INSTITUTE FOR PLASMA RESEARCH

प्लाज़्मा अनुसंधान संस्थान

ANNUAL REPORT
2012-2013

वार्षिक प्रतिवेदन

2012-2013

On the west bank of the river Sabarmati, a few kilometers upstream of the Gandhi Ashram, a small number of low buildings are clustered on a little hillock rising among the ravines and grazing land. The pastoral setting and the quiet surroundings belie the fact that here, scientists and engineers at the Institute for Plasma Research are engaged in one of the most exciting and challenging tasks of this century – controlling thermonuclear fusion. The idea that energy can be obtained while nuclei of light elements fuse to produce heavier elements has been known for a long time; in fact it is the fusion of hydrogen that keeps the Sun shining. But the real challenge lies in trying to release this form of energy on earth by recreating the conditions of the Sun in the laboratory. The pursuit of this goal has been a worldwide effort over the last forty years. The work at the Institute is the prime expression of India's commitment to this futuristic energy source.

The Institute has a broad charter to carry our experimental and theoretical research in plasma sciences with emphasis on the physics of magnetically confined plasmas and certain aspects of the nonlinear phenomena. India's first high temperature plasma device 'Aditya Tokamak', built at IPR, produces plasmas at 5 million degrees temperature - comparable to that of the sun. The Institute also has a mandate to stimulate plasma research activities in the Universities and to develop plasma-based technologies for industries. It also contributes to the training of plasma physicists and technologists in the country. The Institute has recently embarked on an ambitious project of building a Steady State Superconducting (SST-1) Tokamak. This machine is at present undergoing pre-commissioning trials.

ITER (International Thermonuclear Experimental Reactor) is an important step on the path to develop nuclear fusion as a viable, long-term energy option. Realizing the importance of nuclear fusion to the future national energy security, India has joined ITER as an equal partner along with China, the EU, Japan, Korea, the Russian Federation and the United States of America. The Institute for Plasma Research is the domestic agency responsible to design, build and deliver advanced systems and sub-systems for ITER, which have been assigned to India under this agreement. This is being done through an organization called ITER-India.

While IPR prepares for meeting its commitment to ITER, it has been realized that it is imperative to start planning a long-term programme aimed at developing indigenous competence in all aspects of fusion science and technology with a view to be ready to take up designing and building a demo reactor after the successful operation of ITER. This is the charter of the National Fusion Programme, under which strong links are being forged between educational institutions and IPR.

साबरमती नदी के पश्चिमी तट पर, गाँधी आश्रम से कुछ किलोमीटर की दूरी पर उजान में, तंग घाटी तथा कम चारावाही भूमि पर एक छोटे टीले के ऊपर कुछ संख्या में छोटी-छोटी इमारतों का एक समूह है। ग्राम्य परिवेश एवम् शान्त वातावरण यहाँ पर वास्तव में प्लाज़्मा अनुसंधान संस्थान में वैज्ञानिक तथा अभियन्ता जो कि इस सदी के सर्वाधिक उत्तेजक एवम् चुनौतीपूर्ण कार्य नाभिकीय संलयन के नियंत्रण में लगे हुए है, को मिथ्या सिद्ध करते हैं। यह विचार कि हल्के तत्त्वों के नाभिकीय संलयन से भारी तत्त्वों के निर्माण द्वारा ऊर्जा प्राप्त होती है, लम्बे समय से ज्ञात है और वास्तव में हाइड्रोजन के संलयन द्वारा ही सूर्य ऊर्जा प्रदान करता है। परंतु मुख्य चुनौती, प्रयोगशाला में सूर्य जैसी परिस्थितियाँ उत्पन्न करके पृथ्वी पर इस प्रकार की ऊर्जा को प्राप्त करने के प्रयास में है। पिछले चालीस से अधिक वर्षों से इस उद्देश्य की प्राप्ति एक विश्वव्यापी लक्ष्य बन चुकी है। संस्थान में चल रहा कार्य मुख्यत: भविष्य की इस ऊर्जा स्रोत के लिए भारतीय प्रतिबद्धता को दर्शाता हैं।

संस्थान के पास चुम्बकीय परिसीमित प्लाज़्मा भौतिकी एवम् अरैखिक घटनाओं के कुछ मुख्य पहलुओं पर जोर देते हुए प्लाज़्मा विज्ञान में प्रायोगिक एवम् सैद्धान्तिक शोधकार्य करने के व्यापक लक्ष्य हैं। IPR में निर्मित भारत का प्रथम उच्च तापीय प्लाज़्मा संयंत्र 'आदित्य टोकामॉक' सूर्य की तरह 5 मिलियन डिग्री तापक्रम पर प्लाज़्मा का निर्माण करता है। संस्थान के पास विश्व विद्यालयों में प्लाज़्मा शोध को प्रोत्साहित करने के तथा उद्योगों में प्लाज़्मा पर आधारित तकनीकों को उत्पन्न करने के अधिदेश भी हैं। देश में प्लाज्मा भौतिकविदों और प्रौद्योगिकीविदों के प्रशिक्षण में यह योगदान भी देता है। संस्थान आजकल एक महत्वकांक्षी योजना, एक स्थायी-अवस्था अतिचालक टोकामॉक (SST-1) के निर्माण में लगा हुआ है। वर्तमान में इस मशीन का कमीशन-पूर्व परीक्षण किया जा रहा है। ITER (अंतराष्ट्रीय तापनाभिकीय प्रायोगिक रिएक्टर) अर्थपूर्ण, दीर्घ अवधि ऊर्जा विकल्प के रूप नाभिकीय संलयन के विकास की दिशा में एक महत्वपूर्ण कदम है। भविष्य की राष्ट्रीय ऊर्जा सुरक्षा में नाभिकीय संलयन के महत्व को ध्यान में रखते हुए भारत चीन, यूरोपीय संघ, जापान, कोरिया, द रशियन फेडरेशन तथा संयुक्त राज्य अमेरिका के साथ बराबर के भागीदार की तरह ITER से जुड़ गया है। ये सभी कार्य ITER - India नामक एक संगठन के द्वारा किये जा रहे है।

इस समझौते कि अंतर्गत भारत को प्रदत्त ITER के लिए उन्नत प्रणालियों तथा उप-प्रणालियों का अभिकल्पन, निर्माण तथा प्रेषण के उत्तरदायित्व के लिए प्लाज़्मा अनुसंधान संस्थान एक आंतरिक संस्था है। IPR जब ITER के लिए अपनी प्रतिबद्धता निभाने की तैयारी कर रहा है तब यह अनुभव किया गया कि ITER के सफल प्रचालन के पश्चात एक डेमो रिएक्टर के अभिकल्पन तथा निर्माण की तैयारी के लिए संलयन विज्ञान तथा तकनीकी के सभी पहलुओं में स्वदेशी क्षमता के विकास को लक्ष्य बनाने के लिये एक दीर्घ अवधि का कार्यक्रम प्रारंभ करना आवश्यक हो गया है। शैक्षिक संस्थाओं एवं IPR के बीच मजबूत सबंध स्थापित करना राष्ट्रीय संलयन कार्यक्रम के चार्टर मे निहित है।

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प्लाज़्मा अनुसंधान संस्थान

Institute for **Plasma Research**

Bhat, Gandhinagar 382428

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EXECUTIVE SUMMARY

In the 12th five year plan period, keeping with the pace of the ongoing developmental projects, some new projects viz- large cryogenic systems, remote handling and robotics and fusion fuel cycle – were also initiated. New collaborations with big facilities in the world dedicated for fusion research and related technologies have been started. It is expected that these collaborations will train adequate manpower in fusion relevant frontier technologies of the world and give a head start to some of the technology developmental projects within the country.

The scope of certain 11th five year plan projects have been expanded upon in the prevailing 12th five year plan. For instance, the project on development of fusion relevant superconducting magnets of 11th plan, now caters to the development of various kind of magnets pertinent to fusion. In this regard this programme has now also taken up the task of building the prototype magnets for the suppression of Edge Localized Modes (ELM) for Joint European Torus (JET) machine at United Kingdom. The divertor technology development project has been expanded to include the entire first wall technology. This is progressing well with the development of ITER-like divertor cassette body and support structures and has also kept pace with the development of testing facilities in India. Some other fusion technology areas which are being pursued rigourously include Cryogenic Surface study facilities for the development of various cryo-pump related parts and subsystems. For the Liquid Lithium cooled Ceramic Breeder Test Blanket Module design activities, neutronic performance of various variants are being examined and the neutron safety analysis have been performed for the ITER safety document report. A liquid metal loop has been commissioned for testing and calibrating liquid metal diagnostics. Presently pressure sensor and flow meter are being tested in the loop. Relevant experimental facilities for the indigenous development of structural material and for extensive characterization of material is being set up. The development of negative ion beam source is also being actively pursued by carrying out relevant experiments in the already available test bed.

