these measurements. The hot source used in calibration is an electronically heated device at 873 K with black body properties and the cold source is LN2 at 77 K. Periodic switching between these sources is done during calibration. In-lab calibration is carried out to find equipment's sensitivity. Raw data stored during in-lab calibration is transformed into averaged interferograms and the averaged difference interferograms are Fourier transformed to generate difference frequency spectrum. The difference input intensity is calculated using Rayleigh-Jeans Law. Based on the difference frequency spectrum and difference input intensity, the radiation temperature of the hot source is determined and finally the in-lab calibration factor / sensitivity of the diagnostics is decided. The interferometer has a frequency resolution of 3.66 GHz and a temporal resolution of 16.67 ms. In-lab calibration of the Michelson interferometer has been carried out successfully and measurements have been taken with monochromatic source. The results of in-lab calibration and measurements with monochromatic source have been presented.

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328/PD-37/P

1-CHANNEL WIRELESS ACQUISITION SYSTEM FOR MAGNETIC DIAGNOSTICS OF ADITYA-U TOKAMAK

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Abstract

In recent years Data Acquisition Systems have proficient advances mainly due to the reduction in cost and gaining functionally of systems based on microcontrollers and microcomputers. This paper invites a prototype model of one channel wireless data acquisition system. The system contains a ratiometric linear Hall Effect sensor, embedded system with Atmeg328 microcontroller for both transmitter and receiver and wireless transceiver module NRF24L01+. The readings from the ratiometric linear Hall Effect sensor,IC - A1301KUA-T are digitized by in built A/D converter present in the embedded system then they are sent to the wireless transceiver NRF24L01+. NRF24L01+ performs GFSK modulation technique for transmission of the digital data.When the bar magnet is kept close to the sensor we found 448 gauss (0.0448Tesla). We received the same transmitted data without any error. Moreover we show the results from Hall Effect sensors mounted in 3-axis perpendicular to each other and observations of Hall Effect sensor in presence of High voltage. Helmholtz coil experimental results validated the Hall Effect Sensor used it for magnetic diagnostics.

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352/PD-38/P

MAGNETIC DIAGNOSIS OF PLASMA IN A DC NON-TRANSFERRED ARC PLASMA TORCH

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Abstract

In a novel experiment, magnetic probes have been used to investigate the behavior of the plasma column inside a dc non-transferred plasma torch. The probes were incorporated inside the anode cooling channels of the torch to capture the time-varying magnetic field components arising due to the return currents through the anode material. While the current was dc, it was spatially varying due to the arc root rotation arising due the magnetic field. It was this field that was captured by the probes. Experiments were performed for a wide range of gas flow rates (20 to 60 lpm) and currents (70 - 120 A) in the presence of a strong axial external magnetic field (100 to 500 G) at atmospheric pressure with nitrogen as working gas. Results show that the probes were able to capture not just the arc root rotation, but also phenomena such as shunting, whether the arc root is constricted or diffused, stagnation time of the arc root on the anode etc. It is observed clearly that the stagnation time of arc root decreases with increasing magnetic field. A clear shift of rotational frequency is also visible with higher discharge current showing the effect of current density on the arc root motion, in agreement with results obtained using fast imaging diagnostics [1].

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363/PD-39/P

CONCEPUAL DESIGN OF LANGMUIR PROBES FOR THE DIAGNOSIS OF PLASMA EDGE OF ADITYA-U

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Abstract

The role of the tokamak edge plasma in influencing the fusion energy yield of tokamaks is now widely recognized and is reflected in the increasing efforts devoted to the experimental and theoretical study of scrape-off layer (SOL) physics. Of particular concern are aspects of the plasma-surface interaction leading to impurity production and the subsequent impurity transport and contamination of the core plasma. The impurity transport depends strongly on the background properties of the SOL plasma, such as the plasma density, potential, electron and ion temperature, ion flows, flow velocity and their fluctuations and transport coefficients. Understanding of the underlying physics in the edge plasma of tokamaks requires knowledge of these parameters with a high spatial and temporal resolution. It is widely recognized that the electric probes are important tools for studying edge plasma physics in tokamaks because required spatial and temporal resolution can be easily achieved, cost-effectively. Various types of Langmuir probes, namely limiter flush mounted probes, rack probes and garland probes are conceptualized and installed on Aditya-U to diagnose its edge plasmas. The poster discusses the design considerations and technical details for variety of probes installed on Aditya-U.

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401/PD-40/P

BOOST-BUCK BIAS FLOATING HIGH VOLTAGE POWER SUPPLY FOR DOUBLE/ TRIPLE PROBE DIAGNOSTICS IN LVPD

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Abstract

Introduction of double and triple probe diagnostics largely overcomes the problem encountered by conventional Langmuir probes but these diagnostics still suffer from signal corruption problem due to ground leakage current. Problems like signal corruption due to finite galvanic insulations of the mains driver power supplies, deriving power from ground referenced grids, the ground current interference, distributed ground capacitance of probe transmission line can be nullified by adopting to floating power supplies, capable of working in boost/buck mode. Conventionally available power supplies suffer from these problems [1, 2].

In this regard, we configured a scheme in LVPD for feeding power to double/ triple probes where floating bias voltage is derived through a specially configured bank of floating batteries of capacity $\sim 140V$ (10 nos. each of rating $12-14.5V$). An optically isolated, gated triggered ramp generator circuit is developed for this purpose which draws power from the floating battery bank. The basic ramp signal is amplified with a gain of ~ 50 before being applied to the probe. A high voltage, OPAMP (IC PA85) based, regulated power supply compatible to work in boost and buck control operations is used for sweeping the probes. The bias circuit has a facility to switch between Ramped and DC bias within +/- 70V range for symmetric operation and between -84V to +56 V when used in offset mode of operation. Results on its design and performance with and without plasma load will be presented in the conference.

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416/PD-41/P

INFLUENCE OF THE MAGNETIC FIELD ON NEAR ANODE PLASMA PROPERTIES OF REFLEX PLASMA SOURCE

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Abstract

Experimental study of the effect of applied magnetic field on the discharge properties of argon gas in the reflex plasma source is carried out. A reflex plasma source used is a combination of modified hollow cathode and penning ionization gauge discharge. A uniform axial magnetic field generated by Helmholtz coil configuration is varied from 0 to 125 gauss. It is observed that axial magnetic field lowers down the required breakdown voltage. The discharge current - voltage characteristics for argon plasma is studied at four different magnetic fields. The dependencies of plasma parameter like plasma density, electron temperature, and plasma potential on the magnetic field were studied by single Langmuir probe

It is found that current-voltage characteristics obey a relation $I \alpha V^n$ .The value of 'n' increases with magnetic fields. The discharge current increases two fold with application of 100 Gauss magnetic field indicating enhancement in plasma density. The potential drop and electron temperature near the anode increases with magnetic field. At higher magnetic field, the anode sheath is transformed into anode spot. The plasma potential with reference to anode gets locked to the ionization potential of argon gas after the anode spot formation. The oscillations of few KHz frequencies in the discharge current and floating potential are observed when anode spot formation takes place.

421/PD-42/P

FEASIBILITY STUDY TO UPGRADE THE SPACE RESOLVE VUV SPECTROSCOPY SYSTEM TO MEASURE ION TEMPERATURE IN ADITYA-U TOKAMAK

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Abstract

VUV spectroscopy in 120 to 300 nm wavelength ranges is important to get space resolved measurement of impurity emissions for studying the impurity transport in the tokamak plasma. It can also give the impurity ion temperature measurement using the Doppler broaden spectral line profile from the highly ionized carbon and oxygen ions. To measure the ion temperature, VUV spectrometer has to have good spectral resolution since the wavelengths are in VUV region and then Doppler widths become smaller. To carry out feasibility study, the existing space resolved VUV spectroscopy system coupled to Aditya tokamak was studied for in terms of dispersion and spectral resolution. This system is having a 1 m Czerny-Turner type spectrometer with 1200 grooves/mm grating [1]. An X-ray sensitive CCD camera having 1024x252 pixels and its width of 20 um was coupled with spectrometer for this study. The reciprocal linear dispersion of the spectrometer has been estimated at 228.8 nm using Cd-Ne hollow cathode lamp and compared with theoretical value. The variation of spectral resolution with entrance slit width has been also studied and compared with calculated one. Then the Doppler width for the 154.8 of C^{3+}, 162.3 of O^{7+}, 227.1 of C^{4+} and 229.6 of C^{2+} impurities ions has been calculated using Matlab code. It is found that 200 eV of ion temperate measured by C^{4+} spectral line 227.1 nm is equivalent to the spectral resolution of 0.7 nm at the entrance slit width of 50 um. Through this study it is found that upgraded system having a 2400 grooves/mm grating would be very good to measure the ion temperature of 100 eV using C^{4+} spectral line at 227.1 nm. In this presentation the details of this feasibility study will be discussed.

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422/PD-43/P

PARAMETRIC VARIATION OF RADIATED POWER IN ADITYA TOKAMAK

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Abstract

We report the study of parametric variation of radiated power in Aditya tokamak for ohmic discharges. The radiated power was measured using AXUV diodes that are responsive to radiation in the range 1eV to 4keV and are insensitive to the neutral particles (<0.5 keV). Hence only the radiation power loss is measured and charge exchange losses are excluded. The measured radiated power was also used for the estimation of the effective ion charge, Z_{eff} based on the scaling obtained by the regression analysis of the data from multiple tokamaks [1]. The estimated values were compared with the experimental Z_{eff} values obtained from the visible continuum measurement. We also tested the scaling for modelled radiation power loss [2].

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425/PD-44/P

PASSIVE CHARGE EXCHANGE NEUTRAL PARTICLE ANALYZER FOR ADIYA-U TOKAMAK

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Abstract

Passive charge exchange diagnostic is well established technique for measuring core-ion temperature of tokamak plasma. Energetic neutral particles that are formed due to charge exchange of plasma ions with neutral atoms, escape the plasma readily. These neutral atoms that are re-ionized and analyzed using analyzer can provide information about the energy distribution of plasma ions.

A passive charge exchange neutral particle analyser has been designed and developed for Aditya-U tokamak. It consists of a gas cell based stripping cell, a 45-degree parallel plate electrostatic energy analyser, Channel electron multipliers as detectors and an integrated measurement system CEM-IMS as DAQ. The stripping cell, which is made of soft iron, is a 200 mm long narrow tube of diameter 4 mm. The analyzer box is made of soft iron (to reduce the stray magnetic field) and houses the 45-degree parallel plate electrostatic energy analyser and detectors. The CEM-IMS is a modular integrated measurement system capable of recording the measurements by remote control via network. CEM-IMS will be used as a pulse counting module to acquire output pulses of channel electron multipliers of charge exchange neutral particle analyzer. This paper will describe the Passive Charge Exchange Neutral Particle Analyzer designed and developed for estimating the core-ion temperature and its temporal evolution for ADIYA-U Tokamak plasma.

435/PD-45/P

IMPURITY BEHAVIOR IN THE HIGH DENSITY ADITYA TOKAMAK PLASMAS

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Abstract

Impurity behaviour has been studied for the high density Aditya tokamak plasmas. These discharges were operated with increasing toroidal magnetic field and thereby it sustained higher plasma current. Higher densities were achieved with the help of multiple gas puffs. High energy confinement times, sometimes higher than the values predicated by Neo-Alcator scaling for Ohmically heated tokamak plasma were achieved for these discharges [1]. The neutral hydrogen and impurity emissions were monitored by optical fiber, interference filter and PMT based system in the visible range. The spectral line emissions from higher ionized charge state of impurities, such as C^{4+}, O^{5+} and Fe^{14+}, were recorded by VUV survey spectrometer operated in the 10 - 180 nm. This wavelength range covers the important lines of partially ionized low and medium *Z* impurities, as for example iron and also emissions from higher excited states of highly ionized low Z impurities, like carbon and oxygen. It has been found that H_{α}, OII, and CIII emissions normalized with density (n_e), and visible continuum normalized with n_e^2 show a gradual decrease with increase in density. This clearly suggests the achievement of improved confinement for Aditya plasma and mostly correlates with obtained higher confinement times of these discharges. In this presentation, details studies on visible and VUV emissions will be discussed for its role in these high densities plasma discharges.

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439/PD-46/P

ITER-INDIA PROGRESS ON THE DESIGN OF THE ITER ECE DIAGNOSTIC SYSTEM

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Abstract

The ITER ECE diagnostic system will provide important information on the time evolution of the electron temperature profile, magneto hydrodynamic (MHD) fluctuation spectra, the runaway electron spectrum, and the radiated power in the electron cyclotron frequency range (70-1000 GHz). These measurements will be used for advanced real time plasma control and physics studies [1]. The scope of the design and development of the ECE diagnostic for ITER is shared between the Indian Domestic Agency (ITER-India) and the US Domestic Agency (US-ITER). The ITER ECE diagnostic system has two measurement views in the plasma, a radial and an oblique view (12^0 with respect to radial), for the measurement of ECE radiation. ITER-India is responsible for providing the polarization splitter units and broadband (70-1000 GHz) transmission system, a high temperature calibration source for the ECE diagnostic room, two Michelson interferometers (70-1000 GHz), a low-frequency radiometer (122-230 GHz) and a RF stray radiation protection system. The remainder of the ECE system including the front-end components, in-situ calibration sources in the front-end and the high-frequency radiometer (220-320 GHz) will be provided by US. The control, data acquisition and analysis software will be developed by both the DAs for their respective systems.

The preliminary design of various sub-systems is in progress and they are in different phases of design, prototype development and testing. The major design challenges are: 1) Development of the ~ 43m long low-loss transmission lines that transport the 70-1000 GHz ECE radiation from the front-end to the diagnostics hall, 2) High throughput and fast (20 ms) continuous scanning mechanism for the moving mirror in vacuum for Fourier Transform Spectrometer, 3) Radiometer for wide band (122-230 GHz) with low noise, high sensitivity with minimum number of mixers, 4) RF Stray radiation protection system at 170 GHz, 5) High temperature black body calibration source, and 6) Integration of transmission lines and auxiliaries into the tokamak infrastructure

(ports, building etc). Therefore, prototypes are being developed in order to demonstrate that components meet the ITER requirements. Prototypes of the transmission line and the Fourier Transform spectrometer have been designed, developed and are being tested. A prototype 200-300 GHz radiometer based on highly integrated millimeter wave technology has been developed and tested on the DIII-D tokamak [2]. Prototype design, development and characterization of the calibration source and stray radiation protection system are in progress.

In this paper, ITER-India progress towards the ITER ECE diagnostic along with some prototype designs and their test results will be presented.

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444/PD-47/P

ARMING THE NON-NEUTRAL PLASMA SYSTEM WITH IMAGING DIAGNOSTICS – A SCHEME

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Abstract

Electron plasmas confined in linear traps (The Penning – Malmberg traps) have already shown striking similarities with the two dimensional Euler fluids. Imaging mechanisms have also been established [1] in linear traps to view the relaxation of initially turbulent electron vortices to single vortex or vortex crystals after vortices merge with one another as the time progresses [2]. A similar imaging scheme has been planned and currently being executed in order to view the vortex structures of electron plasma in Non-neutral Plasma System SMARTEX – C that has the sharp B – field gradient $\partial_r B_\varphi$. The position of imaging components in and out of the vessel has been shown in this paper. A significant difference between the vortex images obtained in linear traps and SMARTEX – C is anticipated owing to the field gradients.

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477/PD-48/P

DEPENDENCE OF INTER-ELECTRODE DISTANCES ON THE FLUCTUATIONS BEHAVIOUR IN A CO-AXIAL GLOW DISCHARGE

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Abstract

Observation of chaos in Langmuir Probe (LP) floating potential (V_f) oscillations have been reported earlier in coaxial electrode geometry [1]. Recently a hysteresis in the amplitudes of these oscillations near the transition zone of order-to-chaos-to-order has been reported in identical electrode geometry by Kumar et al [2]. However, the evolution of this hysteresis is seen to depend on the initial condition and how the discharge evolves after the 1st Negative Differential Resistance [NDR] as reported in Ref. [3]. Since the behaviour of the discharge voltage (V_d) versus discharge current (I_d) characteristics is seen to be linked to the central pin being the anode, which is indicative of a role of the electrode geometry, studies were carried out using different inter-electrode distances.

This paper attempts to understand the role of the electrode dimensions in the evolution of V_f oscillations with the V_d-I_d characteristics and order-to-chaos-to-order transitions in a co-axial DC electrode discharge system. Experimental observations indicate that the ratio of the anode-to-cathode radii determines the evolution path of the transition and the anode dimensions determine the discharge conductivity after the 1st NDR region. The onset of the order-to-chaos-to-order transition is linked to the cathode dimensions. The above experiments and observations will be reported in this paper.

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317/PD-50/P

DESIGNING AND FABRICATION OF LASER HEATED EMISSIVE PROBE FOR ADITYA – U TOKAMAK

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Abstract

Electron emissive probes are tools for direct measurement of plasma potential. Laser Heated Emissive Probe (LHEP) has several advantages over conventional emissive probe (CEP), especially in tokamaks where the frequent vacuum breaks are not at all desirable to change the burnt filaments of CEP. Very few attempts have been made to use LHEP's in high temperature magnetically confined systems. In this paper we present a unique design of the LHEP for ADITYA-U tokamak overcoming many constraints of the complicated geometries and limitations of a big device like tokamak. The design involves a lot of understanding of the laser optics, probe material studies, tokamak geometry and its operation parameters and material science. A radially movable probe tip made up of LaB_6 (low work function and the high melting point) is heated by a CW CO_2 laser at 10.6 μm having a maximum power of 55 watts. The Laser is shined on the probe tip using a specially designed force air-cooled fiber as the laser cannot be kept close to high magnetic field environment of tokamaks. The probe shaft also contains another probe tip for simultaneous cold probe measurements at close locations inside the plasma. The set-up will provide direct measurements of radial profiles of plasma potential in the edge plasma region of ADITYA-U tokamak, which will give the radial electric fields in the edge region.

396/PD-51/P

RECENT DEVELOPMENT AND PRIMARY RESULTS OF 2.45 GHZ MICROWAVE DISCHARGE ECR ION SOURCE ALONG WITH HIGH POWER BEAM DIAGNOSTICS FACILITY

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Abstract

Future trends in ion source technology aims at increasing the ion current in the tens of mA range. It also requires very intense beam and its emittance in the range of 0.2pi.mm-mrad-0.01pi.mm-mrad for the accelerator applications. Despite the limitations of obtaining complex magnetic structure, microwave power and frequency, there is another alternative for acquiring these stringent requirements. High density plasma generation using microwave discharge and ECR technique simultaneously can achieve this demand [1, 2].

A continuous wave (CW) as well as a pulse mode microwave discharge ECR ion source was developed along with Allison Type high power Emittance Scanner. The first plasma generated was characterized by UV-VIS-NIR spectrometer by varying the microwave input power from 10-180W and pressure from 5x10-4mbar to 1.5mbar.Microwave power reflection was measured using a crystal detector placed after the circulator (isolator and water dummy load) on the magnetron power display unit. The power transfer was maximized between the ridged waveguide transformer and plasma by tuning the three stubs. Silver-Nova super range TE cooled spectrometers is having resolution of 1nm and slit dimension of 25um.Detector type is 2048 pixel CCD and Detector array wavelength ranges from 190-1110nm. The parameters of the Collimating lens for UV-VIS are 5mm Diameter and Wavelength of 190-2200nm.The field of view of the lens is ~ 3 degrees. Fiber optic cable is having length of ~1-2 meter and Diameter of 400 µm with Connector SMA905.The spectrum is studied using SpectraWiz software. The emission lines of operating gas argon is identified between 700nm-900nm wavelength at an operating gas pressure of 1.1mbar and power 150W.The temperature ranges 0.4eV-1eV for the same operating conditions.

53/PD-52/P

AN EXPERIMENTAL SET-UP TO STUDY NON-RADIATIVE COLLISIONAL PROCESSES RELEVANT TO FUSION EDGE PLASMAS USING LOW ENERGY ION AND ELECTRON IMPACT

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Abstract

It is the era to search for the alternative to conventional source of energy. It was Albert Einstein who established the mass-energy equivalence that opened the window to think about the application of peaceful nuclear energy. Worldwide there are several fusion program going on in which DT reaction is confined either by magnetic or inertial confinement. There are numerous reactions taking place when the plasma particles interact with the wall of the reactor. Non-radiative collisional processes play vital role in the understanding of the various mechanisms in edge plasma boundary. Tungsten is suited as the best candidate for the wall material in fusion devices and for radiative cooling inert gases are supposed to circulate in diverter region. In view of the above, we have developed an experimental set-up using time of flight mass spectrometry to investigate the non-radiative atomic and molecular processes relevant to fusion edge plasma using low energy ion as well as electron impact. Low energy N2+ ion beam produced from Coluron ion source is allowed to interact with tungsten surface and we found the formation of tungsten nitride layer on the surface of the tungsten surface [1, 2]. In addition, we investigate the collision of keV electron beam with neutral Argon gas which led the formation of multiply charged Argon ions [3]. The details of the experimental work with theoretical comparison will be presented and discussed.

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261/PD-53/P

STUDIES OF OXYGEN IMPURITY BEHAVIOR IN ADITYA TOKAMAK PLASMA

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Abstract

Impurities (species other than the fuel species)affect the tokamak plasma significantly through radiation loss and fuel dilution. Hence studies of their concentration and dynamics is of great importance in the tokamak plasmas research. Oxygen is one of the most dominant low-Z impurity species other than carbon, limiter material, in the Aditya tokamak. The emission from oxygen ions are routinely monitored using vacuum ultraviolet (VUV) survey spectroscopic system coupled to Aditya tokamak. It is having three gratings with grove density of 290, 450 and 2105 grooves/mm for having measurements in different wavelength ranges with different resolution. For the reported work, grating with 450 grooves/mm, having capability to cover wavelength range from 10 nm to 110 nm with resolution of 0.45 nm has been used. Spectral emission lines of three oxygen ions O^{3+} (79.01and 23.85 nm), O^{4+} (62.97 and 17.22 nm) and O^{5+} (103.2 and 15.01 nm) in the VUV spectral range from the typical discharges of ADITYA tokamak have been recorded and analyzed. The intensity ratios of the spectral lines of same ionization stages and that of O^{5+} and O^{3+} has been obtained for different plasma scenarios. Asthe O^{5+} and O^{3+} charge states originate at different radial location of the plasma depending upon the radial profile of electron temperature, the intensity ratio of these two and its time evolution provide insights of Oxygen transport in ADITYA tokamak. It is observed that the intensity ratio of O^{5+} and O^{3+}varied differently in comparison to emissions from plasma edge, for example H_α and that of O^{1+}, providing insights in the impurity behavior in the core plasma region. In this presentation, understanding of oxygen transport is attempted through observing the variation of the ratio of O^{5+} and O^{3+}. The ratios are also simulated using impurity transport code, Strahl and compared with the experimental data for understanding the optical process responsible to these spectral lines.

282/PD-53/P

CHORD AVERAGE Z_{eff} CALCULATION FOR SST-1 AND ADITYA TOKAMAK USING MODIFIED ANOMALY FACTOR α

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Abstract

The effective ion charge Z_{eff} represents the average molecule mass of Z_i of gases inside the system, which indicates the level of impurity in to the plasma. This impurity can be either single chemical element or variety of compounds coming out from vessel wall or plasma facing component. To keep impurity level low in tokamak chamber, adequate conditioning is performed to avoiding sputtering of particles in plasma wall interaction. Z_{eff} measurement routinely performed with line-integrated visible bremsstrahlung measurements using electron density and temperature profiles along with the plasma geometry. In this communication we are reporting a new technique to calculation of Z_{eff} by modified anomaly factor α, which is the ratio of plasma resistivity(η_p) to Spitzer resistivity(η_{II}) predicted by spitzer for pure hydrogen plasma. This method assumes the plasma is purely resistive. Salient feature of this technique that it is totally independent from plasma density and uses total radiated power(P_{rad}) measured by bolometric measurement and chord average electron(T_e) temperature by Soft X-Ray(SXR) diagnostics as input. Temporal profile of Z_{eff} is calculated for plasma discharges in SST-1 and ADITYA. Calculated Z_{eff} datas are validated with the Z_{eff} measured from line integrated visible bremsstrahlung. Average Z_{eff} measured at plasma flattop with this method is varies from 2 to 5 in SST-1 and 3 to 6 in ADITYA for some shots.

474/PD-55/P

APPLICATION OF FRACTAL DIMENSION FOR THE STUDY OF TOMOGRAPHIC IMAGES OF A MICROWAVE INDUCED COMPACT PLASMA

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Abstract

Tomography is a non-invasive technique that generates 2D and 3D images of an object from its measured projection data [1]. This data carries the signature of the inner profile in the form of the attenuated energy spectrum. Tomographic diagnostics for non-thermal plasma (such as microwave induced multicusp compact plasma source) open up new possibilities to study the fundamental physical mechanisms in this area.

Tomographic plasma images have a degree of randomness associated which is self-similar in nature. Intensity of the plasma surface can be viewed as a rugged surface, if pixel intensity act as a height of the plane. The fractal concept developed by Mandelbrot [2] provides a detailed understanding of ruggedness of natural surfaces and many other natural phenomena. It has been applied to many different areas of science and engineering fields. Fractal Dimensions (FD) represents a reasonable quality index for a tomographic image [3].

An optical emission tomography set-up for compact plasma system has been developed [4]. Experiments have been carried out (for strong argon emission lines) by varying the incident microwave power, gas pressure and the axial position of the multicusp. The profile of plasma emissivity, N_e and T_e in the plasma cross section are obtained using a combination of optical emission spectroscopy [5] and tomographic reconstruction method [6]. Box-Count method is used for FD measurement in the present work. Analysis of reconstructed plasma intensity using fractal dimension reveals interesting information on physical phenomenon occuring inside the plasma.

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3/LP-1/P

DYNAMICS OF *Q*-GAUSSIAN LASER BEAM IN PREFORMED COLLISIONAL PLASMA CHANNEL WITH NONLINEAR ABSORPTION

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Abstract

Analysis of dynamics of *q*-Gaussian laser beam propagating through preformed collisional plasma channel with nonlinear absorption has been presented. Following Drude model, the dielectric function of the plasma channel has been obtained for collisional nonlinearity. An approximate numerical solution of the nonlinear Schrodinger wave equation (NSWE) for the field of the laser beam has been obtained with the help of moment theory approach in W.K.B approximation. Particular emphases are put on the variations of both the beam width and the longitudinal phase delay with the distance of propagation alongthe channel. Self-trapping of the laser beam also has been investigated.

14/LP-2/P

LASER BEAT WAVE CYCLOTRON HEATING OF RIPPLED DENSITY PLASMA

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Abstract

A kinetic formulism is developed for cyclotron heating of a ripple density plasma by beating two collinear lasers across the static magnetic field. The beat ponder motive force drives a large amplitude Bernstein quasi mode which suffers cyclotron damping on electrons. Finite Larmor radius effects play a prominent role in the heating. Electron temperature scaling with plasma density, ambient magnetic field, ripple wave number and laser frequency has been obtained. Its relevance to beat wave magnetic field generation experiments would be discussed.