In Aditya, a record number of 1600 plasma discharges were attempted during the year. The discharges were highly repeatable in nature and were aimed at the performance improvement as well as addressing certain fundamental research issues. For instance, gas breakdown and plasma start-up studies relevant for the SST-1 machine etc., were taken up. The disruption studies from the selected Aditya discharges were added to the database of the International Tokamak Plasma Activity (ITPA). In addition, the experiments carried out on Aditya machine have led to the training as well as Ph.D research of IPR students.

The assembled and refurbished sub-systems of Steady-state Superconducting Tokamak-1 (SST-1) of the Institute, were made to go through rigorous engineering validations for the designed parameters. After testing for necessary leak tightness of both the cryostat and the vacuum vessel, the toroidal field (TF) system was successfully charged up to 3.6kA. A short campaign of hydrogen gas break-down using Ion Cyclotron Resonance Heating (ICRH) system was attempted in which toroidal spreading of the plasma was also observed through H-alpha signals indicating plasma break-down. This campaign has also ensured the functionality of many diagnostic systems integrated with SST-1 and the system as a whole is ready for plasma discharges. In the meantime other Radio-Frequency systems- Electron Cyclotron Resonance Heating and Lower

Hybrid Current Drive – are also getting ready to power up the plasma in the SST-1 machine.

The experimental projects under the fundamental plasma sciences programme were rigorously reviewed and their continuity in the 12th five year programme has been established with the aim of exploring research areas of fundamental and applied importance in plasma physics. Such projects include the investigation of low energy plasma surface interaction, microwave-plasma interaction, plasma based wake-field acceleration scheme, multi-cusp plasma experiment to investigate the properties of a quiescent plasma, dusty plasma experiments, helicon plasmas and non-neutral plasma. The Electron Energy Filter (EEF) developed for the Large Volume Plasma Device (LVPD) has opened up many other possible physics studies in addition to Electron Temperature Gradient (ETG) Turbulence studies. New experiments on high power plasma torches and magnetized beam plasma interaction with surfaces have also been started.

The theoretical and computational studies at IPR are dedicated towards pushing the frontiers of plasma science and interdisciplinary areas and also providing support to the experimental program of the institute and other laboratories in the country. Frontline contributions have been made in a broad spectrum of topics ranging from fast electron time scale phenomena to the slow dusty plasma time scale regime, coherent to turbulent phenomena etc. In the computational front, the existing computing facilities at the institute are being used to their full potential. Apart from fluid simulations, expertise on other complex simulation techniques such as Particle – In – Cell (PIC), Molecular dynamics (MD), Global Gyro-Kinetic simulations are being acquired and implemented to study variety of fundamental research issues in plasma science. Modelling and simulation of experiments carried on Aditya and SST-1 devices as well as the design activities for future tokamaks and Fusion Demo reactors are also being pursued.

Through the Facilitation Centre of Industrial Plasma Technology (FCIPT), the monetization of various plasma technologies developed is being realized by relevant hand-shaking with industries. This is being achieved by ensuring good quality control and by timely completion demanded by the industries. The success of this is evident from the various new projects that are being received by the centre.

At ITER-India, after the completion of procurement arrangements for most of the Indian commitments, the signing of different major manufacturing contracts with relevant industrial partners have been started, in line with the detailed work schedule of ITER project.

The review process of BRFST projects was also continued this year. However, no new projects have been sanctioned, keeping in view the major revamping of the BRFST funding process by DAE. The various research programmes in Centre of Plasma Physics (CPP-IPR) were reviewed and their orientation towards the main objective are being refreshed and refurbished. relevant experiments to study plasma surface interaction (PSI) in divertor region have been initiated. Preliminary Neutronics analysis have been performed for the Indian TBM model and for the model of the proposed fusion reactor design at the centre.

Director,
IPR.

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APRIL 1, 2012 TO MARCH 31, 2013

Since 1986 the institute has been excelling in plasma physics research with fast growing facilities, trained man power and many fruitful national and international collaborations. Started with small tokamak experiments and basic plasma experiments, the institute has been acquiring expertise in all the relevant scientific and technological requirements for controlled thermonuclear fusion. Through the participation of the country in the International Thermonuclear Experimental Reactor (ITER), the developed technologies are being tested in the international arena. The activities of the Board of Research on Fusion Science and Technology (BRFST) and the Fusion Technology Development Programme under the past and current Five Year Plans are fuelling the required growth. At the same time basic experiments related to immediate plasma technology dissemination to industry through Facilitation Center for Industrial Plasma Technology (FCIPT) forms an integral part of the programme. Now the programme of the Center for Plasma Physics, are also being aligned to the main theme of fusion research

CHAPTERS

CHAPTER A

SUMMARY OF SCIENTIFIC & TECHNOLOGICAL PROGRAMMES

A.1 Fusion Plasma Experiments

There are two existing facilities in the institute to do experiments related to fusion plasma, namely Aditya tokamak and Superconducting Steadystate Tokamak-I (SST-I). In this section the status of the device, new developments and details about the experiments done are given.

A.1.1 Aditya Tokamak

A.1.1.1 Status of the Device & Experimental Results

During the report period Aditya tokamak has been regularly operated for obtaining repeatable plasma discharges of 70 - 90 kA of plasma current and of 70 - 90 millisecond duration depending upon the experimental requirements. In these discharges electron density is of the order of 1 - 2 X 10^{13} cm^{-3} and electron temperature is ~ 300 - 500 eV. Total ~ 1600 plasma discharges have been attempted. These experiments were done mainly aiming at the plasma discharge performance improvement, fundamental research towards students Ph. D. programme. The experiments related to gas breakdown and plasma start-up for necessary input for making first plasma in SST-I tokamak were also continued during this period.

Molybdenum Limiter: The comparative study of recycling with Molybdenum (r = 24 cm) and Graphite (r = 25 cm) limiter showed reduction in carbon impurity with Molybdenum limiter. However, attempts of low hard X-ray high temperature discharges were not successful with Molybdenum limiter. A typical discharge with different limiter is shown in the figure A.1.1.1.

Effect of Helium Glow Discharge Cleaning: An appreciable reduction in Hydrogen partial pressure was observed, while Oxygen partial pressure was found to increase with 100 % helium discharge cleaning. Discharge cleaning experiments with mixture of hydrogen and helium are underway.

Local Vertical Field (LVF): A Local vertical field (up to ~ 150 G) was deliberately applied as error field to study its effect on breakdown. A significant delay in breakdown time has been recorded in the presence of this error field.

Plasma Flow measurements in the SOL region of Aditya Tokamak: The magnetized Mach probe is used to make measurement of plasma flows in the scrape-off layer of the Aditya tokamak. This probe is further used to measure dependencies of Mach number on local plasma densities and radial distances of the probe in the scrape-off layer. The measured Mach number has contributions from E×B drift, Pfrisch-Schlüter, and transport driven flows. We have determined that the toroidal flow is towards the ion side of the limiter and the poloidal flow direction is towards the contact of the last closed flux surface with the limiter. The parallel Mach numbers are measured at three locations in the scrape-off layer (SOL) plasma of Aditya tokamak by using Mach probes. The flow pattern is constructed from these measurements and the modification of flow pattern is observed by introducing a small puff of working gas. In the normal discharge, there is an indication of shell structure in the SOL plasma flows, which is removed during the gas puff. The plasma parameters, particle flux and Reynolds stress are also measured in the normal discharge and in the discharge with gas puff. It is observed that Reynolds stress and Mach number are coupled in the near SOL region and decoupled in the far SOL region. The coupling in the near SOL region gets washed away during the gas puff.

Electrode Biasing Experiments: An electrode has been placed inside the last closed flux surface and biased positively with respect to vessel up to 400 Volts. Out of many interesting observations, one about the density fluctuation suppression with the application of bias voltage is presented.

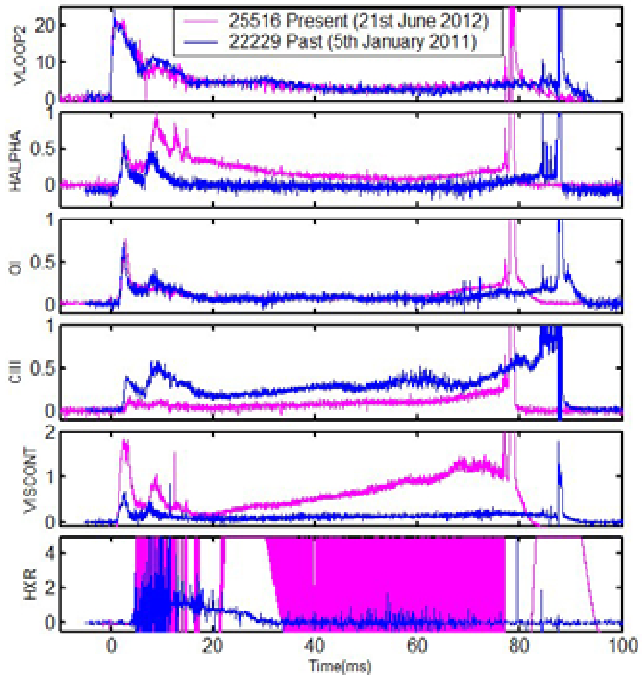

Figure A.1.1.1 Comparison of discharges with Molybdenum and Graphite limiters.

Apart from electrostatic fluctuation suppression, significant effect of bias on Mirnov Oscillations are also observed.

Disruption studies for database: The different disruption mechanisms were studied in Aditya tokamak and a disruption database has been generated as per the suggested format of International Tokamak Physics Activity (ITPA) working group. This database has been loaded in ITPA disruption database.

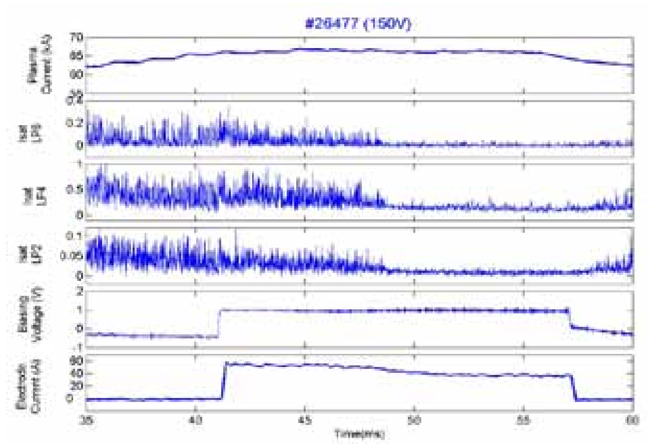

Figure A.1.1.3 Fluctuations suppression in electrode biasing experiments.

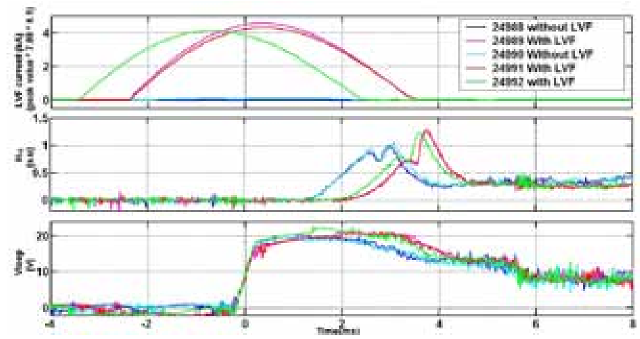

Figure A.1.1.2 Effect of local vertical field in the breakdown time.

A.1.1.2 Diagnostics Developments

InfraRed Thermography: The operation of the Infrared Imaging Video Bolometer (IRVB) installed on the Aditya tokamak was done regularly and total radiated power loss estimation was also done.Up-gradation and re-design of the IRVB system for the tangential viewing geometry is being carried out. A signal estimation code for tangential view IRVB system is being developed. Regular operation of the Limiter Thermography diagnostic was helpful in heat flux estimation. The operation of newly designed and developed tangential viewing infrared imaging video bolometer was smoothly done. The development of the analysis algorithm / code for tangential viewing is undergoing.

Spectroscopy Diagnostics: Spatial profile of emissivity of O4+ spectral line at 650 nm monitored using high resolution multi-track spectroscopy system showed asymmetric

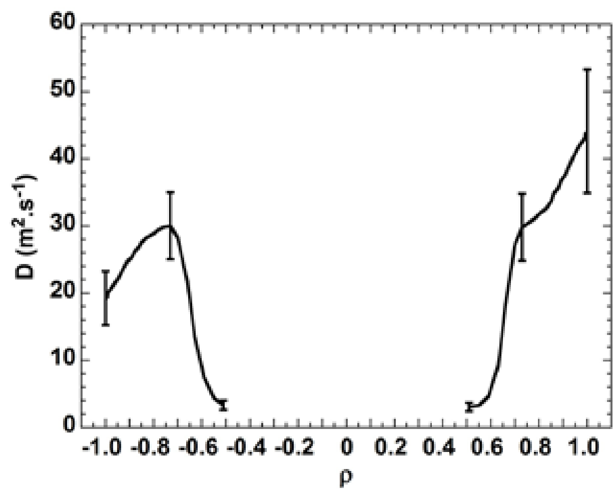

Figure A.1.1.4 Diffusion coefficient profile for high (-ve) and low (+ve) field sides of Aditya tokamak plasma nature in low and high field sides of Aditya tokamak plasma. These have been modelled using impurity transport code, STRAHL, with different diffusion coefficient profiles for low and high field sides. It shows steep increase from core to edge plasma for low field side (outboard) whereas in the case high field side (inboard) after an increase diffusion coefficient falls again at the edge of plasma as shown in the figure A.1.1.4. This nature of diffusion coefficient has been explained by the resistive ballooning and ion temperature gradient (ITG) driven turbulence transport. Detailed data analysis of Lithium coating experiment in Aditya tokamak was carried out and it revealed the increase in particle and energy confinement times, decrease in neutral oxygen emission, recycling of hydrogen and Zeff of plasma indicating overall improvement of plasma performation. Studies of VUV emission line from Fe XV at 41.7 nm indicates lower impurity content in core plasma. Monitoring of Li I spectral line using 0.5 m visible spectrometer showed the effect of Li coating sustains for 12 to 15 discharges in the Aditya tokamak. Improvement has been made in PMT based impurity monitoring system installing shutter in front of viewport which enables exact quantification of impurity behaviour in Aditya plasma. Regular operation of low resolution survey visible and VUV spectrometers brings out details behaviour of impurities emissions during various experiments, as for example, Ratio of intensities of two successive ionization stages of low ionized impurities shows remarkable modification during electrode bias experiment. Linux based centralized data server system has been developed to store and retrieve data from all spectrometer based systems operating on Aditya tokamak. This enables error-free access of data for the analysis by users connected through institute computer network. Vacuum system of Normal Incidence Monochromater (NIM) system has been upgraded using TMP based pumping system, this enable better vacuum and regular operation of NIM system during various experiment in Aditya tokamak.

A.1.2 Steady-state Superconducting Tokamak (SST-1)

A.1.2.1 Status of the Device

Systematic rigorous 'Engineering Validations' of the assembled and refurbished subsystems of SST-1 as an essential preparations towards the First Plasma was the primary focus of the SST-1 Mission since April 2012. The Engineering Validation spectrum of SST-1 comprised of experimental demonstration of the SST-1 cryostat volume as appropriate for cooling down the superconducting Toroidal and Poloidal Field Magnet systems, experimental demonstration of the leak tightness of the entire superconducting magnet circuits including the potential breakers and distribution manifolds under all operation conditions, experimental demonstration of the SST-1 vacuum vessel as an ultra-high vacuum system suitable for plasma discharges, experimental demonstration of the assembled SST-1 subsystems residing at 5 K and 80 K being compatible to thermal stresses arising during cooling down of the distributed system, experimental demonstration of the distributed baking of the assembled SST-1 vacuum vessel sectors and modules with acceptable thermal gradients, experimental demonstration of the assembled SST-1 80 K thermal shields having temperature uniformity within the nominal range of < 85 K within the parallel groups and absence of 'thermal runaway' and 'hot spots', cooling down of ~ 40 ton SST-1 superconducting magnet system in a controlled fashion using the SST-1 Helium Refrigerator and Liquefier maintaining a maximum thermal gradient of < 50 K avoiding 'thermal runaway' from 300 K till 5 K, experimental obtainment of the 'superconducting transition' of the assembled SST-1 Toroidal Field Magnet system and charging the SST-1 superconducting magnets system.