18/LP-3/P

PROPAGATION OF ELECTROMAGNETIC WAVE IN QUANTUM DUSTY MAGNETOPLASMA WITH TWO DIFFERENT ELECTRON SPIN STATES

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Abstract

Dusty plasma is an ionized gas containing dust particles. Dusts are micron-sized particles that become electrically charged through interaction with the background plasma causing them to act as a third charged plasma species. The dust particulars are quite common in different environments of space and astrophysical plasmas such as interstellar medium, interplanetary space, molecular clouds, planetary rings, Earth's environments and in low-temperature laboratory dusty plasmas devices [1,2]. The evolution of intrinsic spin effects of electrons in dusty plasma is significant when it is cooled down to an extremely low temperature such that the de-Broglie thermal wavelength [3,4] associated with the charged particle is comparable to or larger than the inter-particle distance. In such a condition, the Fermi temperature which is related to equilibrium density of charge particle must be greater than the thermal temperature of the system. Till now, the plasma electrons in dusty plasma were considered as a single fluid. In the present paper, we consider the existence of two electrons population namely spin-up and spin-down relative to the background magnetic field. The spin state of particles will be also perturbed by the presence of electromagnetic waves. The seperation of spin is well defind provided the force associcated with spin flip [5,6] can be neglected.

The present paper is devoted to the study of propagation of electromagnetic wave in quantum dusty magnetoplasma with two different spin states of electrons.The effects of quantum Bohm potential, electron Fermi pressure and spin magnetic momenta has been analysed taking into account the difference in spin-up and spin-down concentration of electrons caused by external magnetic field. The longitudnal dispersion relation for electromagnetic waves in dusty magnetoplasma has been setup. The right circularly polarized, left circularly polarized wave, ordinary mode and extra-ordinary mode have been analyzed. Growth rate has been calculated and effect of spin polarization has been studied.

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19/LP-4/P

LASER COUPLING TO ANHARMONIC CARBON NANOTUBE ARRAY AND TERAHERTZ GENERATION

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Abstract

A scheme of terahertz generation, by beating two collinear lasers in a matrix of anharmonic carbon nanotubes (CNTs), is proposed. . The lasers induce large excursions on CNT electrons. The restoration space charge force on electrons is anharmonic and gives rise to nonlinear current at the beat frequency in the nanotube matrix. Each nanotube acts as a dipole radiator and one obtains THz radiation with high antenna gain. THz power is resonantly enhanced at the plasmon resonance, $\omega = \omega_p (1+\beta)/\sqrt{2}$ (where ω_p is plasma frequency and β is a characterizing parameter) only limited by the collisions and anharmonicity.

34/LP-5/P

NONLINEAR PROPAGATION OF TWO INTENSE ELLIPTICAL LASER BEAMS IN COLLISIONLESS PLASMA

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Abstract

This paper presents the propagation of two intense cross-focused elliptical laser beams (ELBs) having different frequencies along with the combined effect of relativistic and ponder motive nonlinearities in collision less plasma. Due to mutual interaction of two elliptical laser beams, cross-focusing takes place in the plasma. The effective dielectric constant of the plasma and nonlinear differential equations for the beam width parameters of elliptical laser beams have been set up and solved numerically. A paraxial ray approximation has been used in the present analysis. The effect of various laser and plasma parameters such as incident laser intensity and plasma density on the focusing of laser beams has been explored. The results are compared with only relativistic nonlinearity and the Gaussian profile of laser beams. It is observed that the focusing of the beams in plasma is faster in relativistic-ponder motive regime. This study is useful in determining the propagation dynamics of ELBs in plasma and finds application in particle acceleration schemes and tera hertz generation in laser plasma interaction.

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35/LP-6/P

INTERACTION OF LASER PULSE WITH MASS-LIMITED THIN PLASMA TARGET IN RADIATION PRESSURE DOMINANT REGIME

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Abstract

Lasers are sources of the strongest electromagnetic radiation under terrestrial conditions[1]. This gave impetus to extensive theoretical and experimental studies of ion acceleration using high-power lasers[2].Ion acceleration is due to the radiation pressure of the super-intense laser pulse on the electron component of the thin plasma, with the momentum being transferred to the ions through the electric field that arises from the charge separation [3]. This mechanism of ion acceleration has been called the radiation-pressure-dominant (RPD) mechanism. Recent studies on laser driven ion acceleration suggest that transversely inhomogeneous laser pulse irradiating a target of transverse size comparable with laser pulse waist (mass limited target) leads to enhanced ion energy. The portion of the irradiated target is pushed in the longitudinal direction and it expands in the transverse direction [4]. As a consequence the number of ions to be accelerated in the longitudinal direction is decreased and thus laser energy per ion is increased in the longitudinal direction [5]. It is, however, important to investigate the ion acceleration dependence on the parameters of the laser pulse and its shape. In this presentation we investigate analytically and numerically the effect of laser pulse transverse inhomogeneity on ion acceleration in RPD regime. Our results show that due to transverse expansion of the thin plasma foil, the momentum and energy of the ions grow faster than in the case of nonexpanding foil.

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38/LP-7/P

TERAHERTZ RADIATION GENERATION BY NONLINEAR MIXING OF LASERS INCIDENT ON A STEP DENSITY PROFILE PLASMA

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Abstract

An analytical formalism of the terahertz (THz) wave generation by nonlinear mixing of two lasers in hot magnetized plasma with step density profile is studied. In this process, the lasers incident on plasma surface couple nonlinearly through the ponder motive force. The plasma electrons start oscillating and give rise to space charge field in the plasma. Now space charge field and drives a non-linear current density $\vec{J}^{NL}$, giving rise to the THz wave generation on the reflection side. Presence of the static magnetic field may enhance the coupling between space charge mode and generated THz wave. Maximum THz radiation amplitude is obtained at an optimum angle of incidence θ ~60°.

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79/LP-8/P

OSCILLATING TWO-STREAM INSTABILITY IN PRESENCE OF STRONGLY COUPLED IONS

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Abstract

Oscillating two-stream instability (OTSI) of a high amplitude laser or a plasma wave is investigated in plasmas with strongly correlated/coupled ions. It is shownthat in the regime $\Gamma > 3.2$, the pressure of strongly coupled ions become negative which leads to an enhance bunching of ions and concomitant destabilization of oscillating two-stream instability. Applications of these results to ion accelerator and inertial confinement fusion experiments are discussed.

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87/LP-9/P

IONIZATION DYNAMICS OF THE INTERACTION OF SHORT XUV PULSES WITH DEUTERIUM CLUSTERS

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Abstract

The study of interaction of lasers and clusters has seen a lot of development in the past two decades. Due to the flexibility of the laser and cluster parameters used in these studies, the scope of this field of research is quite wide. Recent years have seen a lot of work being put into studying the interaction of atomic clusters with extreme ultraviolet (XUV) pulses. XUV pulses have the wavelength range of 10-130 nm. The ionization dynamics of laser-cluster interaction in case of XUV pulses is quite different as compared to intense, infrared (IR) pulses. The initial ionization is caused by single photon ionization in which the photon carrying sufficient energy is absorbed by the neutral atom and an electron is ejected. This electron carries some kinetic energy which assists in the subsequent collisional ionization of the cluster [1]. However, since the pulse wavelength is quite short, the ponder motive potential is not strong enough to cause outer ionization and strip the cluster completely of its electrons, as in the case of intense IR pulses. Thus, there may or may not be formation of nano plasma and consequently, the cluster expansion may be driven either by hydrodynamic pressure or coulomb repulsion [2].

Various experimental studies have been conducted for noble gas clusters like Argon and Xenon using different pulse duration of XUV pulses. However, sub-cycle pulse duration of XUV pulses has not been looked into in much detail. For our study, we have first formulated the initial ionization of the cluster using the technique of atomic photoionization, as the ionization mechanisms used for IR pulses cannot be used for XUV pulses. We have firstly studied the atomic photoionization of a single hydrogen atom using the approach presented in Astapenko et. al[3]. This code can be employed to further study the atomic photoionization of Deuterium clusters. Since the XUV pulses don't provide enough energy for outer ionization of a cluster, it will be interesting to see whether the sub-cycle pulses can provide with sufficiently strong intra-cluster fields to aid the stripping of electrons from the cluster.

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89/LP-10/P

CYCLOTRON EFFECTS ON HOT ELECTRON GENERATION AND THEIR ROLE IN PROTON ACCELERATION BY A SHORT PULSE CIRCULARLY POLARIZED LASER FROM OVERDENSE PLASMAS

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Abstract

Generation of high energetic protons has been an interesting area of research due to its wide range of applications [1,2]. Multi-MeV proton beams driven by hot electrons have been generated experimentally by the interaction of high intensity lasers with solid targets and thin foils [3]. Generation of hot electrons is affected remarkably in presence of magnetic field. Acceleration of ions in presence of a strong magnetic field has been studied analytically by Sinha et al. [4]. Kuri et al. [5] have reported that the protons get accelerated from the target rear side more efficiently in case of a right circularly polarized (RCP) laser whereas the front side acceleration is more efficient in case of a left circularly polarized (LCP) laser due to enhanced effect of radiation pressure in presence of an axial magnetic field. Hence, LCP laser generates high energetic protons. In the present work, we study the generation of hot electrons and their role in proton acceleration by a short pulse circularly polarized moderately intense laser from overdense plasmas in presence of an axial magnetic field with the help of three dimensional (3D) particle-in-cell (PIC) simulations using the code Picpsi-3D [6]. Since, the laser is moderately intense, the effect of radiation pressure is weak. It is observed that at the initial stage of acceleration, the protons are accelerated more effectively from the target front side in case of LCP laser producing high energetic protons. But at the later stage of acceleration, the energy of protons obtained by the RCP laser is high due to efficient generation of hot electrons which accelerates protons from the target rear side.

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96/LP-11/P

THZ RADIATION FROM AXIALLY MAGNETIZED COLLISIONAL PLASMA USING COSH-GAUSSIAN LASER BEAMS

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Abstract

Two cosh-Gaussian[1-2] laser beams focused in axially magnetized plasma lead to Terahertz (THz) radiation generation under the presence of spatially periodic density ripples. The laser beams exert a nonlinear ponder motive force and the plasma electrons acquire nonlinear quiver velocity under the influence of ponder motive force. These oscillatory velocities couples with preformed density ripples to generate a strong transient nonlinear current, which resonantly derives THz radiation of frequency ~ ω_h (upper hybrid frequency). Laser frequencies (ω_1 and ω_2) are chosen such that the beat frequency (ω) lies in the terahertz region. The phase matching conditions ($\omega = \omega_1 - \omega_2$ and $\vec{k} = \vec{k}_1 - \vec{k}_2 + \vec{\alpha}$) is controlled by the periodicity of density ripples and may be tuned to transfer maximum momentum from laser to THz radiation. The presence of external axial magnetic field enhances the nonlinear coupling and controls various parameter of generated THz radiation. The effects of cosh-Gauss decentered parameter and magnetic field strength are analyzed for strong THz radiation generation. Analytically results show that the amplitude of THz wave enhances with decentered parameters as well as magnitude of axially applied magnetic field.

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98/LP-12/P

SURFACE PLASMON RESONANCE IN ULTRA-SHORT LASER IRRADIATED GRATING TARGET AT RELATIVISTIC INTENSITIES

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Abstract

Grating targets are found to be very attractive for near complete absorption of intense ultra-short laser pulse irradiation [1]. The use periodic rippled structure as targets has lead to the demonstration of directional hot electronjet [2], fast ion production [3] and also for producing copious hard x-ray emission [1]. The strong energy coupling in a grating target relies on the Surface Plasmon Resonance (SPR) excitation. This depends on the wave vector or momentum matching assisted by the grating.The grating provides an additional quasi-momentum to the incident light to match the surface plasmon momentum associated with the metal/plasma/dielectric interface [4].There is no role of laser intensity in the conventional low intensity SPR excitation, however in this work we bring out the role of laser intensity in laser energy coupling to a periodic structure. The present state of art high contrast, chirped pulse amplification based laser systems are capable to produce intensities exceeding 10^{18}W/cm^2. At such high intensitiesthe electron quiver motion is highly relativistic. This has a strong effect in the momentum matching condition for the excitation of SPR. First and foremost the dielectric properties of the metal plasma get modified at relativistic intensities resulting in change of the surface plasmon momentum. Secondly the geometric parameters like angle of incidence have a dominant impact on the effective intensity on the target and the electric field component along the grating which excites the surface plasmons. Lastly the grating period seen by the relativistic and longitudinally oscillating electrons also get modified depending on incident laser intensity and angle of incidence. All these conditions restrict the possibility of exciting SPR in sub wave length and super wavelength gratings at ultrahigh intensities. In this paper we will be presenting a systematic analytical study of the effect of laser intensity, angle of incidence, laser wave length, target electron density and grating period on SPR excitation in grating. This is important since it will help in choosing the laser and grating parameters for efficient energy coupling mediated through SPR. This will also help to understand the conditions in which SPR excitation is not possible at relativistic intensities.

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111/LP-13/P

PARTICLE IN CELL (PIC) SIMULATIONS OF PROTON ACCELERATION USING LASER PLASMA METHODS

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Abstract

A higher-intensity and intense laser pulses have been realized by the chirped pulse amplification. The energy of protons, which are accelerated by an interaction between the intense laser pulses and a gas target (plasma), reaches over a few tens of MeV. The issue in the laser proton acceleration include the proton beam collimation, proton energy spectrum control, proton production efficiency etc. Depending on proton beam applications, the proton particle energy and the ion energy spectrum should be controlled. This kind of protons can be accelerated from an intense laser pulse interactions with solid targets. However, the proton energy tends to be relatively low. Thus, it is necessary to enhance the proton beam energy as well the collimations. In this work, we have proposed to study the PIC simulations to generate proton beams from laser-plasma interactions. We have taken laser and target parameters which are feasible with current experimental conditions. In our simulation work, we have discussed the proton acceleration with linearly and circularly polarized laser pulse with varying target thickness. The two mechanisms of ion acceleration namely Target Normal Sheath Acceleration and Radiation Pressure Acceleration are explored through simulations.

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117/LP-14/P

LASER WAKEFIELD ACCELERATION OF ELECTRONS BY ASYMMETRIC LASER PULSES

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Abstract

The variation in refractive index $\eta = [1-\omega_p^2/\gamma\omega_L^2]^{1/2}$ leads to the asymmetry in laser pulses in terms of a compressed front edge. Pulse amplitude increases as the front part of the pulse get compressed, which leads to the increment in laser pulse intensity and hence pulse imparts comparatively strong ponderomotive force on the ambient plasma electrons. Ponderomotive force might affect the injection of electrons into wakefield**.** We propose to revisit the laser wakefield acceleration of electrons using a temporally asymmetric laser pulse in plasmas to explore the quality of the injected bunch in terms of the injected charge, mean energy and emittance. Different ratio of leading to trailing pulse edge duration has been considered to maintain the balance between injection of electrons into wake and the energy gain of the injected electron bunch.Based on two-dimensional particle-in-cell simulations and reasonable analytical considerations, we investigated the beam quality in laser wakefield acceleration (LWFA) for asymmetric laser pulses. Our study reports that the pulse asymmetry is good in terms of monoenergetic beam; low emittance and improved injection for pulse duration of 30 fs in laser wakefield acceleration (LWFA).

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129/LP-15/P

ENHANCED PLASMA ELECTRON TRAPPING IN LASER WAKEFIELD ACCELERATION

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Abstract

The number of particles in an electron beam from laser Wakefield acceleration isdetermined at the moment of trapping of background electrons.The longitudinal and transverse wave-breaking initiatesthe electron trapping. After some time, the trapping stops because of the repulsive force by the trapped particles. From manysimulations and experiments, it has been well known that trappingof the background electrons begins much below the longitudinalwave-breaking limit. This is related with transversemotion of the electrons. As an ultra-intense laser pulse propagatesthrough a plasma,it pushes out the background plasmaelectrons and leaves behind a periodically-repeated bubble-likeregion. Inside the bubble, the electron density is very low,while the electron density at the rim of the bubble is very high.Highly energetic electrons make their trajectories along the rimof the bubble. Though many of such electrons turn around therim and leave the bubble, some of those electrons are trappedin the transverse direction when their kinetic energies are lowerthan the depth of the potential well of the bubble. The idea suggested in this paper is that a magnetic field applied in the longitudinaldirection is ableto suppress the transverse drift of the electronsso that their trajectories are dragged more inward the bubble.Because of the sensitivity, even a very weak suppression of thetransverse drift of the electron may be able to turn the outgoingpath into the trapping path.The advantage of this technique is obtaining one more controlof the beam charge in the laser-plasma accelerators, whilekeeping other parameters unmodified. Though the requiredmagnetic field is strong, i.e. like a few tens or one hundred Tesla,magnetization of the plasma is still weak enough to put theWakefield uninfluenced.

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139/LP-16/P

ELECTRON ACCELERATION BY A FAST PLASMA WAVE IN PRESENCE OF A SHORT WAVELENGTH LANGMUIR WAVE

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Abstract

A relativistic plasma wave (wake) can be driven by the laser ponderomotive force in laser wakefield accelerator. The longitudinal field of the wake can trap and accelerate electrons from the plasma. In this connection, we report a significant enhancement of electron energy gain during acceleration by a long wavelength plasma wave in the presence of a short wavelength Langmuir wave. The long wavelength plasma wave is generated by nonlinear mixing of laser with short wavelength Langmuir wave. Resonant wave mixing can generate a long wavelength plasma wave, which can help in amplifying the electron energy gain during acceleration. By solving the momentum and energy equations, the average motion of the particle was analyzed. Our study revealed a significant enhancement in electron energy gain by this mechanism. The physical mechanism is described with a theoretical formulation for this scheme. Two-dimensional particle-in-cell simulations confirm the validity of the proposed theory.

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145/LP-17/P

MAGNETIC FIELD GENERATION IN FINITE BEAM PLASMA SYSTEM

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Abstract

The magnetic field generation is an important issue in a variety of contexts. In a beam plasma system it is typically believed that the Weibel destabilization process causes the generation of magnetic fields at the electron skin depth scales. It has recently been shown, however, that a finite transverse size of the beam leads to the generation of magnetic field at the long scale length of the beam [1]. This has been attributed to a new instability associated with the Finite Boundary Size (FBS) operative in this context. In a realistic situation the beam in addition to having a finite transverse extent would also have a finite temporal width. Keeping this in view in the present work a finite longitudinal extent of the beam has also been considered. Particle - In - Cell (PIC) simulations using OSIRIS were conducted which illustrate that in this case too the FBS instability is the first one to appear which is followed up by the KH at the edge and the Weibel in the bulk region. The magnetic field power spectrum has been observed to maximize at the longest scale of the beam size, as expected. In addition the relativistic shock formation, the beam focusing at the front and wake structures can also be seen in this particular case which will be presented in detail.

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159/LP-18/P

TERAHERTZ EMISSION IN PLASMA VIA OPTICAL RECTIFICATION OF SUPER-GAUSSIAN LASER BEAM IN THE PRESENCE OF AXIALLY MAGNETIC FIELD

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Abstract

Terahertz sources in spectral range (0.1-10THz) can be used in various scientific and technological applications such as, remote sensing [1], terahertz communication [2], explosive and concealed weapon detection [3]. The aim of present study is to generate high power THz radiation by considering the nonlinear interaction of an amplitude modulation of super-Gaussian laser beam and periodic density plasma along with axially magnetic field. Numerical Results show that in such plasmas the radiative movements are guided by the space charge fields which are induced via nonlinear ponderomotive force. In the presence of an applied static magnetic field along the axis and the appropriate index of laser, a controllable current is procured for the generation of THz wave. Resonant THz excitation occurs by employing the density ripple that provides the phase matching condition. Consequently, it acquires focused radiation at modulation frequency and high power along with striking efficiency by optimizing the mentioned laser plasma parameters.

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210/LP-19/P

SELF-INDUCED TRANSMISSION OF CIRCULARLY POLARIZED ELECTROMAGNETIC BEAM PROPAGATION IN RAMPED DENSITY MAGNETIZED PLASMA

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Abstract

This paper presents an analysis of self-induced transmission of a circularly polarized electromagnetic beam incident normally on a plane interface of a ramped density magnetized plasma with an intensity dependent dielectric tensors. Considering the nonlinearity to arise from the relativistic variation of mass of electron and cyclotron resonance effect due to Lorentz force. Following Wentzel–Kramers–Brillouin (WKB) and paraxial ray approximation the phenomenon of relativistic self-focusing of the transmitted electromagnetic beam in ramped density magnetized plasma has been analyzed for the arbitrary magnitude of nonlinearity. Change in the intensity distribution along the wave front of the circularly polarized electromagnetic beam, due to refraction at the interface has also been taken into account. The variation of beam width parameter with distance of propagation, self-trapping condition and critical power has been evaluated for ramped density magnetized plasma. Numerical estimates for typical parameters of beam plasma interaction process indicate the refraction at the interface to have a significant effect on self-focusing.

214/LP-20/P

ELECTRON ACCELERATION BY LASER DRIVEN BEAT WAVE EXCITED BY CROSS-FOCUSED COSH-GAUSSIAN LASER BEAMS IN THERMAL QUANTUM PLASMA

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Abstract

This paper presents a scheme for electron acceleration by excitation of an electron plasma wave (EPW) by cross-focused Cosh-Gaussian (ChG) laser beams in thermal quantum plasma. The plasma wave is generated on account of beating of two laser beams having slightly different frequencies ω1 and ω2. Formulation is based on deriving a set of coupled differential equations governing the propagation dynamics of laser beams, with the help of moment theory approach in W.K.B approximation. Due to no uniform irradiance along the wave fronts of the laser beams the background electron concentration gets modified. The amplitude of EPW, which depends on the background electron concentration, thus gets nonlinearly coupled with the laser beams as a result of which EPW gets excited. The high phase velocity and longitudinal field of the EPW accelerates the electrons to higher energies. Numerical simulations have been carried out to envision the effects of laser as well as plasma parameters on energy gained by the electrons. Simulation results predict that within a specified range of decentered parameters ChG laser beams show less divergence and hence provide higher acceleration to the electrons.

217/LP-21/P

2-D FLUID SIMULATION OF RELATIVISTIC ELECTRON BEAM DRIVEN WAKEFIELD IN A COLD PLASMA

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Abstract

Two-dimensional fluid simulations have been employed to study the excitation of relativistic electron beam driven wake field in a cold plasma. It is observed that for both under-dense and over-dense beam, in the limit when the transverse dimensions of the beam are much larger than its longitudinal extent, our simulation results show a good agreement with the 1-D results [1]. For an over dense beam, and in the limit when the transverse extensions are smaller or close to the longitudinal extension, the excited wakefield exhibits a "blowout" structure which matches closely with the analytically modeled results given by Lu et al. [2], before phase mixing occurs. We also address issues related to particle acceleration in such a potential structure by injecting the test electrons in fluid simulation. It is found that the maximum energy gained by the test electrons from the back of the driver beam of energy ~28.5GeV, reaches up to 2.8 GeV in a 10 cm long plasma; this matches with the experimental result presented in ref. [3]. Maximum energy gained by the test electrons doubles to ~5.7 GeV when the bunch is placed close to the axial edge of the first blowout structure.

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219/LP-22/P

THE STABILITY OF 1-D SOLITON IN TRANSVERSE DIRECTION

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Abstract

The complete characterization of the exact 1-D solitary wave solutions (both stationary and propa- gating) for light plasma coupled system have been studied extensively in the parameter space of light frequency and the group speed [1]. It has been shown in 1-D that solutions with single light wave peak and paired structures are stable and hence long lived. However, solutions having multiple peaks of light wave are unstable due to Raman scattering instability [2]. Here, we have shown with the help of 2-D fluid simulation that single peak and paired solutions too get destabilized by the transverse filamentation instability. The numerical growth rates obtained from simulations is seen to compare well with the analytical values. It is also shown that multiple peaks solitons first undergo the regular 1-D forward Raman scattering instability. Subsequently, they undergo a distinct second phase of destabilization through transverse filamentation instability. This is evident from the structure as well as the plot of the perturbed energy which shows a second phase of growth after saturating initially. The growth rate of the filamentation instability being comparatively slower than the forward Raman instability this phase comes quite late and is clearly distinguishable.

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255/LP-23/P

TERAHERTZ RADIATION GENERATION BY TWO INTENSE COSH GAUSSIAN LASER BEAM IN MAGNETIZED PLASMA

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Abstract

In the present work, generation of terahertz (THz) radiation by beating of two high intensity cosh-Gaussian laser beams (CGLBs) in magnetized plasma has been carried out under non-paraxial-ray approximation along with the combined effect of relativistic and ponder motive nonlinearities.The laser beams imparts a relativistic-ponder motive force to the electron and this force exerts a nonlinear velocity component in both transverse and axial directions which drives the THz wave in the plasma.An expression forthe beam width parameters of cosh Gaussian laser beams and THz field have been set up and solved numerically. The effects of various laser and plasma parameters such as incident laser intensity, plasma density and magnetic field on the focusing of laser beams in plasma and further its effect on the efficiency of THz radiationhas been explored. The results are compared with only relativistic nonlinearity and the Gaussian profile of laser beams. It is found that inclusion of higher order terms with relativistic-ponder motivenonlinearity does significantly affect the focusing of laser beams and the efficiency of generated THz radiation.

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260/LP-24/P

PARAMETRIC SCATTERING IN QUANTUM SEMICONDUCTOR PLASMA MEDIUM: DISPERSION CHARACTERISTICS

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Abstract

Study of dispersion characteristics of acoustic wave is the main focus of this theoretical investigation. In the case of parametric scattering each incident photon spontaneously breaks down due to the nonlinearities in the medium into a pair of photons. Parametric scattering can be viewed as mixing of the incident photon with the quantum mechanical zero point fluctuation of the electromagnetic radiation leading to a nonlinear polarization oscillating at scattering frequency leading to scattered light. Quantum hydrodynamic model for one component plasma along with coupled mode theory is used to derive the expression for second order nonlinear optical susceptibility. Dispersion characteristics are explored in this paper through second order susceptibility of the medium which is a measure of the strength of second order nonlinear interaction. It is found that doping concentration and pump amplitudes could be used to tune the dispersion characteristics. Possibility of observation of group velocity dispersion is also investigated via admitting a small degree of phase mismatch in the analysis.

284/LP-25/P

ROLE OF TEMPERATURE IN THE EVOLUTION OF 1-D LOCALIZED LASER PLASMA

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Abstract

There are well-known varieties of exact nonlinear localized solutions for the laser plasma system which have been studied extensively [1]. The evolution and stability of these structures have also been numerically investigated. These solutions, however, have been obtained in the cold plasma limit and their evolution studies so far has also been restricted to the limit of zero temperature. We have considered the evolution of these structures by considering a fluid description with a finite temperature. We observe that at low temperatures the solutions remain robust and evolve stably. However, when the temperature is chosen to be high new effects are observed.