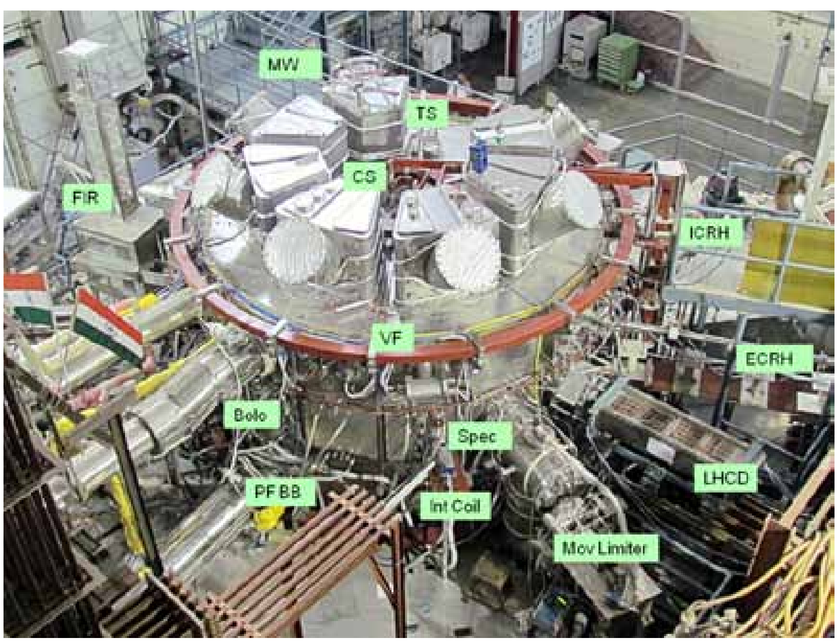

Figure A.1.2.1 SST-1 with auxiliary sub-systems as of March 2013

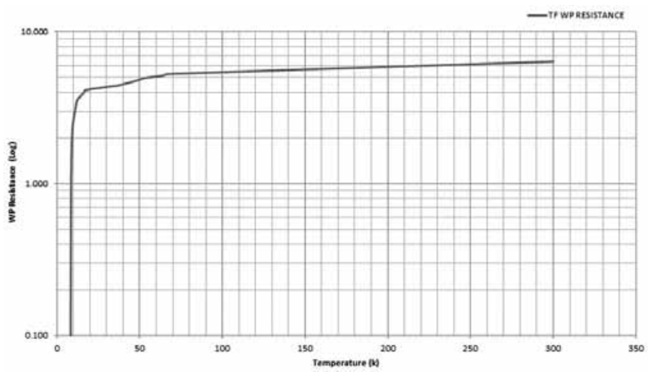

Figure A.1.2.2 Superconductivity in Toroidal Field coil system of SST-1

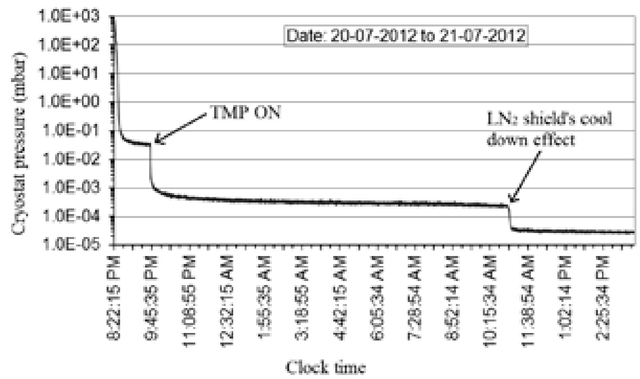

Figure A.1.2.3 Engineering validation of SST-1 Cryostat

All these engineering validations have been successfully carried out. The cryostat could be pumped down to 10^{-5} mbar, the vacuum vessel could be pumped down to higher orders of 10^{-7} mbar, the helium and nitrogen circuits could be shown leak tight to the sensitivities of the instruments, the thermal shields could be cooled down with a maximum temperature of 81 K, the vacuum vessel could be baked at 120 ^{o}C on continous basis, the magnet system could be successfully cooled down including the bus-bars to 5 K and made superconducting on Sep 27, 2012 after twenty nine days of cooling, the TF magnet system could also be charged up to 3600 A (1.1 T at the major axis of SST-1) demonstrating that SST-1 as a magnetic device is also rugged. SST-1 was also equipped with some essential first plasma diagnostics as well as Ion Cyclotron Resonance Heating (ICRH) and Electron Cyclotron Resonance Heating systems. After SST-1 was cooled down, in a finite toroidal magnetic field varying between 0.75 -1.1 T, some gas break-down was also attempted successfully after filling the SST-1 vessel with hydrogen gas through a 'Gas feed system' in the pressure range of 10^{-4}. Preliminary observations of gas break-down and toroidal spreading the gas was also observed indicating that plasma break-down confirmed from the H-aplha signals and some weak recombination observations. Next the plasma burn through and start up would possibly be achieved in subsequent campaigns. These campaigns have ensured the functionality of the microwave diagnostics, Reflectometry diagnostics, Electron Cyclotron resonance diagnostics, electro-magnetic probe diagnostics, Infra red imaging diagnostics, visible imaging diagnostics, spectroscopy diagnostics namely H-alpha, H-beta, carbon and oxygen lines etc along with their signal conditioning and front-end electronics. On the hardware front; the Ohmic system is now routinely operated in a remote manner from the SST-1 central control, the synchronized timing systems is fully functional along with the data acquisition systems. The operational systems of ECRH, ICRH and Lower Hybrid Current Drive (LHCD) have also been integrated with SST-1 central control and are operated remotely. 'Error Field measurements with internal loops', successful 'DC error compensation with VF and PF-4 magnets', 'experimental assessment of eddy currents in the vacuum vessel and cryostat', 'experimental assessment of preliminary NULL' etc were some of the significant physics experiments carried out till date.

A.1.2.2 Diagnostics Developments

Infra-red Thermography : Analysis code - algorithm has been developed for the SST-1 Infrared Imaging Video Bolometer (IRVB) system to analyse the raw data to be acquired from SST-1 tokamak and to estimate the total radiated power. Selection of diagnostic port, viewing location and accordingly engineering design for IRVB diagnostic has been done. Assembly, testing and calibration of the SST-1 Limiter Thermography has been done and then the diagnostics has been installed. DAQ testing of Infrared diagnostics has been performed.

Charge-Exchange Neutral Particle Analyser (NPA) diagnostics : Calibration of the Channel electron multiplier (CEM) detector (CEM 4816, Photonics) has been carried out using Deuterium Source (VUV source, model C710, ARC). Gain characteristic, dark count and the optimum operational pressure for the CEM has been worked out. Mechanical chopper has been tested for the desired rpm under UHV conditions. Discharges were tried in indigenously developed ion source (repeatability was an issue). The detector electronics (detector coupled with I-to-V converter for TOF NPA) has been developed and tested using current source. Calibrated ion source is required for testing the performance of the same in real time domain. Calibration and performance testing of detector module in pulse counting mode using H+ Ion Source has been done. Vacuum testing of assembled C-CXNPA will be done after ensuring the vacuum compatibility of various subsystems of the same. The C-CXNPA system thereafter will to be integrated with the SST-1 radial port #15.

Spectroscopy Diagnostics : To diagnose the first plasma in SST1 tokamak, optical fiber, interference filter and PMT detector based H-alpha, H-Beta, visible continuum and impurities monitoring system have been developed and integrated with SST1 tokamak. These systems are having capabilities to be operated and monitored remotely. Three channel broadband low resolution survey spectrometers in visible wavelength range have been installed and coupled with SST-1 using optical fiber for overall monitoring of impurity radiation from various toroidal locations of SST-1 tokamak during its operation.Conceptual design of CXRS system for SST-1 tokamak has been taken up during this year in collaboration with expert from DIII-D, Sun Diego, USA, keeping in mind to study the H-mode physics. For these purpose 40 views at the interaction area between NBI and plasma has been considered using 1 mm core diameter fiber. To achieve high temporal resolution (~5 ms) a high through-put spectrometer and sCMOS detector has been selected.

Silicon Drift Detector (SDD) spectrometer : This is a new diagnostics which is installed in Aditya Tokamak. This spectrometer works in soft X-ray region on the basis of multichannel analysis, measures continuum spectrum from bremsstrahlung and line emission. One can measure plasma temperature from the slope of the spectrum. If temperature is high enough one can see the impurity lines from Fe, Mo, etc. Limitation is that if the temperature and density are not high enough we may not have measurable photon emission. Once it works in Aditya, it will be installed in SST1 tokamak. The system is calibrated at laboratory with standard soft X-ray source as well as radioactive sources.

A.1.2.3 Heating and Current Drive Systems

Lower Hybrid Current Drive (LHCD) System

The site acceptance of both the recently procured klystrons (TH2103D) is carried out. The test bed prepared for site acceptance test using old klystron is used. New magnet and klystron is mounted on the test bed. The cooling, electrical and data acquisition and control connections are made. After initial conditionings (vacuum and filament), the klystron is conditioned with high voltage power supply. Once the klystron tube is conditioned for high voltage operation up to 65kV, it is operated in diode mode for more than 1000 seconds. Finally the tube is operated for an output rf power of 500 kW for period in access of 1000 seconds. The output rf power is measured by rf detectors and by calorimetric technique. Both the measurements confirm tubes operation at 500 kW rf power. The unspent energy which is dissipated in collector is also measured using calorimetric method and is well explained with given input electrical power. A robust and efficient thermal management system plays an important role in achieving the high power and long pulse operation successfully. In the above mentioned klystrons testing, at rated power for CW operation, the conventional high voltage DC power supply is used. After the successful testing of klystrons for CW operation it is configured with regulated high voltage DC power supply (RHVPS). For the first time, klystron is operated at full cathode voltage (65kV) with RHVPS for short pulses (typically about 300mS) as required by Aditya tokamak. The beam current obtained in these operations were around 17A. The klystron is operated successfully with the in-house developed klystron tank. The operation of two klystrons with a single modulator power supply is being tried out. The configuration of the klystrons and high voltage power supply is accordingly modified to operate both the klystrons with single anode modulator power supply. The resistance (~2.5 Ohm) which were earlier used in the tanks has been removed to reduce heat load on the klystron tank and avoid beam current imbalance. The current limiting resistor bank (~40 Ohm), included in the high voltage electrical circuit to limit the beam current, makes it safe to remove these resistors. The mock up assembly of in-vessel components is carried out. The support structure and assembly for LHCD in-vessel components is simulated. A frame is fabricated on which radial flange is mounted. Rectangular to circular transition is mounted on it. The Bellow is mounted on the transition. After tag welding the guides, on the in-vessel module, the module is introduced into the bellow. On the other end the in-vessel support structure is mounted with rails on support platform. The positioning and planarity of the in-vessel module front surface is measured with the theodolite, with respect to the flange plane as reference plane. Once the planarity is established final welding of the guide is done. The in-vessel module is moved +/- 40mm and again its position and planarity is measured and found to be within +/- 1mm. One of the critical issues is to align and connect both the out-vessel module and the in-vessel module to get good rf performance, since both are very large and heavy modules. A special technique, employing flange with appropriate jigs and fixtures together with dowel pins arrangement is used to align both the modules which yielded good rf results. The vacuum window is pumped with TMP and a vacuum of 2 X 10^{-8} mbar is obtained after baking the pumping system up to 160 ^{o}C. The window temperature was about 60 ^{o}C. Vac-seal is used to plug the minor leaks to improve the performance of the window. The seal is cured at about 100 ^{o}C over few hours. Further it is cured at room temperature for a week long period. The HLD measurements show leak rates better than 6 X 10^{-10} mbar-lit/sec. Further the window is being subjected to high pressure test (4 bar on air side and vacuum on the other side) and sniffed test for leaks in simulated operational conditions. The repaired leaks qualified these simulated experimental conditions and thus stringent QA & QC tests mandatory for SST-1 machine. The support structure inside the radial port for supporting, guiding and isolating the LHCD system is successfully installed. This demanded in-situ welding of supporting plates and mechanical fitting of ceramics and base plates. The radial port transition is successfully mounted on SST1 radial port number four. After qualifying its joints for UHV compatibility, the preparation for inserting in-vessel LHCD system is started. The bellow is inserted through the in-vessel module and fastened to in-vessel end flange. The grill antenna, vacuum window and in-vessel joints are successfully made using helicoflex seal. With systematic and uniform torque application, the system is integrated and made compatible for UHV application with leak rate of better than 6X10^{-10} mbar-lit/sec. The cooling lines are welded in-situ for active cooling of antenna and vacuum window. The cooling lines are qualified for pressurization up to 7 bar and UHV leak rates up to 6 X 10^{-10} mbar-lit/sec. Finally, the entire integrated module is lifted and inserted in radial port#4. Several special tools, jigs and fixtures are made for appropriate and easy integration of the LH system with machine. A typical lifting device for inserting assembled in-vessel module in to the SST-1 machine is shown in figure-A.1.2.4. After integration with the machine radial port, the integrated module is subjected to several qualification tests like pressurization, leak tests both in vacuum mode as well as in sniffing mode, in order to meet the QA & QC norms of SST1 machine. The probe-hat, housing multiple electric probes, on either side of the grill antenna is also installed and electrical connections are made employing multi-pin vacuum feed through. The integrated LHCD system as viewed from inside the machine is shown in figure-A.1.2.5. The activity related to connecting the layer-2 waveguides of LHCD system to the out-vessel module is initiated. Inter-connecting waveguides length is measured as per onsite requirement and given for fabrication. Also E-bends and H-bends required for the assembly are fabricated. Narrow waveguide-Transformer assemblies are kept ready for the integration work. The technical specification for 5 GHz. klystron systems is prepared and proposal of supply from competent vendor is in process. The development of data acquisition and control system based on PLC's and PXI has been initiated. The construction of new laboratory for LHCD Division is completed.

Figure A.1.2.4 The In-vessel module is lifted and inserted into the radial port using special lifting device with counter weight to balance the non-uniform load of IVM and avoid interference with vertical coils.

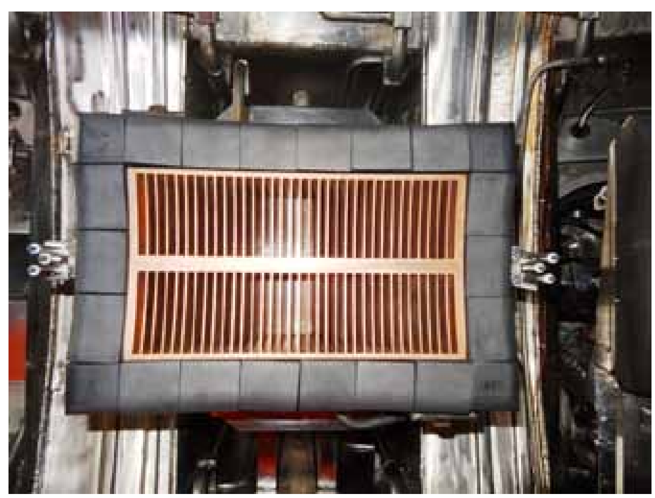

Figure A.1.2.5 Photograph shows the installed LHCD antenna system on SST-1 machine when viewed from inside the machine. The probe-hats housing electrical probes are also seen on either side of the antenna.

Electron Cyclotron Resonance Heating (ECRH) System

The 82.6GHz and 42GHz Electron Cyclotron Resonance Heating (ECRH) systems would be used in tokamaks SST-1 and Aditya to carry out various experiments related to ECRH assisted plasma breakdown and start-up at fundamental and second harmonic. The 82.6GHz Gyrotron system has been tested on dummy load for 200kW power for 1 second duration. The 42GHz-500kW ECRH system has been commissioned on tokamak SST-1 and Aditya. The major developments of ECRH system are follows:

High power test of 82.6GHz/0.2MW ECRH system with RHVPS : The 82.6GHz Gyrotron has been tested in pulsed condition for ~200kW power with pulse duration varies from 100ms to 1 second required for the breakdown experiments on SST1. The RHVPS (Regulated High Voltage Power Supply) is used to carry out the high power testing of Gyrotron in pulsed condition. The entire commissioning of 82.6GHz Gyrotron system for 200kW-1s operation is carried out on a pulsed dummy load. The new stable filament power supply (FPS) for 82.6GHz Gyrotron has been commissioned and Gyrotron is tested with this new power supply.

RHVPS for Gyrotron testing in pulsed condition : Prior to test the Gyrotron on dummy load with RHVPS, it is mandatory to qualify the power supply for its safe operation. The RHVPS (Regulated High Voltage Power Supply) has been commissioned using Ignitron crowbar system. The normal switch-off time of RHVPS is less than 5 microseconds. A 10-Joule wire test is also carried out successfully with RHVPS, which ensured safe operation of Gyrotron with RHVPS.

70kV Ignitron crowbar system : A two series ignitron based crowbar system has been developed, commissioned and operational with high voltage power supply system for Gyrotrons. The Ignitron crowbar system consists of two 50kV ignitrons (NL-37248) with suitable trigger modules. The high voltage capacitors and resistors are used for dynamic and static compensation of high voltage in the system. The Ignitron based crowbar system has been successfully tested up to -90kV for its performance. The switch-off time of high voltage with the crowbar system is ~5 microseconds; it includes total delay from sensor to field electronics to crowbar operation. The crowbar system has been tested successfully up to 90kV voltage.

42GHz / 0.5MW ECRH system for Tokamak SST-1 and Aditya : The 42GHz-500kW ECRH system has been commissioned on tokamak SST-1 and Aditya. Initially the Gyrotron is commissioned on dummy load and tested for its performance for its full parameters (500kW-500ms), after the successful testing of Gyrotron on dummy load, the ECRH system is commissioned on tokamak SST-1. Approximately 20 meter long transmission line laid to connect the gyrotron to tokamak. The transmission line consists of DC breaks, Mitrebend with bi-directional coupler, polarizer, circular corrugated waveguides, bellows and two waveguide switches. The first switch is connected between dummy load and transmission line for SST-1 tokamak. The second switch is connected at a junction point to SST-1 or Aditya. The 42GHz ECRH system has been commissioned successfully on Aditya tokamak also. The Gyrotron is placed in SST-1 and approximately ~55 meter long transmission line is laid to connect the system on Aditya tokamak. The 42GHz/500kW/500ms ECRH system is ready to carry out experiments on SST-1 and Aditya.

Composite Launcher for 82GHz and 42GHz ECRH systems on SST-1: A composite launcher consisting of four mirrors (two profiled and two plane), two gate valves and two vacuum barrier windows is developed for two ECRH systems (42GHz and 82.6GHz). The distance between plasma center and plane mirror is 900mm. The mirror size for 42GHz ECRH systems are 170mm X 240mm, the focal length of mirror for 42GHz system is 353mm. The mirror’s size for 82.6GHz launcher is 140mm X 200mm and focal length for mirror is 481mm. The beam size at plasma center for 42GHz launcher is 35mm (1/e beam radius) and for 82.6GHz it is 20mm. The complete launcher system with low power testing has been commissioned on tokamak SST-1.