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285/LP-26/P

LOCALISED 1-D LASER PULSE SOLUTIONS IN STRONGLY COUPLED PLASMA

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Abstract

It is well known that the plasma can support a variety of 1-D localized solutions where electron plasma waves are coupled to the electromagnetic radiation [1]. The ponder motive pressure of light field evacuates the electrons creating a cavity in which the light gets trapped. In this work we study the role of strongly coupling of such localized solutions. The effect of strong coupling is introduced by representing the electrons by a visco – elastic fluid model namely the generalized Hydrodynamic description [2].

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300/LP-27/P

EFFECT OF LASER WAVELENGTH ON RESONANCE ABSORPTION OF ULTRASHORT LASER PULSES IN ATOMIC CLUSTERS

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Abstract

Pronounced absorption of laser light has been observed in laser cluster interaction model [1] and experiments [2], when Mie-plasma frequency (ω_M) of electrons in an expanding cluster meets the laser frequency (ω). However, in previous simulations [3] andin subsequent studies [4] of laser heated clusters, the role of above plasmonresonance was denied without satisfactory physical explanation. The non-uniform electron density inside thecluster was vaguely introduced as the possible reason. In this work, the impact of laser wavelength on theabsorption of short laser pulses irradiating a deuterium and an argon cluster are studied in various conditionsby our molecular dynamics (MD) simulations [5]. It is found that, for a given pulse energy, in the low intensityregime, there exist a wavelength close to the plasmon resonance at which cluster absorbs maximum energy accompanied by maximum outer-ionization (also maximum inner-ionization for argon) of electrons. As the laserintensity increases, the maximum (peak) in the absorption curve and in the outer-ionization grow together but shifttowards higher wavelengths and above a certain intensity the absorption maximum (peak) disappears as outerionization saturates at 100%, i.e., when all electrons leave the cluster. The disappearance of maximum in theabsorption curve for an intensity should not be misunderstood as the negligible (or no) role of plasmon resonance, nor due tothe non-uniform electron density inside the cluster. If the bound population of electrons is more than the freepopulation, then resonance peak survives. On the other hand, resonance peak gradually disappears with the freepopulation increasing beyond the bound population of electrons. For further justifications to our results, we have retrieved the temporal information of Mie-plasma frequency, absorbed energy, average charge state and outer ionization of an argon cluster, subjected to various laser wavelengths in between 100nm and 800nm at 5×10^{16} W /cm^2 peak intensity. MD results are corroborated further with asimple rigid sphere model of cluster where non-interacting electron spheres in a predefined potential of the ionsphere are driven by identical laser fields as in MD.

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403/LP-28/P

HARMONIC GENERATION BY PROPAGATION OF CIRCULARLY POLARIZED LASER BEAM IN RIPPLED PLASMA

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Abstract

Generation of harmonic radiation is an important subject of laser plasma interaction and attracts great attention due to wide range of applications. In general, linearly polarized laser beams interacting with homogeneous plasma lead to the generation of odd harmonics of the laser frequency [1]. However, even harmonics have been observed by laser beam propagation in plasma having transverse gradient in its density profile [2]and also in plasma embedded in external fields [3]. The conversion efficiency of the harmonics is limited due to the phase-mismatch between the generated harmonics and the fundamental frequency of the laser radiation. Recently, an analytical study of phase-matched third harmonic generation by interaction of two-color p- polarized laser beams with spatially varying plasma density has been reported[4].

In the present paper, an analytical study of phase-matched second harmonic generation via interaction of an intense, circularly polarized laser beam propagating obliquely in underdense plasma having a density ripple has been proposed. Considering the mildly relativistic regime, the Lorentz force and Continuity equations are perturbatively expanded to obtain the current density driving the wave equation governing the evolution of amplitude of the second harmonic. The amplitude of second harmonic radiation has been derived and its variation with the angle of incidence is analyzed. The maximum amplitude of the harmonic occurs when the ripple wave vector satisfies phase-matching conditions. It is observed that the generated second harmonic radiation is elliptically polarized and vanishes at normal incidence of the laser beam.

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429/LP-29/P

PROPAGATION CHARACTERISTICS OF A LASER BEAM IN OBLIQUELY MAGNETIZED PLASMA CHANNEL

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Abstract

Optical guiding of intense laser beams in plasma is beneficial for a variety of applications, including harmonic generation [1], development of X-ray lasers [2], advanced laser fusion schemes [3] and plasma based accelerators [4]. At high intensities the interaction between lasers and plasma becomes nonlinear. Jha *et. al.* [5,6] have studied the enhancement of self-focusing of an intense laser beam propagating in plasma embedded in transverse as well as axial magnetic fields. The effects of externally applied static magnetic field on wake excitation [7] and nonlinear evolution of laser pulses have been studied [8].

The evolution of the spot size and amplitude of a circularly polarized laser beam propagating in a plasma channel embedded in an obliquely applied magnetic field has been investigated. The wave equation describing the evolution of the radiation field is set up and a variational technique is used to obtain the equations governing the evolution of the spot size and amplitude. Numerical methods are used to analyze the evolution of the laser beam spot size and amplitude. It is seen that the amplitudes of the two transverse components of the electric field of the laser beam evolve differently, since they are driven by unequal current densities. This leads to the conversion of a circularly polarized laser beam into an elliptically polarized beam, under appropriate conditions.

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450/LP-30/P

GENERATION OF HARMONIC RADIATION BY THE INTERACTION OF TWO-COLOR LASER BEAMS WITH PLASMA

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Abstract

The excitation of coherent radiation at harmonicsof the fundamental frequency of the laser is of muchpractical importance.It has been theoretically seen that oddharmonics of the laser frequency can be generated bythe interaction of linearly polarized laser beams withhomogeneous plasma [1]. In addition,even harmonics can be obtained in the presence ofdensity gradients in plasma [2]. Linearlypolarized laser beams can generate second harmonicradiation in magnetized plasma [3].For practical applications of harmonic radiation, itsconversion efficiency needs to be enhanced. Conversionefficiency enhancement has been obtained by introducing a density ramp [4] or by applying various quasi-phasematching and phase-matching schemes [5].

An analytical theory is developed for studying the phenomenon of generationof efficient odd and even high harmonics by the propagation of two-colorlinearly polarized laser beams in homogeneous underdense plasma. The waveequation governing the evolution of the amplitude of various harmonics drivenby the current density at corresponding frequencies is set up. A numerical evaluation of amplitudes of the third, fourth and fifth harmonicshas been presented. It is seen that the third harmonic amplitude generated by the two-color system is enhanced in comparison to that obtained by a single laserbeam.

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453/LP-31/P

NUMERICAL SIMULATION STUDIES OF SHOCK WAVE PROPAGATION IN CCl_4 PLACED IN CONFINEMENT GEOMETRY CELL

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Abstract

Laser-driven shock-wave is an effective method to generate dynamic high pressure in materials [1].Shock wave experiments provides us essential information of materials under high pressure. To understand the dynamics occurring in a material under shock compression Time resolved vibrational spectroscopy is required which probes the transient vibrational states occurring under shock compression. Time resolved Raman Spectroscopy in particular is well suitable for monitoring the changes occurring in situ in the material during shock wave propagation through the material [2]. We performed experiments to study the molecular response in CCl_4 under laser driven shock compression in confinement geometry using Time Resolved Raman Spectroscopy at different delay time [3].In confinement geometry we make use of layered target of Glass-Aluminum-CCl_4-Glass with thickness of 5 mm, 20micron, 200 micron and 5 mm respectively. The laser is impinged onto the Aluminum glass interface thereby generating plasma confined by the glass which drives a shock wave into Aluminum which then further propagates into CCl_4. In order to validate the experimental result, numerical simulations are performed using a one-dimensional three-temperature (electron, ion and thermal radiation temperatures) radiation hydrodynamics (TRHD) code. We have tried to setup the experimental geometry in simulations and have obtained the spatial profile of shock wave propagation in the layered target for different laser intensities. The shock pressures obtained are in agreement with the analytical scaling [4].

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106/LP-32/P

STUDY ON THE ROLE OF ELECTRON TRAJECTORIES IN HIGH ORDER HARMONIC GENERATION USING SINGLE AND TWO COLOR LASER FIELDS

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Abstract

High order harmonic generation (HHG) is a well-established route for generation of ultrashort coherent extreme ultraviolet radiation. It is a highly non-linear process in which, an ultrashort intense laser pulse is focused in a non-linear medium, which leads to generation of new frequencies that are odd multiple of the fundamental laser frequency. Among the available theories, the three step model proposed by Corkum et al. [1] has successfully explained the HHG process. According to this model, the presence of strong laser field distorts the atomic potential and allows the outermost electron to tunnel out. The tunnelled electron then accelerates in the laser field in different trajectories and with the reversal of laser cycle; they recombine and emit high energy photons. Recently, the theoretical studies predicted that these electron trajectories affect harmonic intensity, their spatial, spectral and temporal characteristic [2].

In this paper, we present the study on the role of electron trajectories that affects the harmonic spectrum. The study was carried out using a 45fs Ti: Saphhire laser system operating at 1 kHz repetition rate that can deliver a maximum energy of 7.5mJ per pulse. High order harmonics were generated by focusing the laser pulse in argon gas and the generated harmonics were dispersed and detected using flat field grating spectrograph. In the study, both fundamental (λ~ 800nm) laser pulse and two color laser pulse (fundamental at 800nm as well as its second harmonic at 400 nm) were used for HHG. In case of single color (at 800 nm) laser pulse, the harmonic spectrum starts broadening with increase in gas pressure and the spectrum of all individual harmonics split with increase in gas pressure beyond ~ 40 mbar. Two separate bands in spectrum of each harmonic order were observed, e.g. for 23^{rd} harmonic order, one with higher bandwidth (~ 1.2 nm) and other with narrow bandwidth (0.5nm). The bandwidth of these bands also changes with change in gas pressure. However, in case of HHG using two color laser pulses, no splitting in the spectrum was observed. The spatial coherence of harmonics under above conditions was also studied. It was observed that the spatial coherence of harmonics generated using two color laser pulses was higher compare to single color. Further, in case of single color laser pulse, the spatial coherence was higher for the band having narrow bandwidth. The above observations can be explained by considering the role of multiple electron trajectories in HHG, which give rise to spectral splitting and variation in their spatial coherence property. The analysis of results based on the current understanding will be presented.

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110/LP-33/P

EXPLORING X-RAY LASING IN HIGHLY IONIZED CARBON PINCH PLASMA

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Abstract

Experiments had been conducted in carbon plasma using fast capillary discharge scheme to explore lasing at shorter wavelengths. This is based on collisional recombination pumping of fully ionized carbon ions (C^{6+}) to form H-like C i.e. C^{5+} through fast cooling [1,2]. Under suitable conditions, population inversion can be generated corresponding to Balmer-α transition in carbon i.e. at 18.2 nm wavelength. Experiments have been conducted to create highly ionized carbon plasma in our laboratory. Acetylene gas was filled in an alumina capillary (length 9.6 cm, inner-diameter 2.8 mm) and excited by passing a 85-90 kA discharge current (quarter period ~ 46 ns) to form carbon Z-pinch plasma. The temporal profile of capillary emission was recorded with a vacuum diode at different gas pressures. The gas can be also pre-ionized by passing pre-pulse of 50-100 A before the main discharge. It was found that for gas pressures below 1.0 mbar, the rising edge of the diode signal starts developing a discontinuous slope change. For higher pressures, signal pulse remain symmetric. In absence of the prepulse, very fast emission of few ns duration was observed in the diode signal. The recorded spectra show two distinct lines, identified as Ly-α and He-α at 3.4 nm and 4.0 nm respectively when prepulse is switched off. This is in agreement with the fast pulse of few nanoseconds appeared in the diode signal. These emission lines clearly confirm formation of highly ionized charge states of carbon i.e. C^{5+} and C^{4+} respectively. Experiments will be continued to optimize the discharge parameters and to achieve lasing action in carbon plasma.

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132/LP-34/P

HIGH RESOLUTION OPTICAL AND X-RAY SPECTROSCOPIC STUDY TO UNDERSTAND FAST ELECTRON GENERATION AND TRANSPORT IN RELATIVISTIC LASER PLASMA INTERACTION

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Abstract

Fast electron generation and transport in dense matter driven by the interaction of relativistic intensity laser pulses (> 10^{18} W/cm^2) of femtosecond duration is a research area of considerable importance for the fast ignition approach of inertial confinement fusion. In particular, for relativistic intensity and the steep density gradient, the J X B mechanism plays a dominant role over the others (e.g. resonance absorption and vacuum heating) in converting the laser energy into kinetic energy of the fast electrons. However, for such a high intensity interaction even a scale length of the order of laser wavelength may induce plasma parametric instabilities viz. 'Stimulated Raman Scattering (SRS)' and 'Two Plasmon Decay (TPD)' affecting fast electron energy and angular distribution.

High resolution K-shell x-ray measurement is one of the widely used techniques to study the generation mechanism of the fast electrons. The emitted x-ray radiation characteristics are governed by fast electron parameters and subsequent transport through the dense matter. *In situ* study of laser plasma interaction conditions responsible for generation of fast electrons can be done from spectral analysis of the back scattered light from the interaction region. The well-defined peaks at 3/2 ω and 2ω (where ω is the incident laser frequency) in the optical spectrum are well known markers of the parametric instabilities occurring at quarter critical and critical density regions of the plasma. Further, presence of spectral features due to 'Stimulated Backward Raman Scattering (SBRS)' can give vital information about the density gradient of any low density (<0.1 n_c) pre-plasma.

In this paper, we report high resolution measurement of K-α x-ray line emission and x-ray source size measurements along with recording optical emission spectrum in the laser backward direction in high-intensity laser plasma interaction using a 30 fs Ti:Sapphire laser pulse focused to an intensity ~10^{19} W/cm^2 on a thin foil target. The variation of K-α x-ray line intensity and x-ray source size at the target rear along with the change in spectral features in the optical spectrum with laser energy and polarization were studied. In the present experiment despite having a high contrast and hence short pre-plasma density scale length, optical spectrum showed presence of 3/2 ω and SBRS, which could be possible due to use of high laser intensity (~ 10^{19} W cm^{-2}) leading to still measurable growth rate of such instabilities.

144/LP-35/P

DIRECT LASER ACCELERATION OF ELECTRONS IN NITROGEN-ARGON MIX GAS-JET TARGETS

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Abstract

Electron acceleration in high-intensity, short-duration laser plasma interaction has been a subject of considerable interest. For short laser pulses (L $<\lambda_p$: L is the laser pulse length and λ_p is the plasma wavelength) laser wake field acceleration (LWFA) mechanism is applicable where electrons are accelerated by the electric field of the highly nonlinear electron plasma wave. In the long laser pulse regime ($L\geq\lambda_p$) besides wakefield, direct laser acceleration (DLA) mechanism, in which electrons gain energy directly from the laser field, is also applicable [1]. In earlier experiments on DLA mostly low Z-gas targets (e.g. He) were used. However, recently DLA has been considered alongwith LWFA in experiments using mixed gas targets (i.e. He with some fraction of high-Z gas e.g. N_2) where ionization induced injection mechanism is applicable [2]. For much longer laser pulses (L $>>\lambda_p$) one can have acceleration only due to DLA mechanism [3].

In this paper, we report an experimental study on DLA of electrons using pure N_2 and mixture of N_2 and 7.5% of Ar gas jet. Laser pulse of duration ~200 fs and energy ~200mJ from a Ti:Sapphire laser was focused on a gas-jet target of 1.2 mm length (supersonic nozzle: 1.2 mm x 10mm) to a spot of ~5μm (FWHM: full width at half maximum) at a peak intensity of $\sim 2.1\times10^{18}$ W/cm^2. Generation of well collimated electron beams of ~10 mrad divergence and energy ~9 MeV was observed from pure N_2 at a threshold density of $\sim 7\times10^{19}$ cm^{-3}. From a mixture of N_2 and Ar at a lower density threshold of $\sim 5.7\times10^{19}$ cm^{-3},similar collimated electron beams were generated with comparatively higher energy of ~15-25 MeV. Shadowgram of the laser plasma interaction region along with forward and backward scattered laser spectrum were recorded to understand the laser propagation and interaction with the plasma. Results of new regime of DLA using long laser pulses and high-Z gas (cluster) target with possible role of inner shell ionization of high-Z atoms would be presented.

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164/LP-36/P

DEVELOPMENT OF KHZ REPETITION RATE ULTRA-SHORT LASER PLASMA X-RAY SOURCE FOR TIME RESOLVED X-RAY DIFFRACTION STUDY

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Abstract

Interaction of ultra-short laser pulses with solid targets generates ultra-short k- alpha x-ray source, having narrow bandwidth and high peak brightness. The choice of different target materials make them quasi tunable. These sources are very useful in studying the ultra-fast lattice dynamics through time resolved x-ray diffraction (TXRD) studies [1–3] and ultra-fast imaging through phase contrast imaging [4] etc. Here, we report development and characterization of 1 kHz repetition rate, K_α x-ray source from the interaction of a 1 kHz laser having 7.5 mJ energy and 45 fs pulse duration with Cu wire target.

The laser was focused on Cu wire target of 300 microndiameter, using an f/8, off axis parabolic mirrorto an intensity of ~10^{17} W/cm^2.At this rep rate the solid debris emanating from the plasma, contaminates nearby optical components. To avoid the plasma debris deposition on the optics, the wire target assembly was covered from all sides by metal sheets except for the laser entrance and x-ray emission directions. A glue lessplastic tapewas rotated before the OAP to avoid the debris deposition on it. This assembly wasplaced inside the vacuum chamber. A 25 µm thick kapton window was used to take out the K_αx-rays from the vacuum chamber for TXRD application.

The x-ray flux was measured by Cd-Te detector working in single photon counting mode.To ensure this the Cd-Te detector was kept at larger distance from the source and a 1 mm lead aperture was placed in front of it. A 7 µm thick Cu foil was placed in front of the detector to select the desired energy range.The Cd-Te detector shows clear peaks of Cu K_α (8.05 keV) and K_β (8.9 keV) lines. The K_α x-ray flux is calculated from the area under the curve of the K_α line and it was measured to be ~2.3×10^9 photons/sr/sec. Parametric study of this K_α x-ray source was carried out, which includes photon flux variation with laser pulse duration, laser pulse energy. The results of the source characterization with laser parameters will be presented in detail.

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171/LP-37/P

INITIAL RESULTS OF MAGNETIC BOTTLE TIME OF FLIGHT ELECTRON SPECTROGRAPH FOR THE MEASUREMENT OF ATTOSECOND PULSES

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Abstract

High order harmonic generation (HHG) from the interaction of ultrashort laser pulses with noble gases is a well known techniqueof generation of sub-femtosecond/attosecond durationcoherent XUV radiation [1]. The high order harmonics are generated at the odd multiple of the laser frequency and overlap of these harmonics generates attosecond pulse train separated by half laser cycle. The duration of the attosecond pulse is measured by measuring the relative phase between successive harmonic orders via. cross correlation of laser pulse with harmonic radiation. This is done by measuring the energy spectrum of the photo-electrons generated by focusing the harmonic radiation and IR laser pulse in a gas. The photo-electrons are generated by two photon absorption mechanism and their relative yield changes with the phase between laser and harmonic radiation. By measuring the photo-electron spectrum with delay between two pulses the relative phase between the generated harmonic orders can be determined. The Magnetic Bottle Time of Flight Spectrograph (MBTOFS) is a key component to record the photo-electron spectrum. The initial spectrum recorded by MBTOFS is present here.

In MBTOFSfirst the electrons are guided in a magnetic bottle formed by the combination of permanent magnet and solenoid (20 G, 1 m long). Time of flight signal of the electrons gives their energy spectrum. The TOF signal is amplified in a high gain double staged Micro Channel Plate (MCP), mounted at the end of solenoid. The TOF signal was further amplified in a RF amplifier developed in house.

High order harmonics are generated by the interaction of 7.5 mJ 1kHz 45 fs laser pulse with argon gas cell (at ~20 mbar). These harmonics were focussed in MBTOFS (in a low pressure argon gas sheath ~2-5×10^{-5} mbar). An in house developed grazing incidence toroidal mirror was used to focus these harmonics on gas jet kept inside the MBTOFS to generate photo-electrons. The spectrum of generated photo-electrons is measured by MBTOFS.The TOF signal corresponds to 11^{th}- 33^{rd}harmonic order was recorded. However the TOF signal for only 11^{th} H order could be resolved due to poor signal to noise ratio. Experimental results and present understanding of the observation will be presented.

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176/LP-38/P

STUDY ON GENERATION AND OPTIMIZATION OF HIGH ORDER HARMONIC RADIATION FROM GAS CELL USING 1 KHZ LASER SYSTEM

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Abstract

An experimental study was carried out on generation and optimization of high order harmonic radiation from gas cell of length ~ 15mm. Ti: Saphhire laser system delivering laser pulse at 1 kHzrepetition rate, having pulse width 45fs and energy ~ 7.5 mJ per pulse was used for the study. The laser pulse was focused on gas cell using a lens of focal length ~ 750mm to ~ 50µm spot size. The peak intensity at the best focus was ~ 10^{15} W/cm^2, which was varied by moving the position of lens away from the gas cell. The generated radiation was dispersed and detected using a flat field grating spectrograph. The study was carried out in argon and helium gases.

High order harmonic intensity was optimized by moving the laser focus position away from the gas cell and by changing the gas pressure inside the cell. It was observed that in case of argon, maximum harmonic order upto ~ 43rd were recorded, when laser was focused at the centre of gas cell. On moving the laser focus away from gas cell, the harmonic cut-off reduces to ~ 33rd order. The maximum harmonic intensity was observed, when laser focus was kept ~ 20mm after the gas cell, at an optimum gas pressure of ~ 30 mbar. It was also observed that with increase in gas pressure, the peak of spectral envelope of harmonics shifted towards higher harmonic orders and lower harmonic orders starts disappearing from the spectrum. In case of Helium gas, the harmonics upto 99th order was observed, when laser was focused at centre of gas cell. Even in this case, harmonic intensity was maximum at the same focal position as argon (20mm after the gas cell), but the optimum gas pressure was found to be ~ 175 mbar. In case of helium gas the maximum photon flux was estimated to be ~ 10^9 photons/sec/harmonic order, whereas in case of argon it was ~ 10^{11} photons/sec/harmonic orders. Spatial coherence of the harmonics from argon gas was measured using Young's double slit experiment. The fringe contrast as high as ~ 0.7 for 27th harmonic order was recorded. The detailed analysis and present understanding of the experimental observations will be presented.

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179/LP-39/P

IMPACT OF LASER INDUCED PLASMA ON THE IN-SITU DECORATION OF GRAPHENE OXIDE WITH SILVER NANOPARTICLES IN LIQUID MEDIA

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Abstract

Pulsed laser ablation (PLA) in liquid has been used to create highly non-equilibrium conditions with local high temperatures and pressures, leading to complex reactions and the growth of ablated species. Herein, we report the influence of laser produced plasma for the improvisation of graphene oxide (GO) sheets with silver nanoparticles by tuning the laser parameters and plasma parameters like electron temperature (T_e) and electron number density (n_e).Natural graphite powder was used to synthesize graphene oxide (GO) with modified Hummers' method [1]. A pure solid silver target (SIGMA ALDRICH, 99.99% pure trace metal) of thickness 1mm is properly placed inside a glass cuvette which contained 30ml of graphene oxide solution. Second harmonic (532nm) of a Q-switched Nd-YAG Laser (Litron LPY 674G-10) beam having 8ns pulse width and 10Hz repetition rate was focused on to the silver target using a plano-convex lens of focal length 15 cm at room temperature for various laser energies.The expansion dynamics of the plasma was characterised using space resolved optical emission spectroscopy [3].Plasma parameters like electron temperature (T_e) was measured by Boltzmann plot method and the electron number density (n_e) was estimated using stark broadened profiles of isolated lines of the optical emission spectra [2,4]. UV-Vis spectroscopy, fluorescent spectroscopy and high-resolution transmission electron microscopy upholds the optical and morphological characteristics of Ag nanoparticle/ GO sheet composite. The present study provides a simple and green strategy to decorate GO with silver nanoparticles by effectively tuning the plasma parameters via laser ablation in water.

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249/LP-40/P

QUASI MONO-ENERGETIC HEAVY ION ACCELERATION FROM LAYERED NANO-TARGETS

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Abstract

Production of energetic photons and charged particles on a table top using intense, ultra-short laser pulse has been an active area of research in recent times owing to its underlying intriguing physics as well as potential applications spreading across a wide variety of research fields[1]. In particular, interaction of such laser pulses with solids results in emission of energetic ions in copious amount which possess the potential of revolutionize medical healthcare by providing cheaper and efficient alternative to oncology treatment. Based on the present understanding, the acceleration such ions relies primarily on the highly energetic electrons, called "hot" electrons, produced due to efficient collisionless absorption mechanisms in plasma and preferentially lighter atomic species e.g. H, C, O etc. are accelerated efficiently. However, while using such beams in practice, a major concern is the inherent broad energy distribution of the emitted ions from such interactions unless intricate target engineering is involved. Apart from this, interaction of laser pulses having exotic intensity ($>10^{21}$ Wcm^{-2}) has also been accounted as one of the ways to reduce the energy spread of such ion beam with limited success. Therefore, generation of mono-energetic ion beam with high flux has been a challenge since almost the inception of this field of research.

In this work, we address this very pertinent issue of producing mono-energetic ion beams and moreover, we focus on the heavy ion acceleration instead of lighter species. Notably, production of mono-energetic heavy ion beam from such intense ultra-short laser plasma interactions have never been reported in the literature; even with exotic target and laser engineering approaches. We show, for the first time, consistent, highly reproducible, efficient mono-energetic acceleration of heavy gold ions to sub-MeV energies with reasonably high flux from moderately intense (10^{18} -10^{19} Wcm^{-2}) laser pulse interaction with layered targets consisting of high-Z (Au, 5 nm) and low-Z (C, 10 – 40 nm) layers deposited on Si substrate. Though, the pure Au layer yields broad ion energy distribution, presence of thin C layer on top of Au layer reduces the energy spread considerably, thus indicating that presence of C layer is crucial for quasi-monoenergetic heavy ion production. Another interesting feature is that all the charge states possess the same energy which is uncharacteristic of any field induced acceleration mechanisms. Instead of single layers of Au (50nm) and C (20 nm), double layers was also tried as a target.

The double layered targets yield two distinct sets of mono-energetic heavy Au ion bunch. To understand the acceleration mechanism; a 1D numerical model based on hydrodynamic simulation has been developed which reveals that the heavy Au ions are accelerated by the electrostatic field generated inside the plasma and restrained by the frictional forces in the plasma corona. The dynamic balance of these two counter acting forces gives rise quasi-monoenergetic features in Au ion energy spectrum. The details of the experimental results and modeling result will be presented.