Ion Cyclotron Resonance Heating (ICRH) System

This system is required on SST-1 for pre-ionization, current ramp-up, heating and wall conditioning in presence of toroidal magnetic field. The main transmission line gets divided into two transmission lines by hybrid coupler and is further divided into two more branches to have four antennas installed in the SST-1 vacuum vessel. The vacuum interface section isolates the machine vacuum from transmission line. The installation of the transmission line from wall to interface and installation of antenna boxes in the machine completed. The vacuum interface section is baked, right vacuum is produced with the help of turbo-molecular pump and then the antenna and interface sections of both the ports are con-

Figure A.1.2.6 70kV Ignitron Crowbar system

ditioned by introducing RF power from 20 kW to 150 kW in the form of short pulses and then long pulses to increase the power handling capacity. After conditioning both the lines, the hydrogen gas is introduced and gas breakdown is produced near antenna. Then the plasma is spread in the vacuum vessel by adding toroidal magnetic field. The variation of gas pressure, toroidal magnetic field from 1 kG to 1.1 T and RF power variation from 20 kW to 120 kW is done to successfully produce pre-ionization plasma in SST-1. Few attempts were also made to have current ramp-up in presence of Ohmic system at lower loop voltages.

42GHz, 200 kW DST Gyrotron Project : The institute is involved with the project of development of 200 kW, 42.5 GHz high power microwave device called gyrotron and also this institute is the end user of the gyrotron which has to be used for heating and start up experiments on tokamak Aditya and SST-1. CEERI, Pilani is the Nodal Agency of the project and other organizations involved with the project are IIT Roorkee, BHU Varanasi and SAMEER Mumbai. The main responsibility of this institute is to fabricate all magnets including super-conducting magnet, thermal design of the tube, all the components of the transmission line from gyrotron up to dummy load, all the required power supplies as well as the development of a test set up which includes data acquisition and control system, hard wired interlocks cooling system etc. All coils are designed, fabrication completed and testing is in progress. Thermal design of the gyrotron completed and the results are transferred to CEERI for the design of cooling system on gyrotron. All the power supplies are procured and the commissioning of main cathode high voltage power supply of 70 kV, 15 A is in progress. Data acquisition and control system is ordered and will soon arrive. All the components of the transmission line for the mode conversion from TYE-03 mode to HE-11 mode are being procured. Hard wired interlocks are finalized and is in the stage of circuit design. The actual water cooling system for gyrotron is designed and commissioned for gyrotron. The purchase procedure for solid state crow bar completed and soon factory acceptance tests will be done.

Neutral Beam Injection (NBI) Heating System

The positive hydrogen ion source, which is an important component of the neutral beam injector is currently being operated on the ‘NBI test stand’. These operations are being conducted for characterizing the performance of the ion source. It is well known that the extracted ion beam currents are diretly proportional to the discharge current (plasma density) in the plasma chamber of ion source. Experiments were carried out to enhance the discharge currents from its values obtained in earlier experiments. This was achieved by raising temperature of the filaments (hot cathode) of the plasma chamber. A set of new transformers (higher turn-ratio) were incorporated to increase the electric currents passing through the filaments. Discharge currents upto a maximum of 450 Amp (for 12 nos of filaments) was obtained). Also, the hydrogen gas feed system (to the plasma chamber) was modified to deliver higher throughput of hydrogen gas, in a pulsed mode. Ion beam extraction experiments were carried out on the test stand to study the role of the enhanced discharge currents on the extraction parameters. A schematic diagram of the NBI test stand is shown in figure A.1.2.7(a). A photograph of the extracted beam is shown in figure A.1.2.7 (b). The focussing effect in the beam could be seen clearly, this was possible due the improvements brought about in the operation parameters; for e.g. in discharge and gas feed. The beam energy and beam currents measured duringbeam extraction are shown in figure A.1.2.8. An analysis for the results above experi-

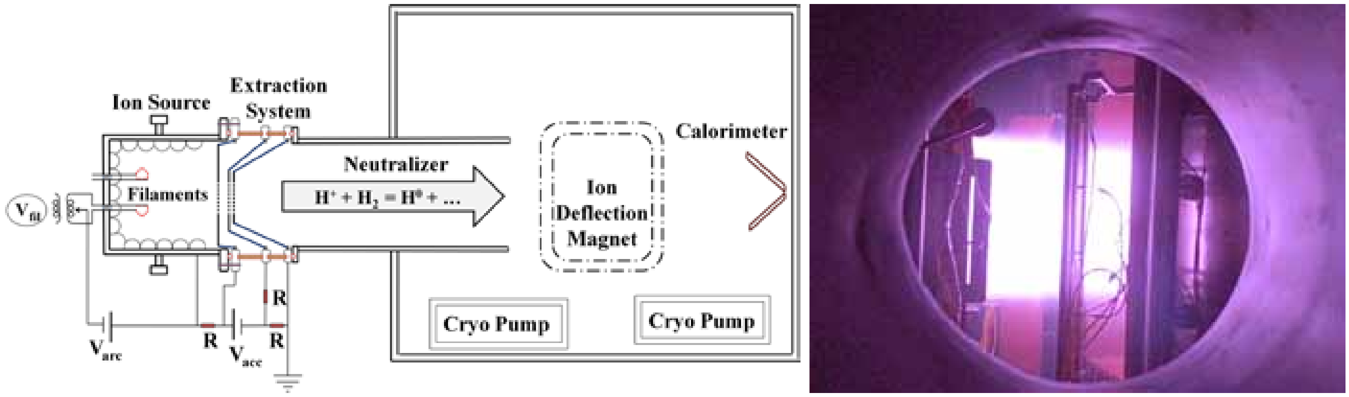

Figure A.1.2.7(a) Schematic of NBI test stand, (b) Extraction of ion beam of energy 25 KeV and current 8 Amp

ments revealed the need for certain modifications in the control logic. These modifications are being carried out for sake of improving the beam parameters. Two cryo-condensation pumps (operate with liquid helium at 4.2 K) each with pumping speed ~ 105 lit/sec have been installed in NBI's vacuum vessel. These pumps are required for extracting higher beam currents (> 20 Amp) and also for producing neutral beams. A newly fabricated He distribution system has been included in the cryopump assembly. Validation of the liquid nitrigen circuits (of this assembly) is completed. Presently this system is being prepared for achieving the required pumping of hydrogen by the process of cryocondensation. In the upcoming operations, the ion beam extraction shall be carried out in combination with cryopumps for producing beam currents > 20 Amp. Under the new five year plan the group has undertaken the project for developing a diagnostic neutral beam based on a multi-slit grid ion source. Conceptual design of the ion source has now begun. This was carried out for the plasma box of the multi-slit grid ion source. A 3D particle orbit simulation was conducted to optimize electron confinement in the magnetic multi-cusp geometry of the plasma box.. The optimization is done so as to produce a low (< 20 G) and uniform magnetic field along the plane of ion beam extraction. This type of magnetic field profile can ensure an isotropic plasma density along the plane of ion beam extraction.

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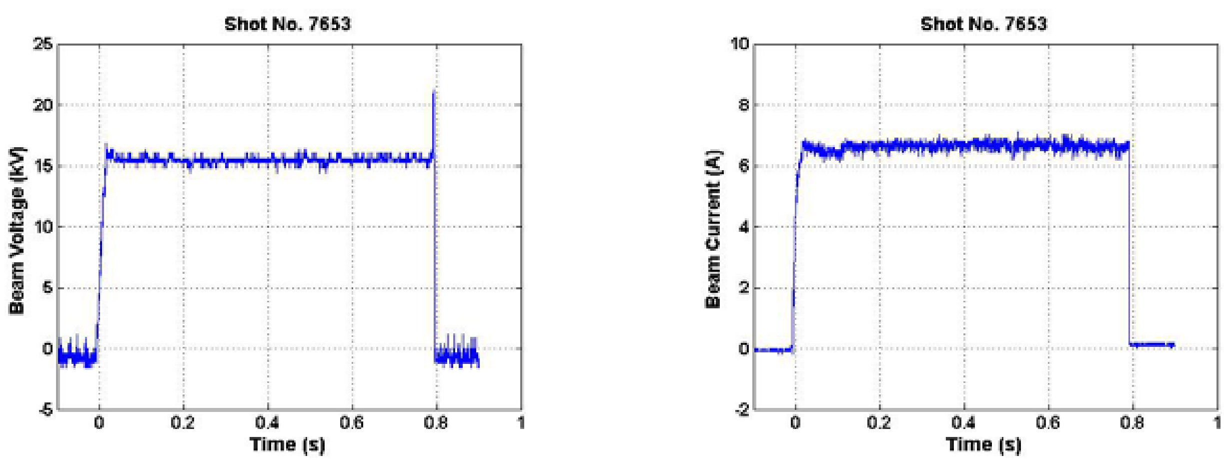

Figure A.1.2.8 (a) H+ beam energy (15 KeV), (b) beam current (~7 Amp) during a typical beam extraction. The pulse length was ~ 0.8 sec.

A.2 Fusion Technologies Development

Under Continuing five year plans, various technologies related to fusion are being developed under the following heads :

Brief details about the progress made in the report period is given in this section.

A.2.1. Magnet Technology

Development of facilities towards the characterization of fusion grade technical superconductors as well as facility development has been the primary focus of `Magnet Technology Development Division' since April 2012. In this duration, a scaled down winding pack comprising of a double pancake having four turns have been wound using the `Special Purpose Winding Machine' (SPWM) with 30000 A NbTi/Cu based cable-in-conduit-conductor (CICC) as the base conductor. The CICC was indigenously developed in association with Indian industries and Atomic Fuels Division at BARC and is 30 mm X 30 mm in cross section. This SPWM was developed as a joint initiative with Indian industry after several technology trials. The winding pack replicating a large fusion relevant Toroidal Field magnet has been since then consolidated, resin and fibre insulated and cured and has been encased inside a casing. The finished scaled down magnet presently ready for functional tests that include pressure drop, friction factor, superconductivity and current carrying ability tests at low temperatures in a test cryostat. Precision magnets of high homogenous category appropriate for gyrotron applications has also been developed successfully along with a low loss cryostat around it for the first time in the country in association with an Indian industry. This system is also now ready for functional tests both at room temperature as well as at lower temperature. Magnet suitable to be used as 'Edge Localized Mode' (ELM) suppression coils have also been taken up with potential applications for Tokamaks such as that for upgraded SST-1 and Joint European Torus (JET). High temperature insulations appropriate for operations in temperature ranges up to 350 ^{o}C have also been successfully developed and characterized in laboratory. The large scale impregnation processes optimisations are presently underway. These insulation technologies would also be suitable for in-vessel magnets of SST-1. In parallel, radiation resistant insulation systems involving cyanate esters and epoxies have also been developed for large magnet insulations. High strength conduit materials have also been developed in laboratory scale during this period in association with associates. A module of a 30000 A DC power supply has been tested successfully. With the power supply being available, the above scaled down magnet can be tested. A 10 T facility has been made operational with variable temperature inserts for quick and reliable tests of NbTi and Nb_3Sn strands as a part of the facility development. This facility is now routinely used for strands characterization. Presently, a long length of Nb_3Sn based CICC is being fabricated which will be heat treated in a custom designed and fabricated Heat Treatment Facility.

This Heat Treatment facility has also been developed with an Indian industry. Low temperature experiments with currents would be carried out next.

A.2.2. Divertor and First Wall Technology

Introduction: This programme deals with research and development of the materials & technologies relevant to divertors and firstwall components for fusion grade tokamaks. During the period the division continued its efforts in developing materials and technologies and establishing new test facilities. Major activities of the division include establishing a new high heat flux test facility using high power electron beam as heat source and large D-shaped vacuum chamber, procurement of high pressure high temperature water and helium coolant loops, ultrasonic-flaw detection of materials and test mock-ups, fabrication of ITER-like divertor cassette body and support structures for vertical targets and dome, developing fabrication technologies for divertor targets and dome targets, development of new tungsten based materials and their characterization, high heat flux testing of test mock-ups, procurement of abrasive water-jet cutting machine. The synopsis of the work done during the report period is as follows :

Divertor Cassette Body Development: Fabrication of ITER-like Divertor Cassette Body and support structures for vertical targets and dome is one of the major activities of the division. Public tender for fabrication is published in the newspapers. Technical bid of quotations submitted by fabricators are being evaluated.

Divertor target development : Tungsten alloy mono-block test mock-ups with copper-alloy tube having 500mm radius of curvature are developed by NFTDC (Hyderabad) using hot radial pressure bonding technique. Material joint interfaces between Tungsten alloy, OFHC Copper (casted interlayer) and Copper alloy tube are tested using high resolution ultrasonic flaw detection system with ultrasonic probe inside the copper alloy tube. Quantification to know percentage area of the joint indicates that overall good quality joints are obtained with minimal defects.

Copper deposition on Carbon-Fibre-Composite (CFC) material : Development of technique to deposit copper on CFC material for attachment with the copper alloy heat-sink is in progress at M/s Magod Laser (Bangalore) using Laser-Cladding technique. Titanium coating on laser textured surface of CFC. Casting of OFHC copper on titanium coated surface is in progress.

Studies on Tungsten Materials Development : Dense pure tungsten material with fine microstructure has been synthesised by plasma assisted microwave heating of tungsten powders. The X-ray diffractograms confirms the BCC crystal structure and Scanning Electron Microscopy revealed the fine microstructure of processed sample. Relative density of tungsten material is reached 91% of the theoretical density. Functionally graded tungsten-copper bimetallic compacts with fine microstructure, good mechanical properties have been synthesised by microwave heating of tungsten and copper powders. Scanning Electron Microscopy, Energy Dispersive X-ray Analysis and Vicker's Micro-Hardenss Test across sample revealed the graded structure of the synthesised samples. Efforts are also being made to study irradiation damage to tungsten materials by simulating the damage using high energy ion beams.

1D W/Cu FGM simulation studies : Present work investigates the effects of the W/Cu Functionally Graded Material (FGM) introduced between Tungsten and Copper interface using finite element method. A representative model problem is formulated to observe different thermal stress characteristics for different compositions of Functionally Graded Material (FGM). Initially a Thermal stress analysis of the model without Functionally Graded Material (FGM) has been performed. A series of Thermal stress simulations (iterations) have been carried out with the introduction of different grades of Functionally Graded Material (FGM) by progressively varying W/Cu compositions

Materials Studies Using Miniature Specimen Techniques : Small specimen test techniques employ small volumes of test material for evaluating the mechanical properties and are very useful in situations where conventional mechanical tests are practically not possible. Two small specimen test techniques viz. (1) Ball indentation and (2) Small Punch Tests, have been employed to evaluate the mechanical properties of tungsten plate procured from PLANSEE. True stress - plastic strain curve is determined from the ball-indentation load-depth data using well established analytical formulations. The ultimate tensile strength and strain hardening exponent for tungsten material is found to be 1282 MPa and 0.11 respectively. Ductile-To-Brittle-Transition-Temperature (DBTT), estimated by employing small punch test, is found to be 4950^{o}C.

Development of high heat flux test facility using electron beam system : High Power Electron Beam System : High power electron beam source capable of producing cylindrical electron beam of 200kW/45kV (in pulsed as well as steady-state mode of operation) has been delivered. The beam will soon be integrated with the vacuum chamber & target handling facility for testing of materials and components.

Data Acquisition and Control System : Quotations received for supply of the data acquisition and control system for the high heat flux test facility are presently being discussed. The Major Component of Data Acquisition and Control System are: Main control & interface; PLC based sequential operation with Safety Interlock; PXI base Real time control loop, fast Acquisition and On line monitoring ; Fast Interlocks and Slow interlocks; Human Machine Interface; PXI based console for the operator; Data Server for Storage, Analysis &andArchival.

Development of Simulator Software for High heat flux test facility : The objective of this software developmental work is to provide a technological bridge to demonstrate plug for useful I&C integration technologies at one end and high level scientific computations at other end. The high heat flux test facility employs the diverse field of emerging engineering and technologies with multiple operation and control scenarios. The application level I&C integration R&D is under development using EPICS control framework. The simulation model of high pressure high temperature water cooling system using "Python" is currently under development. This project is under progress with a M.Tech project student funded by National Fusion Program.

Collaborative Work Repository Development : A collaborative work repository development project is initiated to address the concurrent and location independent code and document development among various labs of the division. A test setup is created, technologies evaluated at client and server end and various use cases are tested.

Setup of Control Room for HHF test facility : The necessary control room setup arrangements like development stations, software installation and configuration, furniture, network to facilitate operation and control lab development have been initiated.

Diagnostic and Calibration System : Calibration facilities for various instruments/ equipment are being set-up at IPR. Contract is signed for procurement of a high temperature Cavity Blackbody for calibration of non-contact type infrared thermal sensing equipment such as IR-Pyrometer and IR-Camera. The facility will allow calibration in temperature range of 600 ^{o}C to 3000 ^{o}C.

High Pressure High Temperature Water Circulation System : Tender document for procurement of high pressure high temperature water circulation system is finalized. For high heat flux testing of plasma facing components/test mock-ups, the system will provide coolant water to test mock-ups or components with pressure 5bar to 60 bar, temperature 25 ^{o}C to 160 ^{o}C and maximum flow rate 300 lpm.