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250/LP-41/P

PROTON ACCELERATION WITH CHIRPED LASER PULSES

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Abstract

Particle acceleration on a table top using intense, ultra-short laser pulses has emerged as a fascinating area of research owing to its underlying highly non-linear, non-perturbative physics as well as its potential applications in a variety of diverse areas in science and technology. In particular, efficient acceleration of lighter atoms e.g. H^+,C ions to MeV energies using thin foil targets shows promise in the fields of hadron therapy, short lived isotope production for PET applications, advanced fusion schemes etc. Therefore it is essential to understand the underlying intricate dynamics of ion acceleration process and maneuver the ion emission phenomena towards practical applications. The interaction of intense, ultra-short laser pulses with thin foil targets is primarily mediated by the energetic “hot” electrons which gain substantial energy owing to specific absorption mechanisms. These “hot” electrons while leaving thin foil target creates an electrostatic charge imbalance resulting in formation of an electrostatic field of ~TV/m. This intense field ionizes the atom present attarget surface and accelerates them to MeV energies. The hydrocarbons because of lighter mass and high q/m ratio are preferentially accelerated.

Several improvisations of this scheme have been implemented to increase the maximum energy of the accelerated H^+. In this report, we have studied the role of laser pulse parameters, in particular, laser pulse chirp on the maximum H^+ energies obtained from such interactions. Intuitively, introduction of laser pulse chirp always increases the laser pulse duration and thereforefor a given laser pulse energy; it will decrease the effective laser pulse intensity at the focus and thus expected to reduce the maximum proton energies compared to unchirped laser pulse. However, our results reveal a counter intuitive behavior i.e. with increase of laser pulse duration; the maximum proton energy instead of decreasingincreases up to 150 % which is quite intriguing. Notably, the variation of laser pulse duration can be implemented by changing the grating separation in two ways i.e. by increasing (i.e. negatively chirped) or decreasing (i.e. positively chirped) from the optimal grating separation. It is found that while the negatively chirped case, the maximum H^+ energies do follow our expectation and monotonically decrease with increasing laser pulse duration but for positively chirped pulses, the maximum proton energy reaches a maximum of 9.5 MeV around laser pulse duration of +400 fs as compared to 5.7 MeV for unchirped pulse of shortest pulse duration of 25 fs. Measurement of electron energy spectra also matches very well with this behavior implying that the coupling of laser pulseenergy with the foil targets (Ni 1.5 µm, Al 0.4 µm and 0.75 µm) is fundamentally affected with

introduction of laser pulse chirp. Moreover, mere rearrangement of frequencies introduced by varying compressor gratings does not explain this intriguing increase of laser pulse absorption. However, varying grating separation may also induce skewness in the laser pulse temporal profile which may influence the laser pulse absorption considerably. Therefore, more rigorous analysis aided by particle-in-cell simulations is required. In this paper we present our experimental findings and present understanding of the results.

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375/LP-42/P

FEMTOSECOND LIBS BASED STANDOFF DETECTION OF EXPLOSIVE MOLECULES

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Abstract

Despite several counter terrorism measures, India witnessed the maximum bombings in last year with 406 blast incidents. Iran was next to us with 221 bombings as reported by national bomb data centre (NBDC). The increased use of improvised explosive devices (IEDs) with 337 out of 406 shows the immediate necessity of detecting the explosives [1]. Thus, homeland security is prime concern in not only India but in all other countries. In comparison with existing explosive trace detection techniques which rely on sample collection and examination, the femtosecond Laser Induced Breakdown Spectroscopy (fs LIBS) technique has several advantages such as robust in-situ elemental analysis has been explored for standoff detection of explosives through the phenomenon of filamentation [2]. Standoff LIBS technique also has tremendous potential for atmospheric [3], underwater and space exploration missions. Several research groups have demonstrated LIBS explosives detection in standoff mode using nanosecond laser pulses for explosive residues on a solid surface, and have even demonstrated detection of residues from behind a physical barrier. A terawatt femtosecond laser (795 nm, 10 Hz, 75 fs, upto 350 mJ) was used by Rohwetter et al. for remote analysis of copper and aluminum samples located 25 m away [4]. Stelmaszczyk et al. demonstrated remote filament-induced breakdown spectroscopy (R-FIBS) of copper and steel plates at distances up to 90 m with a teramobile laser pulses (80 fs, 250 mJ at 800 nm, 10 Hz) [5]. Despite these observations and progress, key challenges persist in detecting explosives and their residues [6].In this work, standoff detection of high energy materials (HEMs) viz., nitropyrazoles and nitroimidazoles was carried out aiming at detection of trace amounts of explosive. The main objective of the study was to evaluate the feasibility of different configurations and understand the problems in the detection of trace amounts of explosives at standoff distances. Results from standoff LIBS detection experiments at 2 m and 8.5 m will be presented in this paper.

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356/LP-43/P

Merging of Current Filaments in Weibel Separated Relativistic Electron Beam Propagation through Over Dense Plasmas

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The relativistic electron beam (REB) propagation in a plasma is fraught with colliisionless Weibel destabilization[1] wherein the forward propagating REB gets spatially separated with the return shielding currents. This results in the formation of current filaments which are typically the size of electron skin depth[2]. We study the non - linear evolution of instability during which the filaments merge into each other, increasing the size of individual filaments. However, the total magnetic field energy may increase or decrease as a result of the merging process depending on whether the original current filament was sub or super Alfv´enic respectively[3]. During the coalescence of filaments the background electrons are observed to get fully expelled from the beam region. In the super Alfv´enic case the the profile of the beam current is observed to become hollow attaining a new equilibrium. Particle - in-cell simulations and analytical modelling have been carried out here to understand the process of merger in detail.

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490/LP-44/P

PLUME DYNAMICS IN MAGNETIC FIELD

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Abstract

An Nd:YAG laser of pulse energy 150 mJ has been used to generate plasma plume in the presence of transverse uniform magnetic field varying from 0 to 0.57 T. The dynamics of the evolving plasma plume along and across the magnetic field lines has been studied by two internally synchronized ICCD cameras, mounted in a direction orthogonal to the plume propagation. A well defined cavity-like structure has been observed at lower delay time and comparatively lower magnetic fields in a plane perpendicular to the direction of the magnetic field. The cavity-like structure changes to jet-like structure which transformed to slab-like structure with further increase of delay time. The formation of these types of structure and their dynamics are correlated to the plume expansion in diamagnetic and non-diamagnetic limits. The collapse of the diamagnetic cavity will be explained by the help of a newly developed elliptical cylinder-like model.

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23/LP-45/P

SELF-FOCUSING OF INTENSE COSH-GAUSSIAN LASER BEAM IN MAGNETIZED PLASMA

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Abstract

The combined effect of relativistic and ponderomotive nonlinearities on the self-focusing of intense cosh Gaussian laser beam (CGLB) in magnetized plasma have been investigated. Non-paraxial ray approximation has been used to set up the self -focusing equations, where higher order terms in the expansion of the dielectric function and the eikonal are taken into account. The effect of various laser and plasma parameters viz. laser intensity (a), decentered parameter (b) and magnetic field (ω_c) on the self-focusing of CGLB have been explored. The results are compared with Gaussian profile of laser beam and relativistic nonlinearity. Self-focusing can be enhanced by optimizing and selecting the appropriate laser-plasma parameters. It is observed that the focusing of CGLB is fast in non-paraxial region in comparison with that of a Gaussian laser beam and in paraxial region in magnetized plasma. In addition, strong self-focusing of CGLB is observed at higher values of a, b and ω_c. Numerical results show that CGLB can produce ultrahigh laser irradiance over distances much greater than the Rayleigh length, which can be used for various applications.

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80/LP-46/P

EFFECT OF LASER AND TARGET CONDITIONS ON PROTON ACCELERATION BY FREQUENCY CHIRPED LASER PULSES

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Abstract

For past few decades, there have been numerous studies on accelerating charged particles to high energies in the field of laser plasma interaction. This includes not only development of various types of acceleration mechanism but also the effect of laser and target conditions. One of the laser characteristic that we have studied is “pulse shaping” where the effect of frequency chirped laser pulse is being investigated on Relativistic Self Induced Transparency mechanism (RSIT) [1]. When a frequency of pulse varies with time, it is termed as frequency chirped laser pulse [2]. In RSIT mechanism, the effective mass of electrons increases due to relativistic effects, hence reducing the value of critical density which makes target transparent for specific laser and target conditions.

In this article, we have studied the effect of frequency chirped laser on hydrogen plasma target using 1D3V LPIC++ [3]. A double layer target is considered with low density layer at the rear side of the target. Here, the chirping function is given by $f(t) = \eta t^2$ where, η varies from $-0.01 < \eta < 0.01$. It is observed that threshold density of target increases with the implementation of chirp parameter. Also, the decrease in target thickness and increase in normalized laser pulse amplitude shows adequate rise in threshold density of the target. Furthermore, change in the laser pulse polarization have also shown the increment in threshold density value of the primary target. The strong longitudinal electrostatic field is observed for linearly polarized Gaussian laser pulse at rear side of the target which results in more promising proton energy when compared to circularly polarized Gaussian laser pulse. With the implementation of chirp parameter a significant rise in proton energy spectrum is being observed compared to unchirped laser pulse.

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488/LP-47/P

NANOSECOND TIME RESOLVED IN-SITU RAMAN SPECTROSCOPIC MEASUREMENTS OF POLYETHYLENE UNDER LASER DRIVEN SHOCK COMPRESSION

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Abstract

Understanding the dynamic nature of shock compression such as fast rise and fast release of the shock loading; it is necessary to find real time information of materials under shock compression. Also, if we wish to tailor the behaviour of material under shock compression, it is essential that we understand the shock wave effect at atomic and molecular level. The time resolved Raman spectroscopy is an effective tool to investigate the real time effects of shock compression induced chemical and structural changes in the material[1]. Polyethylene is one of the most common polymer in daily life, having high ductility and impact strength as well as low friction coefficient [2]. The experiments were performed using pump probe experimental setup and confinement geometry target assembly. A nanosecond time resolved Raman spectroscopy has been performed to study the chemical and physical changes in Polyethylene under laser driven shock compression. The changes in the fundamental vibrational modes of polyethylene were observed with respect to shock wave propagation. The mode recorded under shock gets broadened due to the contribution of signals from shocked and unshocked region. To obtain peak shift information, the obtained spectra under shock compression were analyzed by double Gaussian peak fitting. The intensity of the shock induced peak increases with the increase in delay time. The intensity ratio for shocked to whole volume is plotted as a function of delay time to calculate the shock velocity in polyethylene with experimental laser intensity. The shock velocity results are compared with the 1D radiation hydrodynamic simulation results and are found in good agreement within the experimental errors.

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335/LP-50/P

EFFECT OF ABLATION GEOMETRY ON LASER INDUCED PLASMA OF THIN FILM

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Abstract

Effect of ablation geometry on the characteristic expansion of plasma plume produced by front ablation (FA) and back ablation (BA) of thin film has been investigated using optical emission spectroscopy and fast imaging technique. It has been observed that ablation geometry of thin film highly influence the dynamical, spectral and geometrical properties of the expanding plasma plume. The two dimensional images of the plume shows that BA plume is confined and cylindrical shape, which is striking different than the highly diverge and spherical FA plume. Also, front ablation plume has nearly six times higher expansion velocity in comparison to the observed expansion velocity in the case of back ablation. In presence of ambient gas, plasma plume induces shock front at the contact boundary of expanding plume in case of back ablation because of efficient compression of the background gas. On the other hand in case of front ablation, signature of shock front is not observed rather the plume gets split in slow and fast components. Further optical emission from ionic and neutral species reveals that front ablated plasma is charge particle dominated whereas the neutral particle is the major constituents in back ablation. Above observation is correlated with difference in material removal processes in these two cases. This study is particularly important in controlling the characteristics features of plasma plume.

8/PP-1/P

DEVELOPMENT OF COLDPLASMA JETUSING FLOATING HELIX ELECTRODE CONFIGURATION

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Abstract

Atmospheric pressure glow discharges (APGD) based on dielectric barrier discharge (DBD) offer the prospect of a future basic technology for low-temperature processing of gaseous and solid materials without the use of a vacuum chamber [1]. DBD based atmospheric pressure plasma jets (APPJ's) have wide range of potential applications such as thin film deposition [2], sterilization [3], surface modification [4-5], and etching [6]. Important properties of this type of plasma are that it operates near room temperature, allows treatment of irregular surfaces and has a small penetration depth [7]. A floating helix electrode configuration [8] was implemented for generation of atmospheric pressure DBD based cold plasma jet using Ar/He gas.In this paper, floating helix electrode configuration has been used to generate atmospheric pressure DBD based cold plasma jet using a mixture of argon and nitrogen gas. It was subjected to a range of supply frequencies (10-25 kHz) and supply voltage (6.5-9 kV). The current-voltage characteristics have been analyzed. Furthermore, consumed power has been estimated at different applied combinations (supply frequency & voltage) for optimum power consumption at maximum jet length.

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29/PP-2/P

NEXT GENERATION OPTOELECTRONICS THROUGH PLASMA NANOTECHNOLOGY

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Abstract

Optoelectronics is at the crossroads of electronics and optics. The field of optoelectronics have been revolutionized by use of nanotechnologyat recent time. In the meantime, plasma nanotechnology which addresses the technological development for the synthesis of nanomaterials, also emerges as a potential source in optoelectronics due to its advantage of being a completely dry and green process [1,2]. This work will be emphasized on combining optoelectronic devices/circuitry through plasma nanotechnology. Initially the market and R&D status of optoelectronics at global level will be discussed briefly followed by highlighting the recent developments in organic and inorganic photodetectors. Additionally, some experimental prospects of optoelectronic devices realized using plasma nanotechnology will be discussed and compared.

In the field of optoelectronics, we will specifically highlight the fabrication of various geometries of hybrid photodetectors by plasma based processes. First systematic efforts have been devoted in designing various organic-inorganic nanocomposites which can be directly integrated in the optoelectronic circuitry. We have synthesized both binary and ternary nanocomposites with polymer, small molecule and metal oxides. We have also studied the interesting photophysical phenomena associated with the as-prepared nanocomposite materials. Second, we have fabricated hybrid photodetectors using the as-prepared nanocomposites and studied the photoresponse. We address the various strategies to overcome bottleneck in getting a balance in photoconductive gain and response speed trade-off of the hybrid photodetectors. In parallel, systematic efforts have been devoted in understanding the underlying photo-physics and device physics in such systems. Finally, based on our findings, we can conclude that plasmabased method provides a green and dry technology where the self-assembly of molecules, under plasma environment,emerge as a successful strategy to form well-defined structural and morphologicalunits of nanometer dimensions that can be directly integrated in the fabrication of exceptionally stable optoelectronic devices.

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54/PP-3/P

INFLUENCE OF PLASMA NITRIDING ON WEAR AND CORROSION PROPERTIES OF NITRONIC 50 STAINLESS STEEL

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Abstract

Nitronic 50 is a type of austenitic stainless steel which has corrosion resistance greater than provided by types 316 and 316L, plus approximately twice the yield strength at room temperature. Even though it has found many applications because of the higher corrosion resistance, it is yet to be studied for changes in wear and corrosion properties using surface modification technique such as plasma nitriding (PN).

The present work is an experimental study of plasma nitriding on Nitronic 50 conducted at various process temperatures ranging from 340^{O}C to 580^{O}C for a constant duration of 4hrs using a mixture ratio of N_2:H_2 = 1:4. The modified surface has been evaluated for micro-hardness and characterized by optical microscopy and XRD. Wear (pin on disk) and corrosion tests (3.5% NaCl) have also been performed on untreated and plasma nitrided samples. Results show that the surface hardness is increased by factor of 4 in the case of 500^{o}C PN temperature.As for the case depths it varied from 20 microns for 460^{o}C to as high as 50 microns for 560^{o}C. Optical images confirm results obtained from micro-hardness measurements, i.e. thicknesses of the nitrided layers and provide microstructure-related information. Weight gain measurements have also been carried out for all PN treatment temperatures. XRD results indicate formation of S-phase (expanded austenite) at low temperatures of 360^{o}C & 400^{o}C. For high temperature PN treatment at 460^{o}C, 520^{o}C & 580^{o}C, CrN and Cr_2N are seen while Fe_2N & Fe_4N peaks are found at 520^{o}C and 580^{o}C, respectively imparting increase in corrosion resistance. Corrosion rate is least at 580^{o}C neglecting low temperature treatments while wear rate is minimal at 500^{o}C. Combing all the results, it can be concluded that in applications where wear resistance is more important, e.g. in mildly corrosive medium then plasma nitriding at 500^{o}C is best since weight loss is minimum (1/13.7 compared to untreated). However, if the corrosive medium is not so mild then 580^{o}C

may be considered the optimum plasma nitriding temperature. The importance of the results of the present investigation will be discussed for different applications

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100/PP-4/P

REALIZATION OF COLD ATMOSPHERIC PRESSURE (CAP) PLASMA JET AND ITS APPLICATION IN PET SURFACE MODIFICATION

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Abstract

In the recent years, tremendous growth has been observed in application of CAP plasma for surface modification [1,2] in particular plasma polymerization, functionalization of polymer surface for improved adhesion, wettability etc. and plasma bio-material interactions. Such plasmas are cold or non-thermal because the plasma gas remains at room temperature and highly reactive chemical species are generated by the high temperature plasma electrons and these highly reactive species play the dominant role in surface modification.

In this study, we have designed an Atmospheric pressure plasma jet (APPJ) [3] powered by a 5 KV, 50 kHz/50 Hz power supply and helium/argon as fed gas (flow rate 5-10 lpm). The discharge is made inside a quartz tube (6 mm inner diameter and 70 mm length) between a hollow live electrode placed inside the tube and a grounded copper ring electrode wrapped on outer surface of the tube. A plasma plume (length ~ 3 cm, diameter ~ 1 mm) blows out into open air with the flow of the gas. We plan to use it for surface modification of polyethylene terephthalate (PET) toimproveadhesion, wettability, printability etc. Standard techniques such as SEM, TEM, contact angle analyzer etc. will be used to analyze the treated polymer surface. Characterization [4] of CAP plasma with different fed gas composition using optical emission spectroscopy (OES) will be presented.

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184/PP-5/P

REDUCTION OF CHROMIUM OXIDE USING PLASMA ASSISTED ALUMINOTHERMIC REACTION

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Abstract

The plasma assisted aluminothermic process is developed to reduce the chromium oxide into chromium metal. In this process, mixture of chromium oxide and aluminium metal powders is exposed to the plasma generated by transferred arc mode. The cathode and crucible anode in the transferred arc plasma system are made up of graphite. The role of plasma in the aluminothermic process is to initiate the reaction between chromium oxide and aluminium metal powders as well as to separate metals from the slag. The products of the plasma assisted aluminothermic process are melt and slag. The composition these products are analyzed using XRD diffraction and EDAX. The chromium-aluminium metal is found in the melt whereas aluminium oxide is identified in the slag. Form these results, it can be concluded that there is a potential opportunity for recovery of chromium metal from toxic chromium oxides waste in large quantities using plasma assisted aluminothermic process.

208/PP-6/P

DEVELOPMENT OF ANTIMICROBIAL EFFECT ON THE SURFACE OFMEDICAL GRADE COTTON FABRICS VIA COLD ATMOSPHERIC PRESSURE PLASMA ASSISTED POLYMERIZATION

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Abstract

In this work, we developed antimicrobial effect on the surface of medial grade cotton (MGC) fabrics by immobilization of silvernano particles (AgNP) via multilayered organic polydimethylsiloxane (PDMS) like coatings deposited by cold atmospheric pressure plasma assisted polymerization. The chemical composition of the AgNP immobilized PDMS-MGC fabrics were studied by means of X-ray photoelectron spectroscopy (XPS) and Fourier transform infrared spectroscopy (FTIR). The surface topography, morphology and optical properties of the materials were studied using atomic force microscopy(AFM), scanning electron microscopy and UV-visible spectroscopy (UV-Vis). Furthermore the hydrophilic behaviors of AgNP immobilized PDMS-MGC fabrics were further examined by measuring angle of contact and evaluation of surface free energy components. Finally the antimicrobialeffect of AgNP immobilized PDMS-MGC fabrics wereevaluated against Escherichia coli (E. coli) and Staphylococcus aureus (S.aureus) bacteria.

209/PP-7/P

DEVELOPMENT AND CHARACTERIZATION OF ANTI-FOULING COATINGS VIA ATMOSPHERIC PRESSURE NON-THERMAL PLASMA ASSISTED COPOLYMERIZATION TECHNIQUE

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Abstract

In this study, antifouling coatings were developed on the surface of polypropylene (PP) films via atmospheric pressure non-thermal plasma assisted copolymerization technique using polyethylene glycol (PEG) and allylamine (AA) as precursors. The anti-fouling coatings were developed as a function of various concentration of allylamine (AA). Furthermore, molecules of heparin (Hep) were immobilized on the surface of optimized PP-PEG-AA films, further to enrich their anti-fouling properties. The surface chemistry of surface modified PP films was characterized by X-ray photoelectron spectroscopy (XPS) and Fourier Transform Infrared-Attenuated Total Reflectance (FTIR-ATR) spectroscopy techniques. The changes in hydrophilic properties were determined by measuring the contact angle (CA) values and evaluated the surface energy using Fowkes's approximation method. The surface topography was imaged by means of atomic force microscopy (AFM) and scanning electron microscopy (SEM) analysis. Conclusively, the anti-fouling properties of the surface modified films were examined by in vitro analysis. Virtuous results have been obtained; unveiling that the atmospheric pressure non-thermal plasma assisted copolymerization technique is auspicious in enhancing the antifouling property of the polymeric films.

231/PP-8/P

PLASMONIC RESPONSE OF AG NANOPARTICLE ARRAYS AND AG NANODOTS

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Abstract

A low cost and highly versatile approach to form nanostructured patterns on solid surfaces is low energy ion beam irradiation due to the tunability offered by angle of incidence, energy and the fluence of the incident ions [1]. In present work, we show optical response of silver nanoparticles (Ag NP) deposited on two different nanopatterned structures (nanoripples on silicon and nanodots on GaSb).

Ag NP are well known for their characteristic optical signature known as Localized Surface Plasmon Resonance (LSPR). In the present work, we have used Generalized Ellipsometry (GE) to extract the dielectric functions (DF) of self-aligned Ag NP deposited on silicon ripple patterns which account for the phenomenon of anisotropic LSPR. The biaxial nature of DF shows its presence through the modified in-plane plasmonic behavior. The nature of in-plane optical coupling and out of plane metallic behavior is further investigated by tuning the interparticle gap along the ripple direction and also varying the ripple periodicity.

In the second work, we report on optical response of Ag NP topped GaSb nanodots [2]. Nanodot (ND) ordering and interdot gap play crucial roles for inducing LSPR effect, escalating the absorbing capacity of the structure. Anisotropic Bruggeman effective medium approximation was performed to extract the DF of the system. Calculated DF confirm the directional anisotropy along the length of nanodots. The model was validated by correlating the void fraction and nanodot height to that observed from Scanning Electron Microscopy and Transmission Electron Microscopy, respectively.

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315/PP-9/P

SURFACE MODIFICATION OF POLYMERS BY 50 HZ DIELECTRIC BARRIER DISCHARGE (DBD) AT ATMOSPHERIC AND NEAR ATMOSPHERIC PRESSURE

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Abstract

The industrial application of the dielectric barrier discharge (DBD) has a long tradition. However, lack of understanding in some of its fundamental issues, such as the stochastic behaviors, is still a challenge for DBD researchers. In this project, considerable efforts to understand the fundamental aspects of DBD have been made. The work was carried out at line frequency, 15KV, and at atmospheric and near atmospheric pressure (40 torr). This work focuses on the study of the electrical and optical characteristics of DBD at atmospheric and near atmospheric pressure to determine a suitable condition for utilization of the device for surface modification of polymers like High-density polyethylene (HDPE), Polypropylene (PP) and Polyamides (PA). Several diagnostic tools such as high voltage and current probe, high-speed camera imaging, contact angle and surface free energy measurements and SEM analysis are employed for the investigation.

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348/PP-10/P

OPTIMIZATION AND ANALYSIS OF PLASMA PROCESSING UNIFORMITY

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Abstract

Free form structures made up of brittle optics like fused silica/ Zerodur finds variety of high end applications like hemispherical resonator gyro, Brewster windows for Ring Laser Gyros etc. These applications demand realization of ultra fine surface finish with zero sub surface defects as well as very good profile uniformity after processing. A novel plasma assisted atomistic surface finishing on free form surface of fused silica developed for achieving good surface finishing with less sub surface defects [1]. But the uniform plasma processing to retain complex profile is a matter of concern. Uniform machining depends on the plasma density distribution in the chamber during processing. In capacitive coupled dielectric barrier RF discharges, the plasma density profile strongly depends on the electrode configuration for a given chamber [2]. In this study different kinds of electrode configurations have been utilized to improve the processing uniformity of a hemispherical substrate. The plasma uniformity during processing has analyzed by optical emission spectrometer (OES). Laser Doppler Vibrometer (LDV) technique used to analyze the profile after plasma processing.

The discharge was initiated in a volume of 40 ccwith an inter electrode gap of 30 mm with 40 watt power and 40.68 MHz RF generator. The hemispherical shell (Dia. 30 mm and 1 mm thick) of fused silica has used as a substrate for plasma processing. Two different kinds of electrodes used in this study 1. Flat shaped copper electrodes at top and bottom of the plasma chamber, 2. L and inverted L shaped electrodes occupies four sides of the chamber. Electron temperature of the plasma has been analyzed to understand the plasma uniformity at different locations by using Aryelle 200 OES.Polytec make Scanning LDV PSV 500B is used to analyze surface irregularities of the hemispherical shell after plasma processing from natural frequency split information.

It shows that for flat electrodes the electron temperature is maximum (~1400 K)at axial direction and for L shaped electrodes the electron temperature (~1300 K) is uniform and maximum in radial direction. As it is not possible to achieve a uniform plasma temperature for a particular configuration, processing cycle has been developed by using combination of these electrode configurations to achieve uniform polishing by OES. However LDV technique utilized to reconfirm the uniform plasma machining after processing. About 100 mHzreduction in frequency split has observed for combination of electrodes processing. It is attributed to the reduction in surface irregularities and improvement in mass distribution.

Thus the plasma processing by combinations of electrode configurations has significantly helped to minimize surface irregularities and enhances the profile uniformity with 60% improvement in material removal rate.

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357/PP-11/P

STUDY OF O_2, AIR, AR AND N_2 MICROPLASMAS FOR REMOVAL OF RHODAMINE B IN AQUEOUS SOLUTION

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Abstract

Removal of organic pollutant from contaminated water is an essential process in our day-to-day life due to water scarcity. In this study, a high voltage neon transformer was used to generate microplasma for the degradation of Rhodamine B dye in aqueous solution. Oxygen, air, argon and nitrogen are used as a plasma forming gases. The degradation tests were performed at different treatment time. The degradation efficiency was calculated and active species formed was measured using test strips. The result shows that the decolorization % of dye enhances by increasing the treatment time for all the gases. The tested samples were exposed to UV-Vis absorption studies and calculated the % of degradation. The results exhibited that the absolute degradation (100%) occurs at 16, 18, 23 and 25 min treatment time of O_2, Air, Ar and N_2microplasmas, respectively.

371/PP-12/P

INTERACTION OF ATMOSPHERIC PRESSURE PLASMA JET WITH LUNG CANCER CELL LINE (A549)

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Abstract

Atmospheric pressure plasma jet (APPJ) is non-thermal plasma source producing plasma at room temperature and is touchable by bare hands. In recent years APPJ has been developed as an innovative approach in life science for a wide range of applications, including its role in blood coagulation, cosmetics, dental and cancer treatment. However, the molecular mechanisms of interaction of APPJ with human cells remain unclear.

In this report we present preliminary results on the interaction of APPJ with human lung cancer cell line (A549). Cells were cultured in 35 mm plates and treated with plasma for various time periods (2 min, 5 min, and 10 min). Cell viability was studied using MTT assay after 24h of plasma treatment. Our analysis showed a 50% decrease in cell viability after 24h indicating the effectiveness of APPJ in killing cancer cells. Further studies are currently underway to study the effect of APPJ on the reproductive cell death by measuring colony formation ability of these cells after 14 days.

256/PP-13/P

DEVELOPMENT OF RF BASED CAPACITIVELY COUPLED PLASMA SYSTEM FOR DEPOSITION OF TUNGSTEN ON GRAPHITE FOR ADITYA UPGRADE TOKOMAK

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Abstract

Based on the current thermonuclear fusion research, it is quite likely that future fusion machines, DEMO and beyond, will be operating with tungsten and alloys based on tungsten as the plasma facing material on their walls and targets to dissipate the thermal as well as particle loads under extreme conditions. Tungsten is being preferred because of its superior thermo-mechanical properties as well as for its low tritium retention. However, use of pure tungsten as a structural material itself will substantially increase the manufacturing cost and overall system mass and also it is difficult to machine. Hence, tungsten coatings on light substrate such as graphite are preferred which essentially reduce the cost and structural weight considerably. In order to develop the technology of appropriate coating of tungsten on graphite, a RF based capacitively coupled plasma reactor for tungsten coating on graphite tiles using plasma assisted chemical vapour deposition (PACVD) has been developed at SVITS, India [1]. One of the actual graphite tiles of ADITYA-U tokamak limiter is coated with tungsten in the reactor by reducing the heavy tungsten hexafluoride gas in hydrogen. These tiles are characterized for their tungsten content, thickness of the coating, adhesion of tungsten on grating, uniformity of the coating, thermal fatigue etc. After thorough characterization, these tiles are going to be installed inside the ADITYA-U tokamak and the response of high temperature plasma will be studied. Detailed characterization and post analysis of the tungsten coated tiles along with the coating processes will be discussed in this paper.

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244/PP-14/P

INQUISITION OF CHARGED PARTICLE INTERACTION WITH SXR SYSTEM IN SST-1

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Abstract

A speculative investigation is carried out to study the interaction of ions/electrons on SXR diagnostics system. Interactions occur during plasma discharge may cause significant damage on plasma facing components (like Limiter, first wall component, vacuum vessel and diagnostics system) and also contribute to plasma impurities. During routine opening of SST-1, many erosion spots were observed on SXR diagnostics system. These erosion spots may be due to various phenomena like Sputtering, interaction of Ion beam with material, Arcing or interaction of Runaway Electron Beam to plasma facing component. In this communication, detailed cause finding study is carried out to simulate such effect on SS 304L samples which include RF sputtering and Ion beam irradiation on SS304L samples. Comparative study of microscopic images confirms that these erosion spots are due to melting and material vaporization of SS-304, which ruled out possibility of sputtering. Theoretical assay for energy of ion beam which can cause the erosion or material vaporization is calculated using the average Range of stopping potential. Same efficacy on SXR system is not created by ion beam irradiation experiment experiments. Due to these inadequate results, melting can be attributed to the arcing between Glow Discharge Cleaning (GDC) probes present near the SXR diagnostics or Runaway Electron Beam.

398/PP-16/P

EFFECT OF MICRO-GLASS CAPILLARY AND MAGNETIC FOCUSING OF PLASMA ION BEAMS FOR CREATION OF SUBMICRON STRUCTURES

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Abstract

A microwave plasma confined in a magnetic multicusp has been used as an ion source for obtaining focused ion beams of a variety of gaseous elements [1, 2]. By changing the experimental gas, ionic species that carry different momentum are obtained, corresponding to the accelerating voltage. In our previous work [3], a parameter called current normalized force (CNF), is defined to calculate the total momentum transferred from the beam to the target sample, which is the momentum transferred per unit time, normalized to the beam current. CNF is directly dependent on ion parameters such as number, mass, velocity, including beam irradiation time, beam current and beam angle at the sample. High aspect ratio (line width/depth) microstructures in the range ~ 100 -1000, have been created using Ar, Kr, and Ne ion beams. The beam extraction and focusing system consists of a plasma electrode (PLE) (aperture diameter 500 μm), 2 sets of Einzel lens (EL_1, EL_2) and a beam limiter (BL).

For creating submicron structures, the beam size needs to be further reduced while maintaining the same CNF. One way to reduce the beam size is by reduction of the source size (PLE aperture) for a constant demagnification factor (image size/source size), however, there is a loss of beam current in this method. Therefore, micro-glass capillary is employed, which has demonstrated self-focusing of the beam without significant reduction of the beam current [4]. Therefore, different size capillaries (860 μm inlet diameter, 860/500/300/100/50 μm outlet diameter) are employed after the PLE to reduce the beam source size, while maintaining the beam current. It is found that the ion beams are well guided through the capillary without significant reduction of the beam current. Self-focusing of the beam is observed and it reduces with decrease in capillary outlet diameter. The capillary is then incorporated in the beam optics.

Finally, coupled with capillary beam guiding and self-focusing, miniature permanent magnet octupole is employed at the end of the last electrode (EL_2) to further arrest the expansion of the

beam before impinging on the substrate. It is expected that submicron structures with high aspect ratio may be fabricated using the above improvisations.

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147/PU-1/P

PLASMA STREAM VELOCITY MEASUREMENT IN PULSED PLASMA ACCELERATOR

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Abstract

A quasi-stationary type co-axial pulsed plasma accelerator (PPA) has been developed at CPP-IPR. The pulsed plasma device consist of a co-axial electrode assembly and it is powered by a 200 kJ Pulse Power System (PPS). The device produces high density and high velocity plasma stream and it is useful for studying plasma matter interaction (PMI) taking place due to ELMs events at tokamak. Therefore the characterization of plasma stream such as the stream velocity is important to know the usefulness of the stream. The plasma stream velocity can be measured adopting a well-known time of flight technique. For this we have used a pair of PMTs and two pairs metallic plate-probe separated by a distance. In general, the plasma stream velocity of a PPA varies from few kilometers per second to few tens of kilometers per second depending on the discharge voltage as well as the driving pulse current. The plasma stream velocity, observed at the CPPIPR PPA, is found to be in the order of km/s and it is comparable to the velocity obtained in a similar device elsewhere in the world. The detail analysis of plasma stream velocity measurement with respect to discharge voltage and operating pressure condition along with the PPA facility existing at CPP-IPR has been reported in this presentation.

170/PU-2/P

SPARK GAP TRIGGERING CIRCUIT FOR SYNCHRONIZED SWITCHING IN ULTRA-COMPACT CAPILLARY DISCHARGE PLASMA X-RAY LASER

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Abstract

A three electrode spark gap "trigatron" is widely used in pulsed power applications which can be easily electrically triggered to generate a high voltage pulse [1] in the range of kilovolts and kilo-ampere. Such spark gap switches have been used in ultra-compact capillary discharge plasma setup (UCDS) to generate coherent x-ray radiation at 46.9 nm wavelength [2]. This setup operates at 60 kV having two stages of pulse compression to generate 20 kA current, with a quarter period of 50 ns through a gas filled long capillary. At present, in the first stage a Tesla transformer is energised by discharging a capacitor by a trigatron switch and the second stage consists of a 20 nF impulse capacitor switched through a self-breakdown in spark gap and the capillary gas column.

In order to get stable repetitive generation of current, both the stages must be triggered with a delay of few microseconds, which is being implemented. To use trigatrons in both the stages, the switches must be triggered with jitter and delay below tensof nanoseconds for stable operation of the UCDS. For this purpose a fast pulse generator based on MOSFET stack is developed and tested with a trigatron switch. The MOSFET stack discharges a capacitor to generate a fast rising pulse applied to the trigger pin of the spark gap. The capacitor is charged using 5 kV DC to DC converter (model 12VV5, M/s PICO) was optimised for minimum rise time and delay. The delay between input trigger to the high voltage output pulse is 85 ns and the jitter is 3 ns. Although this scheme does not provide isolation to trigger driver circuit from the spark gap circuit, care is taken to integrate suitable clamp circuits for protection of MOSFET HV switch. A simple 5 kV capacitive discharge circuit with a trigatron switch was assembled to test the trigger scheme. It was observed that the trigger delay between appearance of HV pulse at trigger pin and initiation of the main current is ~ 50ns and jitter less than 20ns. These results will be presented in detail. This triggering scheme is suitable where spark gap is at ground potential and anode switching voltage is of few kilovolts and is appropriate for triggering of Tesla transformer spark gap for UCDS application. This system had been successfully tested at 0.2 Hz repetition frequency to generate soft x-ray laser at 46.9 nm.

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174/PU-3/P

DEVELOPMENT OF PULSED POWER SYSTEM FOR LARGE APERTURE PLASMA ELECTRODE POCKELL'S CELL

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Abstract

Large aperture multi-pass laser amplifier is the main sub-system of the third generation high energy high power laser system [1]. For the development of such amplifiers, large aperture Pockels cell are required for gain holding and pulse switching. High energy lasers are designed with large apertures to keep the fluence below damage threshold. A plasma electrode Pockels cell (PEPC) based system can be scaled up to these sizes [2]. A PEPC of 150 mm aperture has been developed for this purpose. Its optical transmission was tested using laser of 1064 nm wavelength on application of simmering, plasma forming pulse and the high voltage switching pulse.

The PEPC cell is made from a block of Perspex from which a square section of 250 mm x 250 mm x 25 mm was milled out from two faces making cells and space for the crystal was left at the centre where a KDP crystal of 90 mm by 80 mm x 20 mm size was potted with silicone elastomer. Optical windows were fixed on Perspex flanges and bolted to the cell block to close the plasma chambers. After complete assembly of PEPC it was evacuated to ~$8x10^{-2}$ mbar and then filled with He gas at 1 to 5 mbar. Two high current pulse supplies (HCPS) and two simmer supplies (SS) were connected with chokes and ballast resistors for their proper operation. To generate plasma sheet/electrode on both the sides of the crystal a glow discharge is initiated by 1.5 kV, 50 mA simmer supply and then a high current pulse (HCP) 1.6 kA, 20 µs is passed in the low pressure helium gas. When plasma current reaches to peak a HV switching pulse of 15 kV, 100 ns is applied across the two plasma electrodes. Transmission of 1 µm laser through the double plasma chambers is measured by 1 µm /100 mW laser. Results on electrical and optical characterisation will be presented.

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365/PU-4/P

OPTIMIZATION STUDIES OF PSEUDOSPARK SOURCED ELECTRON BEAM FOR DEVELOPMENT OF PLASMA ASSISTED SLOW WAVE OSCILLATOR

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Abstract

In this work an effort has been made to design and developdifferent Pseudo spark (PS) discharge based Plasma Cathode Electrode (PCE) Guns and their optimization so as to develop X-band plasma assisted slow wave oscillator first time in the Country. In fact, some research work has been done in past showing that the presence of plasma in conventional microwave tubes, such as, Travelling Wave Tubes (TWTs), Klystrons, and Gyrotrons increases the beam current transport. The presence of plasma also relaxes the requirement of the external magnetic field and significantly improves their performance with respect to RF power, bandwidth, efficiency, compactness, and long-pulse as well as high pulse repetition frequency (PRF) operation capabilities. The plasma assisted slow wave oscillator largely rely on beam-wave interaction process inside a plasma filled slow wave structure (SWS) for the generation of microwave radiation driven by energetic electron beams from PCE-Guns, which has not been thoroughly investigated. Accordingly five types of PCE-Guns have been designed and developed where PS discharge concept has been utilized.

The developed PCE-Guns include different configurations –like, single-gap single-aperture (SGSA), single-gap multi-aperture (SGMA), a novel single-gap sheet-beam (SGSB), multi-gap single-aperture (MGSA) and a novel tapered multi-gap multi-aperture (TMGMA) [1-5]. The performance of the developed PCE-Guns have been optimized at different operating conditions including operating gas pressure, applied voltage, electrode arrangement, electrode gaps, aperture geometry and breakdown mechanisms. Two diagnostic techniques have also been developedto investigate the generated electron beams. A simple two isolated concentric ring diagnostic arrangement gives the qualitative assessment of focusing and defocusing locations of the electron beam during its propagation inside the drift space region [2,5]. The another diagnostic technique is based on dielectric charging and scanning electron microscope (SEM)

based imaging which enables the exact shape and size estimations of the generated electron-beam from the PCE-gun [1,3]. To better understand the electron beam generation from the developed PCE-Guns, simulations using 'OOPIC-Pro' and Vsim-6 have also been carried out [4]. A good correlation has been found between experimental and simulation results. These studies led to develop first indigenous demountable prototype of X-band plasma assisted slow wave oscillator, which has generated non-coherent microwave signalin the range 10-11.7 GHz.

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388/PU-5/P

INDIGENOUSLY DEVELOPED PSEUDOSPARK DISCHARGE BASED HIGH CURRENT SWITCH

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Abstract

High power switches are among key component of all pulse power systems. Pseudospark switches (PSSs) have all desirable pulse power properties: high hold-off voltage,high rates of current rise,high repetition rate, long life and ruggedness. Pseudospark switches, however, are limited in their high current switching capability. CSIR-CEERI is making an effort in the development of a radial multichannel high current switch based on pseudospark discharge which could be suitable for pulse durations of tens of microseconds and peak currents of up to 200 kA. Such high current PSS would be useful for variety of emerging applications including shock wave generation, electro-magnetic forming process, study of high energy physics, etc. [1-2]. CSIR-CEERI knowledge base of hot cathode and cold cathode thyratrons is being utilized for the same. In this regard a 20kV/20kA radial multi-channel PSS has been realized first time in the countryat CSIR-CEERI [3]. Nevertheless, more refined robust structure is needed to be developed to achieve very high currents up to 100s kA to meet some of the immediate strategic needs in India. Such switches are being presently imported and time to time are subjected to import restrictions.

In this paper a PSS design for very high current up to 100 kA at 20kV hold-off voltage is reported, which has been enriched by geometrical parameters. The electrode shape, material,homogenous distribution of igniting plasma, dense plasma confinement around refractory electrode area and insulator shielding from plasma play crucial role in switching high current and increasing life of the switch. Accordingly these issues have been taken care in the modified design. The proposed design is being validated by switching characteristics. The

developed PSS will significantly extend the capabilities of pulse power technology in the country.

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407/PU-6/P

FIBER OPTIC BASED FIELD SIMULATOR FOR HVPS

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Abstract

Pulse Step Modulation (PSM) based High Voltage Power Supplies (HVPSs) are widely used in fusion research and other applications viz. broadcast transmitters, particle accelerators and neutral beam injectors because of inherent advantages of modular structure, high accuracy and efficiency, low ripple and fast dynamics[1]. Controller for the HVPS is designed to suit requirements during local operation and remote operation. In Local operation mode, protection interlocks within the HVPS are integrated while remote mode has additional interlocks from respective system. Present article discuss the development of multiple channel fiber optic simulator. Field integration of the controller is achieved through fiber optic links to avoid Electro-Magnetic interferences (EMI). A detailed description of component selection criteria, mode of operation and communication protocol is presented. Article also discusses the case study ofutilization of FO simulators in dual output IC RH system and Acceleration Grid Power Supply [2].

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486/PU-7/P

DESIGN AND DEVELOPMENT OF MULTI-GAP AND MULTI-APERTURE PSEUDOSPARK SWITCHES FOR PULSE POWER APPLICATIONS

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Abstract

In the recent decade, a resurgence of interest in high power fast switching devices has occurred in response to their new requirements for civilian as well as strategic applications, such as, Radars, Linacs, Pulsed lasers, Synchrotron sources, Crowbars, Sterilizations, Transient plasma ignition for pulsed detonation engines, High power electron beam sources, etc. [1-2]. CSIR-CEERI has been working for nearly two decades in the field of plasma closing switches, particularly, Thyratron and Pseudospark (PSS) switches to meet the demand of strategic sectors in the country. The thyratron switch is a well-established technology and is commercially available from limited industries. On the other hand, there are many advantages of PSS over the thyratron switch like, low standby power, ruggedness to current reversal and fast rate of current rise. A fast voltage breakdown together with a fast current rise is typical for pseudospark discharge (PSD) resulting in a class of high power gas phase switches used in pulsed power applications. The PSS is a new development and its capability as an alternative to thyratron switch needs to be proven yet at higher voltage ratings [3-4].

In the recent past CSIR-CEERI has successfully developed single gap sealed-off 25kV/5kA PSS which is holding voltage up to 30 kV and delivering current more than 5 kA even at higher (≥ 50Hz) pulse repetition rate (PRR). Keeping the upcoming requirements of strategic sectors for high power plasma switches, demountable and sealed-off versions of double gap 40kV/5kA PSS have beenrecently designed and developed [5]. The developed PSS have two gaps that are separated by a cavity drift space region.Switching characterization of the developed PSS prototypes have been carried out at different operating conditions, such as, gas pressure, voltage, triggering, and circuit conditions. The PSS have been found performing better than the

comparable commercially available thyratron switches for hold-off voltage in the range of 40 kV and current up to 10 kA [5-6]. It employs a single ferroelectric trigger module with a high dielectric constant ferroelectric disc which is inserted in the hollow cathode cavity to provide seed electrons for the efficient discharge ignition in the double gap PSS [7-8]. In preliminary testing, the switch was holding 40 kV with a peak anode current ~10 kA and pulse duration of ~1.5 μs with a resistive load of 2.9 ohm. The switch was operated with deuterium gas reservoir for higher number of discharge shots at different voltages and corresponding peak currentsat repetition rate up to 50 Hz without significant decay of switch performance [5].The design of the developed PSS has been analyzed for higher hold-off voltages with high charge transfer capability at higher repetition rates. The switching performances of the developed PSS validate the design of the double gap pseudospark switch. Recently, CSIR-CEERI has also taken the challenge to design and develop high power 70kV/10kA PSS for crowbar protection circuit applications.

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487/PU-8/P

DEVELOPMENT AND DELIVERY OF 35KV/3KA THYRATRONS FOR LINE-TYPE PULSE MODULATOR APPLICATIONS AT BARC

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Abstract

Thyratron is a low-pressure gas discharge based plasma switching device used as a unipolar closing switch in highpower pulse systems. The switching action is achieved by transfer from insulating gas to the conducting properties of ionized gas. Due to plasma fill, thyratrons can handle much greater current than similar hard vacuum valves/tubes. It finds wide applications for driving pulse laser systems, crowbar systems, pulse modulators, accelerators, synchrotron radiation source, radars, high energy physics, etc. These are presently being imported for various applications and have always been a subject to import restrictions, causing hurdles in Indian efforts for advanced technologies in high energy research areas. At present, CSIR-CEERI is the only Indian organization, which has the capability to develop low pressure plasma switches, which includes thyratrons as well as pseudospark switches (PSS). CSIR-CEERI took up the development of thyratrons for the first time in 1995 at the initiative of RRCAT, Indore. Recently, CSIR-CEERI has taken a challenge to develop and deliver 35kV/3kA deuterium thyratrons to BARC, Mumbai for their use in line type pulse modulator for linear accelerator. Three nos. of 35kV/3kA thyratrons switches have been developed and tested for the rated absolute maximum peak parameters (35kV, 3kA), pulse width of ~5 μs and up to 50 Hz pulse repetition rates at CSIR-CEERI. Successful testing of the thyratrons on pulse modulator at BARC has been carried out on resistive as well as actual Klystron loads for different voltages up-to to 26 kV and 223 pps (max). Efforts for the design consideration, standardization of fabrication processes, development and inspection procedures, switching optimization, performance evaluation and data analysis for the developed 35kV/3kA Thyratron switches will be presented.

344/PU-9/P

NUMERICAL MODELLING TO STUDY MATERIAL RESPONSE UNDER ISENTROPIC COMPRESSION USING PULSED POWER SYSTEMS

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Abstract

To achieve higher compressibility and better energy coupling efficiency between driver and target in Inertial Confinement Fusion (ICF) schemes; isentropic compression is preferred over shock compression. In this direction, knowledge of material behavior under isentropic conditions becomes crucial. Pulse power based systems offer an effective way to understand compressibility and EOS of materials up to Megabar pressures under such conditions.

In this work, a predictive code has been developed in order to simulate ICE experiments.This code has been written on the basis of a circuit model developed at NHMFL, Los Alamos for NHMFL-ICE experiments [1]. The code basically solves a circuit containing the ICE load as a variable inductor L (t) attached to an LCR circuit with the capacitor charged to a certain charging voltage.

The variable factor in load inductance is the inner slit separation between the electrodes which varies as a result of being subjected to high magnetic pressures generated by sinusoidal high currents (~2-3 MA, ~3 µs rise time). A pressure pulse of magnitude ~20 GPa and rise time ~2.8 µs is generated at the inner slit using a ~2.5 MA current pulse. Results show that pressure peak is terminated at ~0.5 µs before current peak because of release waves generated from the free surface for copper electrode pair of thicknesses 3.175 mm and 3.000 mm respectively. Free surface velocities of 1.6 km/s have been obtained from the simulation results. Also, sharpening of free surface velocity with increasing thickness is clearly evident. Sample thickness is limited by formation of shock due to pulse steepening. However, the minimum thickness is determined by generation of release waves, which limit the duration of the experiment[2].

Results of the developed code show high conformity with the published simulation results [1].

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259/PU-10/P

PULSED METAL-PLASMA BASED COMPACT SHOCKWAVE GENERATOR UTILIZING ELECTRICAL EXPLOSION OF ALUMINIUM WIRE IN UNDER-WATER CONDITIONS

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Abstract

Compact pulsed power system for exploding wire based shock-wave generation has been presented. Aluminium wire is chosen to get higher pressure utilizing Aluminium-Water thermite reaction. Additionally sub-microsecond discharge phenomenon enhances generated pressure. Whole system is packed in tubular shape.

408/PU-11/P

SHORT CIRCUIT SWITCH FOR JOULE ENERGY TEST OF HVPS

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Abstract

Pulse Step Modulation(PSM) based High Voltage Power Supply (HVPS) has played significant role in fusion research and other applications viz. broadcast transmitters, particle accelerators and neutral beam injectors. HVPSs are utilized as biasing supply for various vacuum switching tubes and for ion extraction. Voltage range for these systems usually is in the range of 30 kV dc to 100 kV dc with power requirement of 3MW to 7MW [1]. Besides requirements of Voltage regulation, ripple, accuracy, efficiency, fast and programmable rise/fall time, one of the vital specifications is the response and behavior in event of arcing or fault at load. For validation of such HVPS, short circuit should be created intentionally at output side of HVPS. The present article discusses development of short circuit switch having voltage range of 140 kV and peak current capability of 5 kA. Important features of closing time and associated bouncing among electrodes is also presented. Moving arm utilizes rack and pinion arrangement with motor controller and remote trigger option. The switch is frequently utilized for validation of the joule energy limits of HVPS during integration with RF sources [2].

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438/PU-12/P

STUDIES ON THE BEHAVIOR OF MAGNETIC CORE SNUBBERS FOR ENERGY AND SURGE SUPPRESSION

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Abstract

In particle accelerators like Neutral Beam system, breakdowns occur frequently and unpredictably at the Acceleration grids, considered as normal events. It is important to limit the energy during the breakdowns (fast transients) which comes from stray capacitances of system. Passive protection device viz. Core snubbers are considered to be most promising options for limiting the fault energy. Typical core snubbers are tape wound with square B-H loop materials [1]. Frequency of such breakdown ranges from 500 kHz-5MHz and breakdown current pushes the core to magnetization level of 500-800 A/m. Nano-crystalline material is most favorable as it possesses high permeability & saturation flux density at higher frequencies. Cores are normally DC biased to obtain the effective B-H window. Eddy current losses because of induced fluxes in tape are modelled as resistor while the Inductance of core is derived from hysteresis model. Hysteresis model utilizes relative permeability of the core material however datasheet values are available only for very low magnetization levels (~0.05 A/m) [2].

In order to predict the behavior of core at higher induction levels (~500A/m), experiments were conducted with capacitor discharge and DC bias to observe response (flux swing) of the sample core. Permeability offered by the core was calculated and utilized in developing hysteresis model. Improvisation on the core model is attempted to include the effect of the DC biasing and non-linear behavior of the magnetic material.

Present paper discusses experimental observations and modelling of the magnetic core for its effective utilization as energy and surge suppressor.

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218/PU-13/P

SWEEP FREQUENCY RESPONSE ANALYSIS (SFRA) TEST OF POWER TRANSFORMER

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Abstract

IPR has 132 KV, 3ph, 50Hz line coming from 220 kV substation at Ranasan through the single circuit overhead line. Maximum contract demand of IPR is 6 MVA. The Substation at IPR covers various equipment such as Power Transformers, Circuit Breakers, Isolators, Earth Switches, Lightning Arresters, Current Transformer, Potential Transformer, Control and Relay panel and Grounding System rated for 145 kV. There are five Power Transformers of different rating installed in substation which convert 132 KV voltage into 11 kV and 22 kV voltage. This is feed to corresponding 11 kV Bus (S1-S6) and 22 kV (S11-S14). The distribution system at IPR involves various voltage levels. All high power electrical loads are supplied from a 132 kV switchyard through 5 power transformer feeders with associated 11 kV and 22 kV systems. Further distribution in LT (415 V) supplies to various low power loads.

The fifth power transformer of rating 132kV/22kV, 31.5 MVA was installed and commissioned, recently, to cater to the various experimental loads of ITER-India lab viz. prototype of power supplies for Electron Cyclotron and Diagnostic Neutral Beam systems etc. and also supply power to the new labs being built in IPR campus.

The paper discusses SFRA – a modern diagnostic method that detects winding displacement and deformation (among other mechanical and electrical failures) on transformers. These faults change winding geometry. Changes in the geometric configuration alter the impedance network, and in turn alter the transformer function. This enables a wide range of failure modes to be identified.

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001/SA-1/P

STUDY OF KAPPA DISTRIBUTION FUNCTION ON EMIC WAVES IN SPACE PLASMA

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Abstract

Electromagnetic ion-cyclotron (EMIC) waves have been studied are discuss the effect of kappa distribution function by using the method of kinetic approach are evaluated. The dispersion relation, growth rate and growth length on electromagnetic ion-cyclotron waves in low β case (β is the ratio of plasma pressure to magnetic pressure), homogeneous plasma have been obtained. The wave is assumed to propagate parallel to the static magnetic field. In this paper, the effect of kappa distribution on EMIC waves in space plasma is to enhance the growth rate with increases the growth length of EMIC waves in low βcase. It is found that the increasing value of kappa distribution function on electromagnetic ion-cyclotron wave is enhancing the growth/damping rate (γ) with increase the growth length (γ_L) R_E may be due to EMIC emissions.

The results are interpreted for the space plasma parameters appropriate to the auroral acceleration region. The interpreted may be applicable to explain the ion heating and acceleration of plasma particle in the solar wind as well as auroral acceleration region. The results of the work is consistent for EMIC emissions observations by Polar, FAST satellite of the auroral acceleration region as reported by Mozer, et al., 2000.

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006/SA-2/P

STORM-INDUCED IONOSPHERIC PERTURBATION OVER LOW LATITUDE STATION VARANASI

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Abstract

Geomagnetic storm is the temporary disturbances in the Earth's magnetic field which affects the electrodynamics of ionosphere leading to huge fluctuation in ionospheric plasma finally affects the communication and navigation to a great extent and in worst case disturbs the human health and life. Signals recorded from dual frequency GPS receiver at Varanasi (Geographic latitude 25^0, 16′ N, longitude 82^0, 59′ E) near the equatorial ionization anomaly (EIA) crest region in India have been analyzed to study the effect of intense geomagnetic storms on ionosphere, during 2010-2015. Four most intense storms having Dst-index < -100 nT observed during the above period have been analyzed, which occurred on 25^{th} September 2011, 15^{th} July 2012, 19^{th} February 2014, and 20^{th} December 2015.The storm induced features in the vertical TEC (VTEC) have been studied considering the monthly mean VTEC value estimated during quiet days of respective month as reference level. Analysis found positive as well as negative storm effect on ionosphere. The storm induced effects on VTEC depends on local time, storm-induced wind effect as well as dawn-dusk component of interplanetary electric field (IEF) Ey intensity called prompt penetration electric field.

009/SA-3/P

TRANSIENT SOLAR WIND PLASMA FLOWS AND SPACE WEATHER

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Abstract

One of the prime challenges for space weather researchers today is to quantitatively predict the dynamics of the geo-magnetosphere from measured solar wind plasma structures and interplanetary magnetic field (IMF) conditions [1,2]. In the present study a correlative study between geomagnetic storms and the various interplanetary (IP) field / plasma parameters have been performed to search the perpetrators of geomagnetic activity and to develop such model suitable for predicting the occurrence of geomagnetic storms, which are significant for space weather predictions. We have utilized the data provided by space satellites and ground based observations and investigated a possible relationship between geomagnetic storms and solar wind and IMF parameters in different situations and also derived the linear relationship for all parameters in different situations based on the peak values of Disturbance storm time index (Dst). The investigation is performed utilizing the fact that the total interplanetary magnetic field (IMF Btotal) can be used to trigger an intense geomagnetic storms well represented by the Dst index. Our results inferred that the southward Bz component of the interplanetary magnetic field is an important factor for describing geomagnetic storms however its magnitude is not found maximum neither during the initial phase of the storm, i.e. at the instant of the interplanetary shock nor during the main phase, the instant of minimum disturbance storm time (Dst) index. It is also investigated that there is a time delay between the maximum value of southward Bz and the Dst minimum, and this time delay can be used in the prediction of the intensity of a magnetic storm two-three hours before the main phase of a geomagnetic storm.

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012/SA-4/P

SOLAR PLASMA WAVE STUDIES AT THE FIRST LAGRANGIAN (L-1) POINT

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Abstract

Measurement of magnetic field in space is very important to understand various physical phenomena taking place over there. The magnitude of space magnetic field is not that much larger and its unit in nano Tesla (nT). The measurements of local interplanetary magnetic field (IMF) emanating from the Sun are regularly carried out in space to estimate its nature and magnitude. These magnetic field measurements can lead to the estimation of solar plasma wave parameters emerging from the solar corona. The solar plasma waves, coming out from the Sun, carry the history of their generation mechanisms and can provide the information about the physical phenomena as the *in-situ* measurements are not possible due to the extreme hostile conditions prevailing there. The first Lagrangian (L-1) point (out of five such points in the Sun-Earth plane) is a suitable location sufficiently away from the Earth's magnetosphere but towards the Sun to carry out these solar plasma wave studies. WIND and ACE (Advanced Composition Explorer), from NASA (USA), are two missions which are presently stationed at L-1 point to study the Sun having fluxgate magnetometers (to measure the IMF) also onboard along with other instruments to study the Sun. Indian Space Research Organization (ISRO) is also sending a solar mission (Aditya-L1) in year 2020 to study the Sun with a set of fluxgate magnetometers (FGMs) onboard to make the in-situ magnetic field measurements at the L-1 point. With the FGM measurements, the effect of plasma waves on the background magnetic field at L-1 point can be observed and the signatures of solar plasma waves can be marked.

As a prelude to handle the Aditya-L1 magnetic field data, the already available FGM data from WIND and ACE missions has been analyzed to detect the solar (Alfven) wave signatures. In this paper, the local magnetic field environment at the L-1 point is presented along with evidence of solar plasma waves existing there from the observations carried out by WIND and ACE missions there.

016/SA-5/P

PLASMA VELOCITYASSOCIATED WITH COSMIC RAY INTENSITY AND INTERPLANETARY MAGNETIC FIELD DURING SOLAR CYCLES 22-24

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Abstract

We have studied the relationship between the monthly variation of average counting rates of the cosmic ray intensity (CRI) at Moscow having cut-off rigidities (~2.43GV) with the solar wind velocity (or plasma velocity) and interplanetary magnetic field (IMF) based on the observational data during the solar cycles 22–24 (1986–2016). The expected monthly variation of the cosmic ray intensity is inversely correlated with the modulation parameter ‘ζ ’. We have analysed anti-phase pattern for modulation parameter with CRI in range July 2004 to July 2005 and found that it is not prominent for that. We have also examined the patterns of periodicities and their evolution for the interplanetary magnetic field, cosmic ray intensity and solar wind velocity using Fast Fourier Transform (FFT) and Wavelet Transformation. We have found similar mid-term periodicities of ~2.72 years in the cosmic ray intensity, interplanetary magnetic field and plasma velocity during 1986-2016 through FFT. We have reported time-lag between the cosmic ray intensity with modulation parameter during solar cycles 22-24.

020/SA-06/P

ION-ACOUSTIC NONLINEAR PERIODIC (CNOIDAL) WAVES IN PLASMAS WITH NONTHERMAL ELECTRON

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Abstract

Ion-acoustic nonlinear periodic (cnoidal) waves and solitons are studied in plasma with nonthermal electron. The well-known reductive perturbation method is employed to derive the Korteweg de Vries (KdV) equation for ion-acoustic waves in plasmas. The Sagdeev potential approach is used, and the cnoidal wave solution of ion-acoustic waves is obtained under periodic boundary conditions. It is found that non-thermalelectron has a significant effect on the amplitude and phase of the cnoidal waves, while it also affects the width and amplitude of the soliton in plasmas. The numerical results are plotted within the plasma parameters for laboratory and space plasmas for illustration. It is found that nonlinear periodic wave and soliton structure are formed in plasmas with non-thermal electrons.

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039/SA-7/P

ST. PATRICK'S DAYS STORM EFFECT AT MID-LOW-EQUATORIAL D-REGION IONOSPHERE INFERRED VLF WAVES

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Abstract

The effects of the geomagnetic storm on the E and F-region of the ionosphere are well studied using several techniques such as GPS TEC, Ionosonde and satellite measurements. But because of the limitations in D-region probing techniques the storm effect in the D-region remains not well understood. In the present work, we examined the effect of the St. Patrick's daysuper geomagnetic storm of 17 March 2015 via sub-ionospherically propagating VLF signal recorded over low latitude Indian station Allahabad. We have used two VLF transmitter signal GBZ (19.2 kHz) from the Great Britten and NWC (19.8 kHz) from Australia. The transmitter-receiver great circle path (TRGCP) for Allahabad GBZ covers the mid-low latitude region whereas Allahabad NWC covers low-equatorial latitude region. The VLF amplitude measurements show a decrease compared to an average of five geomagnetically quiet days starting on 17th March (the main phase of the storm) and fully recovered on 28th March, 02 days after recovery of the geomagnetic field. The GBZ signal show more decrease (~9 dB) compare to NWC signal (~5 dB). The effects are most marked during twilight and night hours but are usually absent at noon hours. The decrease in the VLF amplitude most probably caused by the absorption of signal due to an anomalous increase in the D-region ionization associated with the storm. The pronounced effect of the geomagnetic storm on VLF signal during twilight and night hours further confirms that the ionization changes in the D-region associated with magnetic disturbances are not significant near noon hours. The delayed recovery of VLF amplitude could be of several reasons such as a change in atmospheric structure, dynamical process during storm and heat conduction from exosphere to thermosphere [1].

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044/SA-8/P

FORMATION AND EXISTENCE CRITERION FOR LABORATORY MULTIPLE DOUBLE LAYERS AND CORRELATION WITH SPACE PLASMA DOUBLE LAYERS

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Abstract

Double layer (DL) in plasma represents a non-neutral region of opposite space charges separated by a small distance with a potential drop of the order of $|\phi_0| \geq kT/e$ across the layer. In laboratory DLs are produced by either passing a current through a plasma or applying a potential drop across it. In this study, multiple double layers (MADL), an extended class of DL, are produced in front of anode of a glow discharge plasma by submerging anode in glow discharge plasma. The dynamics of MADL are then controlled by varying the anode bias in the range of 0-200 V. MADL was generated at a lower threshold value of anode bias with an explosive increase in anode discharge current, ~100 times the electron thermal current. The generation and existence condition are obtained in terms of electron drift velocity (v_d) and electron thermal velocity (v_{te}). The MADL was generated when $v_d \geq 1.3 v_{te}$ and existed up to $v_d \geq 3\, v_{te}$. Beyond this condition, MADL begins to decay. The micro phase space analysis indicate a mechanism of DL formation by the interaction between a growing positive pulse and a decaying negative pulse. The signature of such DL has a characteristic similarity with DLs recorded in auroral region using satellites.kkl $\phi_0 \geq \nu_d$.

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048/SA-9/P

GRAVITY WAVECONTROLON ESF DAY TO DAY VARIABILITY: AN EMPIRICAL APPROACH

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Abstract

The gravity wave control on the daily variation in night time ionization irregularity occurrence is studied using ionosonde data for the period 2002 - 2007 at magnetic equatorial location Trivandrum. Recent studies during low solar activity period have revealed that, the seed perturbations should have the threshold amplitude required to trigger Equatorial Spread F (ESF), at a particular altitude and that this threshold amplitude undergoes seasonal and solar cycle changes. In the present study, the altitude variation of the threshold seed perturbations is examined for autumnal equinox of different years. Thereafter, a unique empirical model, incorporating the electro dynamical effects and the gravity wave modulation is developed. Using the model the threshold curve for autumnal equinox (ae) season of any year may be delineated if the solar flux index (F10.7) is known. The empirical model is validated using the data for high, moderate, and low solar epochs in 2001, 2004 and 1995 respectively. This model has the potential to be developed further, to forecast ESF incidence, if the base height of ionosphere is in the altitude region where electrodynamics controls the occurrence of ESF. ESF irregularities are harmful for communication and navigation systems and therefore research is ongoing globally to predict them. In this context, this study is crucial for evolving a methodology to predict communication as well as navigation outages.

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075/SA-10/P

DAY TIME WHISTLER OBSERVED AT LOW LATITUDE VARANASI

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Abstract

Whistlers are remarkable phenomena of Electromagnetic emissions which are generated from lighting discharges [1].To sense/monitor the characteristic parameters and structures of magnetospheric plasma, analysis of whistlers have been used on the basis of the dispersion features of received wave forms [2, 3].

In this paper, we have tried to explain the features of day time (winter season) whistlers which were recorded first time on 4th January, 2017 at 01 UT and analyzed by the Automatic Whistler Detector (AWD) at our low latitude ground station Varanasi (L=1.07). The computed dispersions, L-value and the columnar ionospheric electron contents of the observed whistlers vary 11.16 $s^{1/2}$-14.44 $s^{1/2}$,1.11±0.1-1.78±0.1 and 23.57× 10^{12}-39.44 × 10^{12} el cm^{-2} respectively. The uniform dispersion of the whistlers suggests that these whistlers propagated along the geomagnetic field lines in the ducted mode.

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168/SA-11/P

GEOMAGNETIC STORMS IMPACT ON IONOSPHERE DURING ASCENDING PHASE OF SOLAR CYCLE 24

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Abstract

With the advent of space era, there has been a tremendous impetus to understand solar-terrestrial relationship, including geomagnetic storms and their interplanetary causes. A geomagnetic storm is characterized by a main phase during which the horizontal component of the Earth's low latitude magnetic fields are significantly depressed over a time span of one to a few hours followed by its recovery, which may extend over several days [1].

Response of low latitude ionosphere to the 12 intense geomagnetic storms during the ascending phase of solar cycle in the Indian longitude sector has been investigated by using the GPS data recorded at three Indian stations namely: Varanasi (25.3176° N, 82.9739° E), Hyderabad (17.3850° N, 78.4867° E) and Bengaluru (12.9716° N, 77.5946° E). In this study vertical total electron content (VTEC) compared with the average of 5 quiet days of month VTEC, which is called background TEC to see the effect of these storms on the variation of TEC. Close examination of the GPS signals revealed the scintillation to be co-located with strong gradients in Total Electron Content (TEC) at the edge of the plasma stream. The data for storms is obtained from the OMNI database. The gradient-drift instability is a likely mechanism for the generation of the irregularities causing some of the scintillation at L band frequencies during this storm.

Penetration electric field, disturbance dynamo, neutral wind, neutral composition, etc., caused by geomagnetic storms have been reported. The results show variation of GPS derived total electron content (TEC) due to geomagnetic storm effect, local low latitude electrodynamics response to penetration of high latitude convection electric field and effect of modified fountain effect on GPS–TEC in low latitude region.

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199/SA-12/P

NIGHTTIME D REGION ELECTRON DENSITY MEASUREMENTS FROM ELF-VLF HIGHER HARMONIC TWEEKS RECORDEDAT LOW LATITUDE STATION, VARANASI, INDIA

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Abstract

The very low frequency (VLF) energy radiated by the return strokes of lightning discharges propagates in the Earth-ionosphere waveguide to large distances by the process of multiple internal reflections. These signals recorded in the conjugate region are known as sferics. The lower frequency ends of the sferics at times show cumulative dispersion and are generally termed as tweeks [1-2]. We present here analysis of tweeks with higher harmonics recorded at our low-latitude station Varanasi (geographic lat. 25^0 20' N and long. 83^0 E), during the year 2015. The analysis of recorded tweeks during one month each from summer (August), winter (December), and equinox (March) seasons are presented. Higher harmonic tweeks up to 12 harmonics in numbers observed for the first time at our low latitude station Varanasi and the analysis shows that these higher harmonic tweeks are usually not associated with whistlers and occur when the ionization in the lower ionosphere would not increases with height. These dispersive atmospherics (tweeks) have been used to estimate the nighttime D region electron density at the ionospheric reflection height under the local nighttime propagation [3]. The summer season shows the maximum number of occurrence of tweeks as compared to that during equinox and winter seasons. We further observed that tweek (ionospheric) reflection height in the pre-midnight (18:00-00:00 LT) in winter is less as compared to that during equinox and summer. Annual (seasonal average) variation of the mean ionospheric reflection height shows a gradual increase in the reflection height.

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202/SA-13/P

EVIDENCE OF MAGNETIC RECONNECTION IN AN X-CLASS SOLAR ERUPTIVE FLARE AND ESTIMATION OF THERMAL/NON-THERMAL ENERGIES FROM HXR OBSERVATIONS

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Abstract

In this paper, we present striking evidence of magnetic reconnection in solar corona during an X1.8 eruptive flare that occurred in the active region NOAA 10656 on 2004 August 18. The high resolution observations are taken by Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI) and Transition Region and Coronal Explorer (TRACE) at X-ray and EUV wavelengths respectively. The flare is driven by a filament eruption during which multiple hard X-ray (HXR) bursts are observed up to 100-300 keV energies. We observe a bright and elongated coronal structure simultaneously in E (UV) and 50-100 keV HXR images underneath the expanding filament during the period of HXR bursts, which provides strong evidence for ongoing magnetic reconnection. This phase is accompanied by very high plasma temperatures of ~31 MK, followed by the detachment of the prominence from the solar source region. From the location, timing, strength, and spectrum of HXR emission,we conclude that the prominence eruption is driven by the distinct events of magnetic reconnection occurring in thecurrent sheet below the erupting prominence.

Another important aspects of this analysis lies in the quantitative determination of thermal and non-thermal energies of this flare through HXR spectroscopy. The non-thermal energies are estimated by modeling the observed HXR spectra with thick-target bremsstrahlung emission mechanism. We compare the temporal evolution of thermal and non-thermal energies to understand that how efficiently energy of accelerated particles is converted to the hot flare plasma.

333/SA-14/P

ELECTRON VELOCITY DISTRIBUTION FUNCTIONS IN THE SOLAR WIND AT 1AU DURING SOLAR TRANSIENT EVENTS

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Abstract

Sun is continuously giving out its energy in the form of both electromagnetic radiation and particles called the *solar wind*. Solar wind is a magnetized plasma emanating from the Sun in all directions with an average bulk velocity of ~400km/s at 1 AU distance. It consists mainly of protons, alpha particles, few amount of other heavily ionized species and electrons. Studies shows that the electrons present in the solar wind are characterized by three different populations based on their thermal energy and the direction of propagation with respect to the solar magnetic field, they are the thermal*Core*, the suprathermal *Halo* and the field aligned *Strahl*. The velocity distribution functions (VDFs) of solar wind particles carries signatures of various acceleration processes undergone by the solar wind starting from the coronal heights to larger heliospheric distances. The observed electron velocity distribution functions (EVDFs) in the solar wind at 1 AU have shown a *Maxwellian core* and a *non- Maxwellian* extended tail in the suprathermal regime.

In this paper, we analyze the signatures of various solar transient events such as solar flares and coronal mass ejections (CMEs) on the electron velocity distribution functions observed in the ambient solar wind at 1 AU during the 23rd and 24th solar cycle. EVDFs integrated over electron thermal velocity component parallel to the magnetic field is used as a parameter to quantify the effects of events. We quantify the enhancement in the total electron population, especially the suprathermal component of the ambient solar wind during the event effective periods at 1 AU. We also quantify the time elapsed between the event signatures, which are seen in the solar wind bulk parameters and in EVDFs. Effects of transient events (Solar Flares and CMEs) on thermal Core, suprathermal Halo and suprathermal Strahl populations are delineated. EVDFs observed by the three dimensional plasma instrument (3DP instrument) onboard WIND Spacecraft at the first Lagrangian point (L1 point) are used for performing the present study.

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369/SA-15/P

A COMPARATIVE STUDY OF THE ERUPTIVE AND NON-ERUPTIVE FLARES PRODUCED BY THE LARGEST ACTIVE REGION OF THE SOLAR CYCLE 24

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Abstract

We investigate the morphological and magnetic characteristics of solar active region (AR) NOAA 12192. AR 12192 is the largest region of the solar cycle 24 and it underwent a noticeable growth and produced 6 X-class flares, 22 M-class flares, and 53 C-class flares in the course of its disc passage. But the most peculiar fact of this AR is that it was associated with only one CME in spite of producing several X-class flares. In this work, we carry out a comparative study between the eruptive and non-eruptive flares produced by AR 12192. We find that the magnitude of abrupt and permanent changes in the horizontal magnetic field and Lorentz force are significantly smaller in case of the confined flares compared to the eruptive one. We present the individual umbral and penumbral area evolution of AR 12192 during its disc passage on the visible solar disc. We find the flare related morphological changes to be weaker during the confined flares, whereas the eruptive flare exhibits a rapid and permanent disappearance of penumbral area away from the magnetic neutral line after the flare. Furthermore, from the extrapolated nonlinear force-free magnetic field, we examine the overlying coronal magnetic environment over the eruptive and non-eruptive zones of the AR. We find the critical decay index for the onset of torus instability was achieved at a lower height over the eruptive flaring region, than for the non- eruptive core area. These results suggest that the decay rate of the gradient of overlying magnetic field strength may play a decisive role to determine the CME productivity of the AR. In addition, the magnitude of changes in the flare related magnetic characteristics are found to be well correlated with the nature of solar eruptions.

377/SA-16/P

OBSERVATION AND MODELING OF A MAGNETIC RECONNECTION REGION IN A SOLAR FLARE DRIVEN BY CORONAL JET

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Abstract

In this paper, we present unique observations of a blowout coronal jet[1] that has possibly triggered a two-ribbon C1.2 flare in a bipolar solar active region NOAA 12615 on 2016 December 5. The jet activity initiates at chromospheric/transition-region heights with a small brightening that eventually grows in the larger volume with well-developed standard morphological jet features, viz., base and spire. The spire widens up with the collimated eruption of cool and hot plasma components, observed in 304 and 94 Å channels of AIA, respectively. The speed of plasma ejection, which forms the jet's spire, was higher for the hot component (□200 km s^{-1}) over the cooler one (□133 km s^{-1}). The NLFF model of coronal fields [2] at pre- and post-jet phases successfully reveal opening of previously closed magnetic field lines with a rather inclined/low-lying jet structure. The peak phase of the jet emission is followed by the development of a two-ribbon flarethat shows coronal loop emission in HXRs up to □25 keV energy. Jet's base coincides with one of the edges of western flare ribbon. The coronal magnetic fields rooted at the location of EUV flare ribbons, derived from NLFF model, demonstrate the pre-flare phase to exhibit "X-type" configuration while the magnetic fields at post-flare phase are more or less parallel oriented. The comparisons of multi-wavelength measurements with the magnetic field extrapolations suggest that the jet activity has likely triggered the two-ribbon flare by favorably changing the geometry of surrounding and/or overlying fields.

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459/SA-17/P

F3 LAYERS OVER THIRUVANANTHAPURAM: A COMPREHENSIVE ANALYSIS ON THEIR GENERATION AND EVOLUTION

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Abstract

Theearth is surrounded by a region of plasma referred to as the ionosphere. The terrestrial plasma is generally stratified into different layers called as the D, E and F regions. The F region further splits into F1 and F2 layers. During some days in addition to these normal layers, some additional layers also occur in the ionosphere. The layers which appear above F2 layer is referred to as F3 layers [1]. Study of F3 layer is important as it plays an important role in changing the ionization budget of the terrestrial upper atmosphere. In the present study an attempt is made to understand the plasma layering properties over the dip equatorial location of Thiruvananthapuram based on an extended data base.

The data for the period scanning for two decades (1990 to 2010) is used in the current study. The data is obtained from the digital ionosonde a sweep frequency radio sounding instrument operational at Thiruvananthapuram. The occurrence of additional layers in the ionosphere is identified by visually scanning the ionograms. It is known that over the low latitudes, meridional winds are responsible for F3 layer formation by enhancing the vertical ExB drifts. However, over the dip equatorial region, inhibited ExB drifts lead to F3 layering, which is quite different from the mechanism operational over the low latitudes.

The present study brings out a comprehensive mechanism explaining the generation and evolution of F3 layers over the dip equatorial region. It is shown that the zonal thermospheric wind plays an important role in the generation of F3 layers over the equatorial region.

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462/SA-18/P

A NUMERICAL SIMULATION STUDY ON THE ROLE OF HORIZONTAL WIND SHEARS IN THE GENERATION OF F0.5 LAYERS OVER THE DIP EQUATORIAL LOCATION OF THIRUVANANTHAPURAM

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Abstract

The earth is surrounded by plasma in the upper reaches of the atmosphererefered to as the ionosphere. This plasma is generally stratified into layers called as the D, E and F regions. On some days along with these normal layers, some additional layers also occur and the layers which appear below F layer is referred to as F0.5 layers [1]. Study of F0.5 layer is important as it is an important tracer for the dynamics taking place in thetransition region between E and F layers. In the present study an attempt is made to understand the plasma layering properties over the dip equatorial location of Thiruvananthapuram based on numerical simulations as well as ionospheric observations.

The data for the period 2004 to 2008 is used in the current study. The data is obtained from the digital ionosonde a sweep frequency radio sounding instrument operational at Thiruvananthapuram. The occurrence of additional layers in the ionosphere is identified by visually scanning the ionograms. A numerical simulation is carried out to estimate the rate of convergence of ionization required to produce F0.5 layer. Horizontal shear in the meridional wind is identified as the causative mechanism for layer formation. It is found that gravity waves are capable of generating wind shears, leading to the pooling of ionization and the generation of the layer over the dip equator. The corresponding shears required to generate the layer with the above convergence conditions are estimated.

004/SA-19/P

STUDY OF INVERSE SHEATH OVER LUNAR SURFACE

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Abstract

The lunar surface has a complex plasma environment. The solar wind or solar vacuum ultraviolet radiation induces photo emission from the surface of the moon. As the photo emission dominates the day-side plasma sheath, it creates an inverse sheath which also affects the dust charging process. In this work, we study the structure and the dust dynamics including the process of dust levitation in such a sheath.

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011/SA-20/P

GENERATION OF ELECTROSTATIC SOLITARY WAVES IN THE LUNAR WAKE

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Abstract

A generation mechanism for the evolution of electrostatic waves observed in the lunar wake during the first flyby of the ARTEMIS mission on 13thFebruary 2010 [1] is proposed in terms of slow and fast ion-acousticand electron-acoustic solitons. A four-component plasma system consisting of hot protons, hot heavier (He^{++}) ions, electron beam and suprathermal electronshaving a kappa distribution is utilized to model the lunar wake plasma. The Sagdeev pseudopotential formulation is used for analyzing the arbitrary amplitude electrostatic solitary waves (ESWs). Threemodes, viz., slow and fast ion-acoustic modes and electron-acoustic modes exist. As all three modes exists simultaneously in the lunar wake plasma, the electric fields associated with all three modes taken together varies in the range ~ (0.0003-17) mV m^{-1}which matches perfectly with the observed electric field ~ (5-15) mV m^{-1}. The width of the solitons varying as ~ (100-8000) m agrees with the estimated wavelength varying as few hundreds of meters to couple of thousands of meters. The velocities of the solitons varying in the range ~ (30-1300) km s^{-1} matches with the estimated phase velocities of the order ~1000 km s^{-1}. The Fast Fourier transform (FFT) of the soliton electric fields results in broadband spectra having peak frequencies in the range of ~ (3-1800) Hz which corresponds to ~ (0.001-0.56) f_{pe}. This matches with the observed frequencies of ~ (0.01-0.4) f_{pe}. Here, $f_{pe}$is the electron plasma frequency (f_{pe}= 3237.78 Hz). Thus, the proposed plasma model is able to aptly explain the observed electrostatic waves in the lunar wake.

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017/SA-22/P

ELECTROSTATIC DOUBLE LAYER IN A COLLISIONLESS, UNMAGNETIZED, MULTI- COMPONENT PLASMA

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Abstract

Space and Astrophysical plasma contain different type of plasma particles which are not in thermal equilibrium. The velocity distribution functions of such particles are observed to be quasi Maxwellian up to the mean thermal velocity with non Maxwellian super thermal tail at higher velocities [1]. Kappa distribution function is very convenient to model such velocity distribution functions, since it fits both of the thermal as well as super thermal part of the observed energy spectra. A large number of works have been performed to study the electrostatic nonlinear excitations (double layers, solitons, shocks etc.) in presence of such super thermal plasma particles and is observed that, their presence alter the nature of the nonlinear coherent structures in large extent [2-4]. In the present work the existence of an electrostatic double layer in collision less, unmagnetized, multi component plasma is examined. The plasma model consists of cold fluid ion, cold fluid dust grain and two components (two temperatures) of super thermal electrons. Following Sagdeev potential method, electrostatic double layer with negative polarity is found to exist in small amplitude region with high Mach number. The effect of the kappa distributed electrons on the formation of such structures is also discussed.

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021/SA-24/P

NONLINEAR ZKEQUATION FOR OBLIQUELY PROPAGATION OF THREE DIMENSIONAL ION-ACOUSTIC SOLITARY WAVES IN MAGNETIZED PLASMA WITH NONTHERMAL ELECTRON

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Abstract

Properties of small amplitude nonlinear ZK(Zkharov Kuznetsov) equation for obliquely propagation of threedimensional ion-acoustic solitary waves in magnetized plasma with nonthermal electron. For this purpose, the hydrodynamic equations for ion, nonthermal electron density distribution and the Possion equation are used to derive the corresponding nonlinear evolution equation; Zkharov Kuznetsov (ZK) equation, in the small amplitude regime. The ZK equation is analyzed to examine the existence regions of the solitary pulses. It is found that nonthermal electron has a significant effect on the amplitude and width of the solitary waves, while it also affects the width and amplitude of the solitary wave in plasmas. The numerical results are plotted within the plasma parameters for laboratory and space plasmas for illustration. It is found that solitary waves are formed in plasmas with nonthermal electrons.

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033/SA-25/P

EFFECT OF LOSS CONE DISTRIBUTION ON KINETIC ALFVEN WAVES WITH MULTI-IONS PLASMA IN PSBL REGION

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Abstract

Kinetic Alfven waves (KAWs) in multi-component plasma with varying loss-cone distribution index (*J*) are investigated in plasma sheet boundary layer (PSBL) region. Kinetic Alfven waves have very low frequencies as compared to the cyclotron frequencies. Recently, many satellites have given evidence of multi-ions like H^+, He^+ and O^+ ions to be present in earth's magnetosphere, hence each ion affects wave nature. In this paper, frequency and damping rate expressions are derived using kinetic approach considering contribution of each individual ion and its effect is analyzed. The loss-cone distribution index is varied for analyzing frequency and damping rate of kinetic Alfven wave with Larmor radius of each ion i.e. $k_\perp \rho_i$ where *i* denotes H^+, He^+ and O^+ ions. It is observed that the wave frequency shows oscillatory character at lower *J* values which ceases with increase in loss-cone index at lower $k_\perp \rho_i$ values for H^+ and He^+ ions. For O^+ ions, the generated frequency shows oscillatory nature at higher *J* index and also, nature of wave converted from KAW to EMIC (Electromagnetic ion cyclotron) wave beyond $k_\perp \rho_{O^+} \geq 2$. These changes in oscillatory nature of frequency may be due to difference in penetration of lighter and heavy ions into the loss cone. The damping rate for lighter ions is observed only at lower values of $k_\perp \rho_i$ whereas for heavy ions, wave shows damping rate over wide range of $k_\perp \rho_{O^+}$. Damping rate is reduced with increase in loss-cone index for each ion, which signifies long distant propagation of KAW from PSBL to auroral ionosphere. Hence, it is observed that each gyrating ion participate differently in frequency generation and damping rate ofKAW. The parameters reported for plasma sheet boundary layer are used for numerical calculation. The application of present study is in understanding the effect of multi-ions in transfer of energy, wave-particle interaction, particle energization, propagation of wave and loss of Poynting flux on travelling from PSBL towards auroral ionosphere.

052/SA-26/P

CONJUGATIONAL MODE DYNAMICS IN ANTI-EQUILIBRIUM MOLECULAR CLOUDS

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Abstract

It is a well-established observational fact that the star formation mechanism in the star-forming dust molecular clouds (DMCs) is a complex bimodal process. The complexity in the involved bimodal mechanism stems from the gravitational inward contraction (by the Newtonian particles) and the electrostatic outward expansion (by the Coulomb particles) in a periodic fashion [1]. As a consequence, such a gravito-electrostatic counteraction in this partially ionized media results in a unique mode known as pulsational mode of gravitational collapse [2, 3]. As far as seen, all the previous theories on such bimodal stellar nursery mechanisms are purely based on the thermalized distributions (Boltzmann) of the electrons and ions. We herein, propose a new theoretical analysis on the bimodal pulsational mode behaviors in a nonthermal astrocloud in the multi-fluidic framework. The tiny electrons and ions are modelled with the help of the κ-modified thermo-statistical distribution laws against the usual convention [4]. The dust grains are treated as viscous turbulent fluids [3, 5]. Application of normal-mode analysis over the perturbed cloud around a well-defined homogeneous equilibrium yields a unique construct of generalized quartic viscosities (η_n^*, η_c^*) and the nonthermality power-law spectral indices (κ_e, κ_i) act as stabilizing (damping) agents against the gravitational collapse. The results are applicable in conceiving the initiation of non-homologous cloud collapse mechanisms leading to the galactic hieratical building-block structure formationdispersion relation in the wave space. The constructed numerical scheme shows that the kinematic.

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057/SA-27/P

EFFECT OF COLD INJECTIONS ON ELECTROMAGNETIC ION-CYCLOTRON WAVES IN INNER MAGNETOSPHERE OF SATURN

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Abstract

In present work, we investigate the effect of cold beam injection on electromagnetic ion cyclotron (EMIC) waves in the magnetosphere of Saturn propagating obliquely to the magnetic field direction. The encounter of Voyager 1, 2 with the environment of Saturn revealed the presence of EMIC waves in Saturnian magnetosphere. Interaction of EMIC waves present in background space plasma with the charged particles trapped in the planet's magnetic field leads to the damping or growth of waves by exchange of energy. Therefore, we investigate this wave-particle interaction to analyze growth of EMIC waves in the presence of A.C field in magnetosphere of Saturn during injection events. Using the method of characteristics, expression for dispersion relation is derived by following the kinetic approach. Magnetic field strength at various points along magnetic field lines has also been considered to calculate growth rate and real frequency of EMIC waves analytically. The work has been performed for both bi-Maxwellian and loss cone distribution of particles in magnetosphere of Saturn. Magnetic field model has been incorporated to calculate magnetic field strength at different latitudes for the radial distance of 6.18 Rs (1 Rs = 60, 268 Km). Various parameters affecting the growth of EMIC waves in the bi-Maxwellian background and after the cold injection has been studied. Parametric analysis inferred that after the cold injection the growth rate of EMIC waves increases till 10^{o} for bi-Maxwellian distribution and till 20^{o} for loss-cone distribution and decreases eventually with increase in latitude due to ion density distribution in near equatorial region. Also growth rate of EMIC waves increases with increasing value of temperature anisotropy and A.C frequency. The ratio of cold injected electron plasma to background plasma density increases the growth rate of waves. Also injection events assuming the loss cone distribution of particles affects the lower wave number of spectra. The analytical model developed can also be used to study various types of instabilities in Saturnian magnetosphere. These results are important in analyzing VLF emissions over wide spectrum of frequency range.

058/SA-28/P

NEUTRINO-BEAM-PLASMA INTERACTIONS IN QUANTUM MAGNETOPLASMA

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Abstract

The collective neutrino-plasma interactions and excitation of plasma instabilities have been recently studied in many astrophysical systems viz. type-II core-collapse supernova, neutron star and white dwarfs [1,2]. In this work, the influence of propagation dynamics of intense neutrino beam on the hydrodynamic Jeans instability in a magnetized Fermi or quantum plasma is investigated. The dynamics of self-gravitating and magnetized electron-ion quantum plasma modified by quantum effects and weakly interacting neutrinos are discussed using the modified neutrino magnetohydrodynamics (NMHD) model [3]. The dispersion characteristics of modified Jeans instability as well as fast neutrino-driven short wavelengths instability are analyzed in the astrophysical situations. For the ultra-relativistic neutrinos the Jeans instability criteria depends upon neutrino beam and quantum corrections. The presence of quantum diffraction parameter and neutrino beam density have stabilizing role on the growth rate of neutrino driven short wavelength instability as well as on the hydrodynamic Jeans instability. The free energy of neutrino beam has destabilizing influence on the growth rate of Jeans instability.

The estimated Jeans time scale is close to the time scale of type-II core-collapse supernova and the time scale of neutrino beam instability is much shorter so as to alter the neutrino mixing very fast in gravitational collapse of supernovae. The various consequences of neutrino-beam interaction with magnetized, gravitating quantum plasma have been addressed in the core-collapse supernova and white dwarfs.

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060/SA-29/P

DUST ACOUSTIC KINETIC ALFVEN WAVES IN THE PRESENCE OF TRAPPED ELECTRON

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Abstract

Kinetic Alfven waves arise when the perpendicular wavelength of ordinary Alfven wave is comparable to the ion Larmor radius. Kinetic Alfven waves play an important role in transporting energy in various space and astrophysical plasma environments[1], coronal plasma heating[2], plasma transport in magnetopause[3] as well as in heating Tokamak plasmas[4], thus heating the plasma to fusion temperatures. Thus, it is very important to study the dynamics of kinetic Alfven waves in order to understand various energy transport mechanisms in plasmas. The trapping of the particles was shown to be important while investigating the nonlinear characteristics of waves. In the present work, we have discussed the effects of vortex-like distribution of electrons on obliquely propagating dust acoustic kinetic Alfven waves in a low β plasma. Using the two potential theory and employing the Sagdeev potential approach, we have investigated the existence of arbitrary amplitude coupled dust acoustic kinetic Alfvenic solitary waves in the frame work of trapped electrons distribution. The present investigation may be beneficial in understanding the propagation of solitary structures in different space environments where trapped populations of electrons have been observed.This study may also be helpful in understanding various non-linear coherent structures in space and astrophysical plasma environments.

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074/SA-30/P

THEORETICAL APPROACH FOR THE UNDERSTANDING OF NOVEL STRUCTURE 'SUPER SOLITARY WAVE'

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Abstract

Electrostatic Solitary Waves (ESWs) have been observed in almost every boundary layers and in the dynamic regions of the Earth's magnetosphere. The large gradient in particle properties and field at the magnetospheric boundary layers act as the free energy sources for instabilities and nonlinear wave growth which leading to the generation of ESWs. Characteristics of ESWs are observed by the satellite borne electric field instruments which are recorded as localized bipolar pulses or monopolar structures in the electric field (E data). The bipolar pulses are interpreted as ion/electron acoustic solitary waves, whereas the monopolar pulses are interpreted as Double Layer (DL) structures. Apart from the usual bipolar structures, there are indications of modified bipolar structures in the E-field data [1]. There seems to have no further exploration or explanation of these modified bipolar structures until the concept of 'Super Solitary Wave (SSW)' or 'Supersolition' came in to picture.

The notion of SSW was introduced by Dubinov and Kolotkov [2], who were studying solitary waves for a five species dusty plasma. The word 'Super' actually coinedbecause of their extraordinary large amplitudes and extra-large speed which are typically larger than the corresponding DLs. The SSW differs from their maternal solitary structures by their modified electric field signatures. As they have larger amplitudes, instead of adopting reductive perturbation methods they are analyzed by using the Sagdeev pseudopotential technique. They are characterized in having an extra subwell or extrema on the conventional pseudopotential profile of the solitary wave. For last few years they are studied mostly analytically. They are also obtained in numerical simulation and in experiment. So far, SSWs were defined in term of theextrema of the Sagdeev pseudopotential which turned thenotation entirely technique dependent. So a more generalized notion of SSWs, independent of any particular method,seems to be necessary.

In the present work we intended to give the physical explanation for the existence of SSW. According to our understanding, the compressive ion acoustic SSW may be defined as a compressive ion acoustic solitary wave structurewhere the overall compression of the ion density is precededby a fluctuation of compressive to rarefactive ion density. Apart from that, we also found that SSWs are a subset of new class of solitary structure called Variable Solitary Wave (VSWs). We proposed to call them as VSW, because of their variability in the Δn. It is generally believed that SSWs are merged out of a DL, but our present work shows that the transition route

of an ion acoustic solitary wave to a supersoliton is not unique. Depending on the electron temperature ratio, a regular solitary wave may transform to an SSW either via DL, or through an extra-nonlinear solitary structure whosemorphology differs from that for a regular one.

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094/SA-31/P

ELECTROMAGNETIC NONLINEAR STRUCTURES AND ACCELERATION OF CHARGED PARTICLES IN SPACE PLASMAS

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Abstract

Electromagnetic waves and nonlinear structures (shocks and solitons) have been extensively studied because of their potential importance in the particle energization in magnetized plasmas and have been applied to laboratory, astrophysicaland space plasmas,such as the tokamak plasma heating,the auroral electron/proton acceleration, the solar coronal plasma heating and the anomalous heating of heavy ions in the extended corona. The nonthermal charged particles accelerated to energies ≈ tens of keV play a major role during solar flares as they contain a large amount of the released energy and provide information about the underlying physics applicable to various phenomena in space and astrophysical environments through their nonthermal radiation. However, the acceleration mechanism of these nonthermal electrons is still not completely understood. We aim to present an investigation of electromagnetic nonlinear waves and the associated charged particle acceleration phenomenon in space and astrophysical plasmas. The results of this investigation may give interesting insights to understand the underlying physical phenomenon that give rise to highly energetic charged particles which may be useful for application in laboratory plasma environments.

107/SA-32/P

BERNSTEIN-GREENE-KRUSKAL THEORY OF ELECTRON HOLES IN SUPERTHERMAL SPACE PLASMA

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Abstract

Bernstein, Greene, and Kruskal (BGK) have developed the theory for one-dimensional stationary nonlinear electrostatic waves in a collision less plasma[1]. It is a nonlinear kinetic theory formulated in the one-dimensional Vlasov-Poisson framework of equations. If the solution obtained after the BGK analysis is positive, it is a model of a one-dimensional electrostatic coherent structure, usually called a BGK wave.There are certain structures called a phase space holes that develop because of particle trapping in a potential, which is a phase space manifestation of BGK wave. As these structures in phase space have a lower density at the center than the rim, they are “Phase Space Holes”. Depending on which species trapped, phase space holes are further classified as Electron Holes (EHs) and Ion Holes (IHs). Most of the coherent electrostatic structures encountered in space plasmas modeled in terms of these different phase space holes. However, these models assume the space plasma in thermal equilibrium, described by the Maxwell distribution [3]. Several spacecraft data observations reveal that the plasmas in space cannot be assumed to be in thermal equilibrium and these plasmas are best-modeled using generalized Lorentzian distribution or kappa distribution [2]. Hence, a nonlinear kinetic theory for nonthermal plasma is an essential component to study the coherent wave structures in space plasmas. We develop a first ever one-dimensional model of nonthermal plasma keeping ions stationary in the electrostatic limit. We have derived the analytical expression for trapped electron density and distribution function of trapped electrons. We find a significant difference in the trapped electron density and distribution function. We find that nonthermal plasma is more prone to trapping and as a result, the distribution function in nonthermal plasma found steeper and denser than the trapped distribution in thermal plasma. EHs formed in a nonthermal plasma are found to have a smaller size than the EHs formed in thermal plasma for same perturbation. The width and amplitude of perturbation play an important role in the development of holes and deciding their characteristics. The analytical expression for width – amplitude inequality relation that decides the stability of EHs has been derived. We have observed that the parametric regime of amplitude and width (perturbation) that supports stable BGK EH solutionsin nonthermal plasma is less than that of weakly nonthermal plasma.We have applied the newly developed

model to EHs observed by the FAST satellite, which operates in the auroral region where the nonthermal population dominant.

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115/SA-33/P

SOLITARY WAVE IN ION BEAM DEGENERATE PLASMA IN PRESENCE OF ELECTRON TRAPPING AND MAGNETIC QUANTIZATION

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Abstract

The evolution of ion acoustic waves in an ion beam driven degenerate plasma in presence of quantizing magnetic field and trapped electron is studied by deriving Zakharov-Kuznetsov (Z-K) equation. The three wave modes namely, fast beam mode, slow beam mode and the background ion acoustic mode is found to propagate in such plasma and their characteristics are greatly influenced by the magnetic quantization and temperature in such plasma system. The aim is to study the uniqueness of soliton especially from the view point of space plasma where the trapping of plasma constituents is inevitable [1]. This trapped state of plasma constituents allows the plasma system to behave as a highly nonlinear system. Besides theoretical features, researches are also working on the experimental aspects of this type of plasma environment throughout the world [2].The standard reductive perturbation method is employed to obtain the Z-K equation governing the evolution of solitary waves in such plasmas. The solution of Z-K equation is examined analytically to study the salient characteristics of solitary waves in such plasma. Both subsonic and supersonic soliton are found to exist in such plasma and their velocity of propagation, width, amplitudes are greatly influenced by the quantization of the magnetic field. The nonlinear co-efficient decreases with magnetic quantization and the soliton amplitude increases in turn. The balance of non-linearity and dispersion helps the fast beam mode to propagate with the characteristics of a typical soliton. The slow beam mode is also found to be greatly influenced by the quantization of magnetic field.

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116/SA-34/P

FIRST REPORT OF ELECTRON ACOUSTIC SUPERSOLITARY WAVE IN A MAGNETIZED PLASMA

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Abstract

Broadband Electrostatic Noise (BEN) have been observed by satellites in various regions of the magnetosphere such as the auroral region, the plasma sheet boundary layer or the polar cusp. The GEOTAIL spacecraft exposed BEN as a series of Electrostatic Solitary Waves (ESWs) which are the solitary waves having monopolar/bipolar/tripolar pulses in the electric field data. The high frequency part of the BEN can often be interpreted by the electron acoustic waves. Moreover electron dynamics are accountable for many space plasma phenomena. In many of such situations, ions are found to be hotter than electrons. It is often customary to interpret these monopolar and bipolar pulses in ESWs theoretically by ion/electron acoustic double layers and solitary waves. However, there are also tripolar pulses and other more composite structures which needs further attentions.

In recent days, the novel extra-nonlinear structure called Super Solitary Waves (SSWs) have gained considerable attentions. They are extra-nonlinear solitary wave pulses with an extra wiggle in their otherwise bipolar pulse in electric field [1]. They have so far been obtained theoretically assuming multi component plasmas. The theoretical works so far studied these waves for low frequency waves in an unmagnetized plasma. But the counterpart of them for a high frequency waves has not been reported yet. To explore their applicability to interpret more complicated structures observed in ESWs, it is necessary to generalize them for high frequency waves and magnetized plasmas as well. This motivated us to adopt a model where the plasma is magnetized and comprising of beam and bulk electron fluids along with two ions. Since they are hotter than electrons, they are assumed to have Boltzmann distributions and the electron acoustic wave is assumed to move obliquely to the ambient magnetic field [2].

In this present work, we are reporting the first ever finding of electron acoustic SSW in a magnetized plasma by using the Sagdeev pseudopotential method. It is known that the presence of the magnetic field invokes singularities in the pseudopotential. We found a close association between the SSW and the singularity where the former appears near the vicinity of the singularity. The comparison with its low frequency counterparts reveal a lateral inversion in the auxiliary sub well for the Sagdeev pseudopotential profile associated with the SSW. Depending on their uniquefeatures, we have incorporated a new analytical tool to study these high

frequency, magnetized SSWs and the associated other extra-nonlinear structures. We intend to apply our theoretical analyses to interpret the observed ESWs in latter course.

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123/SA-35/P

EFFECT OF KAPPA DISTRIBUTION FUNCTION ON KINETIC ALFVEN INSTABILITY IN DUSTY MAGNETO-PLASMA

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Abstract

We have, present work on kinetic Alfven waves instability in dusty plasma. The expression for the dispersion relation, growth rate and growth length of the kinetic Alfven waves are derived using the particle aspect analysis in auroral acceleration region. Our purpose in this paper is to be investigating the effect of kappa distribution function with dusty plasma on kinetic Alfven waves. It is observed that the growth rate and growth length is increase with increase in wave vector for different values of kappa distribution function. The results of the work are consistent for Alfven wave in dusty plasma are applicable of the magnetospheric and astrophysical in auroral acceleration region.

127/SA-36/P

KAPPA DISTRIBUTION FUNCTION ON ELECTROMAGNETIC ION CYCLOTRON INSTABILITY IN AURORAL ACCELERATION REGION

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Abstract

In this studies, we have present investigation of kappa distribution function on electromagnetic ion cyclotron waves in auroral acceleration region by using the method of particle aspect analysis. The dispersion relation, growth rate and growth length of the EMIC waves are derived. The whole plasma is considered to consist of resonant and non-resonant particles. It is assumed that resonant particle participate in energy exchange while the non-resonant particle support the oscillatory motion of the wave. The wave is assumed to propagate obliquely to the static magnetic field. It is observed that the effect of kappa distribution function with plasma densities in multi-ions (H^+,He^+ and O^+) of EMIC waves is to enhance the growth rate and growth length. The results are interpreted for the space plasma parameters appropriate to the auroral acceleration region.

141/SA-37/P

GRAVITATIONAL INSTABILITY OF AN ANISOTROPIC VISCOELASTIC QUANTUM PLASMA

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Abstract

The influence of quantum correction is investigated on the growth rate of Gravitational instability for a viscoelastic and anisotropic pressure plasma. The equations of the problem are formulated by using Generalized Hydrodynamic (GH) model and Chew-Goldberger-Low (CGL) fluid model. The dispersion relation has been derived for transverse mode with the help of linearized perturbation equations. The Jeans instability is discussed for kinetic and classical limits and Jeans instability criterion is obtained for transverse mode. It is observed that Jeans critical wave number in the kinetic limit is modified due to presence of quantum Bohm potential. From the numerical analysis it is found that the quantum effect has stabilizing effect on the growth rate of Jeans instability under classical and kinetic limits. The results of the present work can have extensive application in the field of astrophysics and space plasmas.

151/SA-38/P

INFLUENCE OF NON-THERMAL IONS ON DUST ION ACOUSTIC SOLITARY WAVES WITH WEAKLY RELATIVISTIC ELECTRONS

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Abstract

The nonlinear dust ion acoustic (DIA) solitary waves in weakly relativistic dusty plasma have been investigated using reductive perturbation method. The weakly relativistic effect of electron species, non-thermal distribution of ion species and negatively charged dust grains are taking into account. The governing basic set of equations are firstly normalized and then reduced to Korteweg-de Vries (KdV) equations. The influence of non-thermal ion population and weakly relativistic electrons on the amplitude and width of DIA solitary waves are shown numerically. The results of the present work are applicable in the region of space plasma and interstellar medium.

157/SA-39/P

NONLINEAR ACOUSTIC SOLITARY WAVES IN DEGENERATE ELECTRON–POSITRON PLASMAS WITH EXCHANGE POTENTIAL

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Abstract

The nonlinear acoustic waves in a dense electron–positron (e–p) plasmas have been analyzed incorporating the exchange potential of electrons. The electron and positron fluids are taken as dynamic and ions are taken as stationary. The reductive perturbation method is employed to obtain Korteweg–de Vries (Kdv) equation. The analytical results presented are applicable to study the propagation of acoustic solitary waves in electron positron quantum plasma containing positive ions in addition. The implications of present investigation obtained from this work have been brieflydiscussed for the outer layers of white dwarfs.

166/SA-40/P

EFFECTS OF MAGNETIC TENSION ON PREFERENTIAL ENERGETICS OF ALPHA-PARTICLES OVER PROTONS IN SOLAR CORONAL HOLE

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Abstract

The identification of the solar-minimum polar coronal hole (PCH) as the source of a fast-solar wind (FSW) has been established convincingly. SOHO/UVCS observation indicate strong preferential heating and acceleration of heavy ions in the PCH (Cranmer 2005). Nevertheless, comprehensive theoretical understanding of the solar wind dynamics in the collision less extended corona is still a long way to go. Chakravarty & Bose (2014,2015) have employed a three-fluid Maxwell model in the cold plasma regime comprising electron, proton and alpha-particles at about two solar radii heliocentric distance in the PCH and shown preferential heating of alpha-particles over protons by lower hybrid waves, where the causes of the significant preferential behavior have been found as the alpha-proton differential mass and velocity.

We are now attempting to investigate the effect of magnetic field line curvature on the extreme properties of heavy ions in the PCH where collision less wave mechanisms dominate the plasma heating scenario. This study is based on the currently available magnetic field models (see e.g. Banaskiewicz et al. 1998) with the boundaries of the PCH at about 60º latitude, north and south both (Cranmer 2001). The field lines nearing the PCH boundary, form the magnetic axis taken vertically upward, are expected to exhibit increasing curvature and exert magnetic tension force on the ambient plasma. Therefore, this study concerning the latitudinal impacts on the FSW in terms of the magnetic tension forces on the solar plasma is expected to yield more realistic theoretical reproduction of solar wind measurements.

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180/SA-41/P

SUPER SOLITARY WAVES AND OTHER EXTRA--NONLINEAR STRUCTURES: CHALLENGES AND OPPORTUNITIES .

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Abstract

In recent days, the term supersolitons has drawn considerable attentions to the plasma wave community, especially those who are involved in studying nonlinear structures, like solitary waves and double layers (DLs) in plasma. The structures were first identified by the extra wiggles in their solitary potential profile and bipolar E field structure and were namedas supersolitons or super solitary waves (SSWs) [1]. The word 'super' actually coined because of their extra large speed, width and amplitudes, larger than the associated DLs. As we started working on it, we found that SSWs are not unique, but there are other associated extra--nonlinear structures which can well be marked and quantified by their specific properties [2]. We have also found that there is no unique route of transition from a regular solitary wave (RSW) to a SSW [3]. While the parametric conditions are found to be quite stringent, recent simulation results showed they are very stable structures with extra steepening and extra balancing of that steepening. They have also been identified for magnetized plasma where the presence of the magnetic field further modifies their featuresuniquely. So far all the theoretical investigation of SSWs have been carried out using Sagdeev pseudopotential technique. Is an SSW then just a technique dependent artifact or has some more physics in it? How a solitary structure at all can have a larger amplitude than a DL where it is known as the terminating solution? Whether a regular DL is same as those associated with SSW? There are a few questions we shall try to throw some light on it. Is their study really important? Well, if they exist they will surely modify the transport and trapping processes, be it for more composite structures in the magnetospheric boundary layers, or some other exotic kinds of plasma. We just need to investigate more.

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182/SA-42/P

SELF-GRAVITATIONAL INSTABILITY OF CHARGE VARYING DUSTY PLASMA WITH IONIZATION AND RECOMBINATION

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Abstract

The effect of ionization-recombination and dust charge fluctuation on thegravitational instability of magnetized radiative dusty plasma is investigated consideringsufficient neutral background. The model is constructed using multi fluid theory in which thedust dynamics involves the dust charge fluctuation and dust-neutral collision effect, while theelectrons and ions dynamics describe radiative and ionization-recombination effectsrespectively. The general dispersion relation is derived and further resolved for parallel andperpendicular direction of propagation. The analytical and numerical results are discussed forboth the modes of propagation showing the influence of recombination in the presence ofdust charge fluctuation and radiative cooling of electron. Theapplicability of the present work is shown for astrophysical dusty plasma environments.

189/SA-43/P

ION ACOUSTIC ROUGE WAVES IN ELECTRONEGATIVE PLASMA

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Abstract

Those plasmas which have appreciable amount of negative ions such that their presence cannot be ignored are known as electronegative plasmas. Due to presence of negative ions, density of electrons decreases which results in decreasing of shielding effect produced by electrons. The presence of negative ions significantly modifies the characteristics and properties of solitary waves. In the present investigation we have derived the ZK equation in magnetized plasma having mobile positive and negative ions and non Maxwellian electrons. Further we have reported the influence of density of negative ions, superthermality and density of electrons on the characteristics of ion acoustic solitary waves. Later, we have discussed rogue waves (also known as freak waves) in the same system by deriving 3-D NLSE and reported the influence of various physical parameters on the characteristics of rogue waves. Findings of the present investigation may be useful for understanding the existence of different nonlinear structures and their behavior in space and astrophysical plasmas especially in the Earth's ionosphere where negative ions are in abundance.

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195/SA-44/P

EFFECT OF ELECTRON BEAM VELOCITY AND TEMPERATURE ANISOTROPY ON ALFVEN WAVES IN MULTI-COMPONENT MAGNETOSPHRIC PLASMA: PARTICLE ASPECT ANALYSIS

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Abstract

The main objective of the present investigation is to examine the effect of electron beam velocity and temperature anisotropy on Alfven waves in multi-component plasma by using method of particle aspect analysis and using different plasma parameters in auroral acceleration region. Here one component is Electron (e) and other three components are the Hydrogen (H+), Helium (He+) and Oxygen (O+) ions are mixed. The plasma consisting of resonant and non-resonant particles has been considered. It is assumed that the resonant particles participate in energy exchange with the wave, whereas non-resonant particles support the oscillatory motion of the wave. The effect of electron beam velocity on the dispersion relation of the Alfven waves with general loss-cone distribution function in thermal anisotropy plasma is described by particle aspect approach. The electron beam velocity is injected from the tail side of the magnetosphere at the substorm time constituting field – aligned currents and auroral acceleration. In the same event, the Alfven waves are also observed by various rockets and satellites, therefore, the electron beam may be the cause of Alfven wave generation which modifies the frequency and the auroral acceleration region may affect the field aligned- current and the wave spectrum. The results are discussed the applications of Alfven waves in multi-component magnetized plasma in the auroral acceleration region of interplanetary space plasma as well as the magnetospheric plasma and astrophysical plasmas.

196/SA-45/P

PRESSURE ANISOTROPY EFFECTS ON SOLITARY WAVES IN MULTI-ION PLASMAS

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Abstract

Using Reductive Perturbation Technique (RPT), Zakharov-Kuznetzov (ZK) equation is derived for ion acoustic solitary waves in a multi component magnetized plasma consisting of hydrogen ions, both solar and cometary origin of electrons and positively and negatively charged heavier pair ions. Both electron components are modeled by Kappa distribution function. The Chew, Golberger-Low (CGL) theory [1] has been included in the derivation to study the combined effect of anisotropic pressure of lighter hydrogen and heavier pair-ions. Various combinations of the anisotropy of the three types of ions have been considered in the numerical study. For parameters relevant to comet Halley [2, 3], it is seen that at lower values of the phase velocity, the width and amplitude of the solitary waves depend strongly on the anisotropy parameters. On the other hand, the width and amplitude of the solitary waves are independent of the anisotropy of the ions.

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204/SA-46/P

NONLINEAR WAVES IN NONTHERMAL MAGNETIZED POLARIZED COMPLEX ASTROCLOUD

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Abstract

A nonextensive nonthermal magnetized polarized astrocloud on the unbounded astrophysical scales of space and time is considered [1]. It compositionally contains nonthermal *q*-nonextensive electrons and ions because of the presence of diversified non-local gradient effects due to large-scale inhomogeneties [2]. The constitutive massive dust grains are polarized with fluctuating electric charge treated in the framework of strongly coupled fluid description [3]. Assuming the cloud equilibrium at least initially as a statichomogeneous one, the model cloud is allowed to undergo slightly nonlinear perturbations.It dynamically evolves as a conjugated pair of coupled *extended Korteweg-de Vries* (*e*-KdV) equations having diversified coefficients dependent on the poly-parametric equilibrium plasma parameters [4]. The constructed numerical standpoint shows that the cloud electro-gravitational response results in the collective excitation of a new pair of distinct classes of coherent eigenmodes. The first family indicates periodic electrostatic compressive eigen-structures in the form of stable soliton-chains.Moreover, the second one reveals gravitational rarefactive stable solitary wave patterns. The microphysical insights responsible for the eigen-patterns are analyzed elaborately. A further confirmation to the above bimodal eigen-pair is provided via spatiotemporal illustrative platform. The unique features of the eigen-patterns are discussed in the light of similar findings by others in different contexts [4]. The astrophysical relevance of the investigated results in various transport processes for redistributing fluid matter into dense phases leading to the initiation of various gravitationally condensedstellar structure formations is presented.

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205/SA-47/P

MAGNETOHYDRODYNAMIC MODELING OF SOLAR CORONAL DYNAMICS WITH INITIAL NON-FORCE-FREE MAGNETIC FIELDS

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Abstract

The magnetic fields in the solar corona can be approximated as non-force-free. Their dynamics are often complex and difficult to characterize. Here, the topological evolution of solar coronal magnetic field lines (MFLs), inferred through the photospheric vector magnetograms, are simulated using a magnetohydrodynamic model. Two cases are presented. (a) In the first case, the numerical simulation is initialized using an analytical solution of a non-axisymmetric non-force-free magnetic field which gives best correlation with the input observed vector magnetograms of the flaring solar active region (AR) 11283. The dynamics develops in the simulation due to the initial Lorentz force that pushes the plasma and facilitates recurrent magnetic reconnections at the locations of X-type null lines present in the initial field. This results in an asymmetric monotonic rise of a flux rope, consisting of low-lying twisted MFLs, which approximately traces the major polarity inversion line. Notably, the simulated dynamics also exhibits bifurcation of this flux rope, which is similar to an observed filament bifurcation seen in the AR. This establishes the appropriateness of the initial field in describing dynamics of the AR. (b) In the second case, the simulation is initialized with a numerically extrapolated non-force-free magnetic field based on the principle of minimum dissipation rate and are performed on vector magnetograms of the AR 12192, which had produced multiple flares during the solar cycle 24. Particularly, we examine the strongest X-3.1 non-eruptive flare that took place on October 24, 2014 at 21:30 hours. Our preliminary analysis shows reconnections occurring near a three-dimensional null-type geometry close one of the polarity inversion lines in the vicinity of the flaring site. This can potentially account for the trigger mechanism for the flare and also the subsequent brightening in the ultra-violet channels.

206/SA-48/P

LINEAR STABILITY OF NONEXTENSIVE TURBULENT GRAVITO-ELECTROSTATIC SHEATH (GES) EQUILIBRIUM STRUCTURE

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Abstract

A simplified theoretical model to investigate the linear fluctuation dynamics of the nonextensive turbulent gravito-electrostatic sheath (GES) model is proposed. It couples the solar interior plasma (SIP) on the bounded scale and solar wind plasma (SWP) on the unbounded one via the diffused solar surface boundary (SSB) formed due to gravito-electrostatic interplay [1-3].A plane-wave analysis in the radial direction reveals both dispersive and non-dispersive characteristics of the modified GES-associated collective modes. It is seen that the thermostatistically developed GES stability in the presented configuration depends solely on the electron-to-ion temperature ratio as a free parameter. The damping behavior of the GES mode on both the scales is more pronounced in the acoustic domainthan the gravitational domain of wave space. The fluctuations evolve as a unique type of stable oscillatory patterns with no damping in coordination space. It hereby specifically establishes a unique form of quasi-linear coupling of the gravitational and acoustic modes surviving in the GES-based bounded Sun and its unbounded atmosphere.

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233/SA-49/P

SIMULATION RESULTS FOR AN ELECTRON HOLE FORMATION IN THE EQUATORIAL IONOSPHERE OVER INDIAN SECTOR

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Abstract

Using the SAMI2 (SAMI2 is Another Model of the Ionosphere) model a remarkable phenomenon, namely, an 'electron hole' wherein a reduction in electron density in the topside ionosphere in the height range of about 1500-2500 km near the magnetic equator has been reported [1]. This reduction in electron density has been attributed to the transhemispheric O^+ flows that collisionally couple to H^+ and transport it to lower altitudes, and thereby reduce the electron density at high altitudes. The transhemispheric O^+ flows are caused by an interhemispheric pressure anisotropy that can be generated by the neutral wind, primarily during solstice conditions. The first empirical support of an electron hole (electron depletion) in the topside equatorial ionosphere is recently presented for the SAMI2 model result [2].We have also run SAMI2 model to study the "Electron hole" in the equatorial ionization anomaly region of Indian sector along 75°E. For the Indian region, the reduction in electron density occurs in the altitude range 800-2500 km over the magnetic equator. Compared to the results of [1], significant differences with regard to the strength and time of occurrence of the electron hole have been found. Besides the solar activity dependence, our results also show seasonal variation and longitudinal asymmetry of the electron hole. Contrary to the result of [1], our results showed the occurrence of an electron hole during equinoxes also.

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237/SA-50/P

RELATION BETWEEN SOLAR WIND PARAMETERS, CORONAL MASS EJECTIONS AND SUNSPOT NUMBERS

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Abstract

The solar atmosphere is one of the most dynamic environments studied in modern Astrophysics. The sun has a complex system of magnetic field. Solar activity refers to any natural phenomenon occurring on the sun such as sunspots, solar flare and coronal mass ejection etc. Such phenomenon has their roots deep inside the sun, mainly driven by the variability of the sun's, magnetic field. The present paper studies the relation between various solar features during solar cycle 24.The study reveals that there exists a good correlation between various parameters. This indicates that they all belongs to same origin i.e.; the variability of Sun's magnetic field.

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238/SA-51/P

STUDIES ON THE SOLAR ACTIVITY DEPENDENCE OF MULTIFRACTAL FEATURES OF AURORAL, SYM-H AND DST INDICES

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Abstract

Multifractal methods have been used recently for a better understanding of the self-organized criticality (SOC) phenomena in complex magnetosphere dynamics [1]. Using computational multifractal methods, we compare the solar activity dependence of multifractality of magnetospheric proxies such as auroral electrojet indices (namely AE), symmetric horizontal magnetic index (SYM-H) and disturbance storm time (Dst) index. The results show that the degree of multifractality of the singularity spectra of auroral indices is less dependent on solar activity when compared with that of SYM-H and Dst indices [2]. This indicates that, other than solar wind forcing, certain complex phenomena related with the anomalous transport and energization/dissipation (related with isolated substorms or HILDCAA events that influence the auroral electrojets) also modify the fluctuations of auroral electrojets (in turn AE index) in the high-latitude region.

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241/SA-52/P

MODULATIONAL INSTABILITY OF ION ACOUSTIC WAVE IN ELECTRON-ION-POSITRON PLASMA HAVING WARM STREAMING IONS AND KAPPA DISTRIBUTED ELECTRONS

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Abstract

Modulational instability of ion-acoustic wave in an electron-ion-positron plasma has been studied using Fried and Ichikawa method when the electrons are kappa distributed and ions are warm with constant stream velocity. The nonlinear Schrodinger equation is derived and modulational instability of ion acoustic wave is studied. The stability criteria are established and studied by varying the positron density, positron temperature and stream velocity of ions. The solution of bright- and dark- envelope solitons are obtained and their structures for different plasma parameters are shown graphically. Our results would be applicable in astrophysical plasma of white dwarfs and neutron stars etc.

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268/SA-53/P

ASTROEVOLUTIONARY DYNAMICS OF FLOW-INDUCED INSTABILITY IN COMPLEX STRONGLY CORRELATED GYROGRAVITATING QUANTUM FLUIDS

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Abstract

The excitation dynamics of evolutionary flow-induced (dust-streaming) instability mode [1] supported in illimitable complex gyrogravitating viscoelastic turbulent quantum plasma fluids is analyzed in the framework of a generalized quantum hydrodynamic model together with quantum corrections included. The constitutive lighter electrons, with the larger *de-Broglie wavelength*, are treated as quantum degenerate particles [1-2]. Besides, the constitutive heavier ions and streaming dust particulates (relative to both electrons and ions), with the smaller wavelengths, are modelled classically. The effects of the lowest-order fluid viscoelasticity, Coriolis rotation and fluid turbulence are collectively enforced in a spatially flat-geometry configuration. A linear generalized dispersion relation from the slightly perturbed tri-component quantum plasma is obtained by a standard normal mode analysis [2] followed by a constructed concretized numerical standpoint in the hydro-kinetic regimes. All the realistic tonality factors affecting the stability of the flow-induced mode are identified and characterized. It is interestingly seen that the quantum parameter (H_e^*) plays as a mode-destabilizer in both the hydro-kinetic regimes. The equilibrium dust drift (V_{d0}^*) acts as stabilizing agents in both the regimes. In contrast, the dimensionality-dependent quantum correction factor (γ) introduces respectively stabilizing and destabilizing effects in the considered regimes, and so forth. The implications and applications of the results in the previously poorly understood context of degenerate compact dwarves, specifically circumvented with broad-band concentric dusty atmospheres [2-3], are concisely adumbrated together with futuristic scope for further ameliorations.

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290/SA-54/P

EFFECT OF GUIDE FIELD IN LOCALIZATION OF WHISTLER WAVE AND TURBULENT SPECTRUM IN MAGNETIC RECONNECTION SITES

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Abstract

Whistler waves have ample of observations in the magnetosphere near the dayside magnetopause. Also, the role of whistler waves is well established in the context of magnetic reconnection as well as turbulence generation. In the present work, we examine the combined effect of guide field and nonlinearity in the development of turbulence in magnetic reconnection sites. We have derived the dynamical equation of 3D whistler wave propagating through Harris sheet assuming that background number density and background field are perturbed. The nonlinear dynamical equation is then solved numerically using pseudo spectral method and finite difference method. Simulation results represent the nonlinear evolution of X-O field line in the presence of nonlinearity, which causes the generation of turbulence. When the system reaches quasi steady state, we have evaluated power spectrum in magnetopause and it shows two different scaling. Energy distribution at smaller scales leads to the formation of thermal tail of energetic particles. The energy of these electrons is also calculated and comes out to be in the order of 100 keV.

308/SA-55/P

EFFECT OF SOLAR PLASMA SPEED AND SOLAR IRRADIANCE ON COUPLING OF MULTIVARIATE ENSO INDEX

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Abstract

The Multivariate ENSO Index, the indicator of the intensity of the Earth's strongest climate fluctuations (El Niño Southern Oscillation) plays a decisive role in global climate. Various indices have been developed to describe ENSO but the MEI is considered as the most representative because it links six different meteorological parameters measured over the tropical Pacific. In this study we have analyzed the effects of solar wind plasma speed and solar irradiance on the Multivariate ENSO Index. As a result we have established that the Extreme values of MEI can be correlated to the extreme values of solar irradiance and solar wind speed. We have evaluated the correlation coefficient between MEI and the other two solar parameters using their variation in annual rate. Our results further confirm the idea that the major local and global Earth–atmosphere system mechanisms are significantly coupled and synchronized to each other.

370/SA-56/P

THREE-DIMENSIONAL MAGNETIC NULLS AND CIRCULAR RIBBON FLARES

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Abstract

Numerical simulations are performed to explore spontaneous development of current sheets in presence of three-dimensional (3D) magnetic nulls. The initial magnetic field---with classical spine axis and fan plane---is constructed by superposing a 3D force-free field on an uniform axial magnetic field. Importantly, the simulation identifies the development of current sheets near the 3D magnetic nulls. The morphology of the current sheets is similar to a cylindrical surface where the surface encloses the spine axis and hence their decay may result in circular ribbon flares. The development is attributed to a favorable deformation of magnetic field lines constituting the dome-shaped fan surface. The deformation of field lines is due to the flow generated by magnetic reconnections at secondary current sheets which are located away from the primary cylindrical current sheets.

417/SA-57/P

MAGNETIC SHEAR INDUCED STABILIZATION OF CONVECTIVE FLUID INSTABILITIES

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Abstract

The influence of the magnetic field shear is studied on the EXB, Gravitational and theCurrent Convective Instabilities (CCI) occuring in the High latitude F-layer ionosphere [1][2]. It is shownthat magnetic shear reduces the growth rate of these instabilities [3]. The magnetic shear inducedstabilization is more effective at the larger scale sizes while at theintermediate scale sizes, the growth rate remains largely unaffected. It turns out that the eigen-mode structure gets localised about a rational surface due to finite magnetic shear.

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447/SA-58/P

QUASI-ELECTROSTATIC WHISTLER WAVES IN RADIATION BELT PLASMA

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Abstract

A model is proposed to study the dynamics of high-amplitude quasi-electrostatic whistler wavespropagating near resonance cone angle and their interaction with low-frequency kinetic Alfvén waves (KAWs) in Earth's radiation belts. The wave dynamics clearly indicates the whistlers having quasi-electrostaticcharacter when propagating close to resonance cone angle. A high-amplitude whistler wave packet isobtained using the present analysis which has also been observed by S/WAVES (STEREO/WAVES) instrumentonboard STEREO (Solar Terrestrial Relations Observatory). A numerical simulation technique has beenemployed to study the localization of quasi-electrostatic whistler waves in radiation belts. The ponderomotiveforce of pump quasi-electrostatic whistlers (high frequency) is used to excite low-frequency waves (KAWs). Theturbulent spectrum obtained using the analysis suggests the presence of quasi-electrostatic whistlers and density fluctuations associated with KAW in radiation belts plasma. The wave localization and steeper spectracould be responsible for particle energization or heating in radiation belts.

467/SA-59/P

COSMIC RAY FLUX

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Abstract

The Earth is incessantly bombarded by energetic charged particles called Galactic cosmic rays (GCRs) which are either solar or non-solar origins. The characteristic inverse relationship between cosmic rays (CRs) and some of the solar proxies such as sunspot number (SSN) and solar radio flux (SRF) are also well discussed [1]. Information theoretic estimators (ITE) are known to be playing a major role in statistical analysis of astrophysical plasma systems. As we know, one of the most prominent information theoretic estimators called the divergence estimator which quantifies the statistical 'distance' between two probability density distributions. In the present work, through different divergence estimators, variations in distance between two density functions are statistically estimated [2]. Thus information theoretic approach can be considered as a potential strategy in analyzing the inter-relationship between cosmic rays (CRs) and solar activity proxies such as sunspot number, solar radio flux etc. during different solar cycles. It is also possible to extend the study in such a way that our results are useful to identify the best density function that properly represents the GCR data sets.

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153/SA-61/P

FLUX ROPE ERUPTION FROM A SIGMOID ACTIVE REGION: TRIGGERING MECHANISM AND LARGE-SCALE MAGNETIC RECONNECTION

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Abstract

Coronal sigmoids are complex active regions that exhibit enhanced soft X-ray or EUV coronal emission from a system of twisted coronal loops that overall form an S (or inverse S) shaped morphology[1]. It is well established that sigmoidal active regions tend to produce frequent coronal mass ejections (CMEs) over non-sigmoidal ones[2]. Our understanding regarding the formation stages of coronal sigmoids and triggering of eruption from such magnetically complex regions is still very limited. In this paper, we present a comprehensive multi-wavelength investigation of the onset of flux rope eruption and subsequent reconnection-driven large-scale phenomena from sigmoid active region NOAA 12371 on 2015 June 21. For the purpose, we have analyzed solar observations taken from SDO[3], GOES[4], and RHESSI[5]. The SDO/AIA images at 94 A channel reveals that flux rope underwent eruption in two distinct phases that led to two successive, well-separated M-class flares. LASCO CME observations show that the successful eruption of the flux rope eventually produced a large halo CME. The build-up phase of the coronal sigmoid is characterized by striking magnetic activities in the photosphere which includes counter clockwise rotation of a negative polarity region along with adjacent moving magnetic features. The flux rope activation occurred within a compact coronal volume that displayed enhanced EUV emission. Compact brightenings observed in multi-channel EUV images in the vicinity of photospheric neutral line during the activation phase along with flux cancellation suggest tether-cutting[6] reconnection to be the driving mechanism for the eruption onset. The rapid expansion of the flux rope led to the first M-class flare with relatively less spatial extents. The second flare presents extended chromospheric ribbons and larger loop structures. The multi-wavelength observations further suggest interactions of the expanding flux rope with overlying coronal loops at higher altitude caused the second M-class flare.

109/SA-62/P

THE VARIATION OF NETWORK INDEX AND NETWORK CONTRAST IN THE SOLAR TRANSITION REGION

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Abstract

The solar EUV network is the continuation of the chromospheric network in the transition region. The network and cell structure disappears at corona level. . The most striking feature of images formed in the transition region lines is the strong intensity enhancement at the supergranule boundary as compared with the central areas of the supergranular cells. The extreme ultraviolet (EUV) emissions come both from neutral atoms and from ions upto very high ionization levels in the solar corona. This facilitates the observations of the wide range of temperatures from 8000K to 4x10^6K, from the chromosphere to the corona. Since the temperature of the sun varies slowly with the increase in plasma temperature, the different emission lines gives information at different atmospheric heights. This paper deals with the study of network properties, the network index and the network contrast of the EUV network in the transition region using the daily spectroscopic data from the sun collected from the Coronal Diagnostic Spectrometer on board the SOHO satellite. The change in the network points and network contrast of He I (584.5Å) and O V (630 Å) in accordance with the sunspot number is examined over a period of 17 years (1996-2012). The result of this analysis is presented in the paper.

245/SA-63/P

SOLAR PLASMA EFFECTS ON GEOMAGNETIC Pi2 PULSATIONS

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Abstract

In this paper, we have analysed the solar cycle dependence of Pi2 pulsation using Wp-index (Wave power index) data for the present solar cycle 24. This index is related to wave power of low-latitude Pi2 pulsations. Geomagnetic Pi2 pulsation is classified as the damped irregular waveform pulsation with the period range of 40-150 sec numerically. Detrended Cross-Correlation Analysis (DCCA) has been performed between Pi2 pulsation wave power index (Wp) and the various interplanetary plasma parameters, for the investigation of the effects of the change in orientation of the interplanetary magnetic field (IMF) or an increase in solar wind velocity on the waves related to Pi2 pulsations. For this study we have specified ten interplanetary plasma parameters viz: IMF Magnitude (B), By, Bz, solar plasma Flow Speed, Proton Density, Proton Temperature, Flow Pressure, Ey - Electric Field, Plasma Beta and AE Index. Here we observed a direct relationship with some solar plasma parameters like solar wind speed, plasma pressure and AE index.

221/SA-64/P

ANALYSIS OF SEISMO-IONOSPHERIC PRECURSORS OBSERVED IN GPS/GNSS SIGNALS FOR NEPAL EARTHQUAKES

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Abstract

Total electron contents derived from GPS signals are analysed to study the earthquake's signature in the ionosphere using spectral analysis and statistical method. The anomalous perturbations in the TEC were observed from few days to few hours prior to the main shock of the earthquake. Perturbation depends on distance as well as direction of observation point from the epicentre. In addition to ionospheric perturbations, the wave-like features in detrended TEC (DTEC) were also identified. The spectral analysis of DTEC data showed an efficient tool to distinguish the perturbation between seismic induced perturbations from other sources

234/SA-65/P

STUDY OF QUASI-PULSING VLF/ELF HISS EMEMISSIONS AT A LOW LATITUDE INDIAN GROUND STATION

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Abstract

This paper report an unexpected simultaneous observation of band limited quasi-periodic pulsing ELF/VLF hiss emissions. The data shown in this paper indicate that there is a strong possibility that lightning is an important source of different types of VLF/ELF emissions, at least in the embryonic sense, recorded at Jammu. The present observation is in fact the first simultaneous occurrence of VLF/ELF hiss emissions.

BOARD OF RESEARCH IN NUCLEAR SCIENCES(BRNS)

The BRNS is an advisory body of the Department of Atomic Energy (DAE) to recommend financial assistance to academic institutions and national laboratories.

Main Activities

1. **Identify and fund R&D projects.**
2. **Financial support to conduct Symposia/Conferences.**
3. **Recruitment under Krishnan Research Associate ship (KSKRA).**
4. **Award research projects under DAE-OIA scheme, through DST-SERC council.**
5. **Award fellowships under DGFS - M.Tech scheme.**
6. **Award fellowships to HBNI students under DGFS- Ph.D. scheme.**
7. **Award fellowships to retired Scientists under RRF-HBC schemes, through AEC.**

ITER-India Progress in Manufacturing and Shipment to ITER

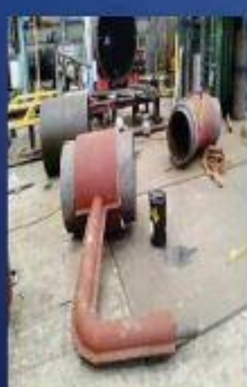
Progress

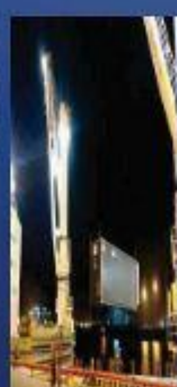
The Base Section of the Cryostat (a 30m dia and 30 m tall vacuum vessel) manufactured L&T, Hazira.

Welding operations for final assembly is undergoing at ITER site in France. 6 segments of Cryostat Base section components totalling 1200 tonnes were shipped to ITER

Progress

Neutron shielding blocks manufactured by Avasarala Technologies, Bangalore. About 600 such blocks delivered to Europe and Korea





Progress

Pipe spools dispatched to ITER site in several batches. A novel concept of "pipe-in-pipe" developed to accommodate thermal expansion in buried pipes, the fabrication of which was highly challenging but in the end successfully achieved.

The Ozonators for the ITER Heat Rejection System Shipped to ITER