High Pressure High Temperature Helium Circulation System : Future Divertor concepts for fusion power plants envisage the use of gas coolants, primarily Helium gas. Efforts are made to establish a unique closed loop Helium Gas circulation system capable of supplying Helium gas at high pressure (~ 100bar) and high temperature (~ 700 ^{o}C) with flow-rate (~ 200 g/s). Quotation submitted by a party against the public tender notice published in the newspapers is evaluated and found to be technically acceptable. After opening the price-bid, the procurement process is postponed due to budget constraints.

Vacuum Chamber and Target Handling Facility : Large D-shaped vacuum chamber with target-handling facility is fabricated by M/s Vacuum Techniques (Bangalore). The chamber has been delivered to IPR and it will be installed soon. CFD simulation of cooling channels of HHF chamber has been carried out in FLUENT. Line pressure of 1.5bar in the cooling channel with incident heat flux of 18,800W/m^2 applied at the inner walls.

Brazing Studies and Brazing Experiments : Small scale curved macro-brush made of tungsten tiles brazed on to curved copper alloy substrate is developed using brazing technique. Fixture development for brazing is a major task in the curved macro-brush development. Fabrication of Curve Dome in Small scale using vacuum Brazing considered the followings: (1) Identification of materials such as Tungsten tiles, CuCrZr block, Brazing Fillers etc.; (2) Design of Curve Small Scale Dome; (3) Design & Fabrication of Casting Fixture; (4) Design & Fabrication of Curve Brazing Fixture; (5) Machining, Grinding/Polishing and Cleaning of tiles and Cu alloy block; (6) Development of Casting Cycle for W/OFHC Cu tiles; (7) Development of Brazing Cycle for W/OFHC Copper/NiCuMn-37/CuCrZr; (8) NDT such as Ultrasonic Inspection of W/NiCuMn-37/CuCrZr 37 brazed joints.

Tungsten Coating Technology Development : Present work is done at ARCI (Hyderabad) to carry out feasibility study to develop the tungsten coating technology for first wall application in ITER like tokamak. Attempts are made to coat pure tungsten powder material having average particle size

(APS) 6µm to 10µm, 10 µm to 20 µm on substrates like stainless steel of grade SS304 (structural material) by using Atmospheric Plasma Spray coating technique. Tungsten coated samples are been characterize by SEM & EDAX analysis, Average coating thickness of tungsten coating is achieved up to 60 micron. Further collaborative work is being planned for development of the technology of tungsten coating for first wall application.

Material Test Facilities : Two important material test facilities are installed viz. (1) Gleeble-3800 thermo-mechancal simulator system manufactured by M/s Dynamic Systems Inc. (USA) and (2) Flashline FL-5000 Thermal Properties Analyzer manufactured by M/s TA Instruments (formerly M/s Anter Corporation) USA. Gleeble-3800 system can be used for material testing (Hot Tensile Testing, Hot Compression Testing, Thermal & Thermal-Mechanical Fatigue Testing, Creep Testing, Dilatometry/ phase Transformation studies, Stress Relaxation studies, etc.) as well as material process simulations (Hot rolling, Forging, Continuous Casting, Weld HAZ cycles, Heat Treatment, Diffusion bonding, Powder Metallurgy/Sintering etc.). Flashline FL-5000 thermal properties analyzer is a Laser Flash System capable of measuring thermal diffusivity and specific heat measurements up to 210^0C.

Highlights of Experimental Work done so far using Gleeble 3800 system :

•Achieved heating rate of 10,500 ^{o}C/sec on CS 1018 material specimen having diameter of 6mm.

•Achieved highest temperature of 2300^{o}C on 6mm diameter Molybdenum sample.

•Maximum cooling rate of 3100 ^{o}C/sec has been achieved using water quenching system.

•Hot compression tests at strain rate of 0.001, 0.01, 0.1, 1, 10, 50 and 100 have been performed successfully on D9I material.

•Hot tension tests have been performed at minimum stroke rate of 0.01mm/sec and maximum stroke rate of 100mm/sec.

•Dilatometry study has been done on CS 1018 material for cooling rates 1 ^{o}C/sec, 2 ^{o}C/sec, 10 ^{o}C/sec, 20 ^{o}C/sec and 100 ^{o}C/sec.

Precision Material Cutting : Contract is signed for procurement of Abrasive CNC Water-Jet Cutting Machine that can be used for precision cutting of various materials including Tungsten, CFC (Carbon Fibre Composite), Stainless Steels, etc. This machine allows precision cutting at room temperature with minimum wastage and near-net finish.

Thermal Hydraulic simulations on Helium gas cooled heat-exchangers : Computational Fluid Dynamics (CFD) software – Star CCM+ - is used for flow simulation of Helium gas in a conceptual geometry that uses jet impingement technique. The simulation results are found to be in good agreement when cross-checked with the published literature. Collaborative work with BARC has also been initiated for thermal-hydraulic simulations, fabrication and testing of a scaled down mock up.

Engineering Analysis of ITER-like Divertor : Engineering analysis of the ITER-like divertor is in progress. It includes: (a) Computational Fluid Dynamic Analysis to estimate the coolant pressure drop and heat transfer coefficients; (b) Electromagnetic analysis to estimate the eddy current and structural loads induced during off normal events; (c) Thermal-Structural coupled analysis to compute stresses on various parts of Divertor as a result of various thermal and structural loads. Ansys Emag is currently used for performing electromagnetic analysis. Benchmarking of a simplified problem is currently in progress.

Security Systems : Security system is a basic necessity for any laboratory. Different types of security systems are procured and installed in the labs including CCTV monitoring systems, Pan Tilt Zoom Camera with Digital Video Recorder and Bio-metric Access Control Systems at entrance of the laboratories.

CFD Software : Star CCM+ is Computational Fluid Dynamics (CFD) software. Star CCM+ software with CAD exchange capability has been successfully installed on HP Z800 workstation having 6Core processor and 24GB of RAM. It is extensively used in a wide range of applications that requires modeling of flow of fluids and gases. The software is being used for simulation of Water cooled and Helium gas cooled divertors.

Thermal Diffusivity Measurements : Thermal diffusivity and thermal conductivity measurements of tungsten materials procured from international manufacturers as well as the materials under development have been carried out at elevated temperatures up to 1000C using Laser flash thermal diffusivity measurement system.

Ultrasonic Testing Simulation : CIVA UT Simulation software is used to study the effects of beam focusing at W/Cu interface of tungsten mono-block and also to distinguish the response caused by defect and interface signal. 3D Model of

W/Cu Mono-block with 0.5mm of Reference Flat Bottom Hole (FBH) at W/Cu interface is made for the simulation. Ultrasonic Phase Reversal techniques have been simulated in order to distinguish the response cause by defect and interface signal. Studies on ability to detect the smallest defect in W/Cu mono-block are also simulated by catching 0.5mm FBH (Flat Bottom Hole) at W/Cu interface. The optimized parameters obtained by the CIVA Simulations have been employed in actual experimental inspection for W/Cu mono-block.

A.2.3. Cryo-pump and Pellet Injector

Studies Carried out on Established Facility for Adsorption Studies (FADS) down to 4.5K : Choice of right sorbent (high adsorption) and the right adhesive (high thermal conductivity) with standing thermal cycling decides the attainable pumping speed and endurance requirement for a Cryopump. An experimental system was set up to measure the adsorption characteristics of porous materials under cryogenic temperatures (4 K to 100 K).

Establishing In-house facility for Development of high sorption sorbent : Micro-porus activated carbonaceous compound sorbents are suitable for adsorbing helium and hydrogen isotopes. Under this sub project coconut shell charcoal (granular size), activated carbon spheres, activated carbon cloth (woven and nonwoven fabric) like sorbents were developed. The sorbents developed were with the surface area ranging from 1200 -2000 square meters per gm.

Out-Gassing Measurement System (OGMS) : Not much information exists in literature with respect to outgassing rates for typical sorbents and their combination with metal substrate. Reported literature gives outgassing rate of standard materials but at times not at the relevant temperature required. Hence a system was setup to measure the outgassing rate of developed sorbents. Operating principal of this system is based on the technique to measure differential pressure across known conductance of orifice.

Figure A.2.3.1 Out-Gassing Measurement system

De-Gassing Measurement System (DGMS) : Degassing measurement of the developed sample is required to estimate the amount of adsorption capacity. Experimental set up was made to provide accurate and sensitive measurements of weight change. It gives microgram sensitivity, for a sample exposed to controlled environmental conditions over an extended period of time. The system operates at vacuum levels (10^{-4} mbar) and measures changes in sample weight at elevated temperatures and also at reduced pressure. Its furnace with control unit enables the sample to be heated to predetermined temperatures (upto 1000 ^{o}C) with an attachment suspending it in a hot furnace.

Establishing Facility for Cryogenic Surface Study: Cryopump contains an adsorbing surface of 4 Kelvin on which charcoal is coated with the adhesive. The characteristic of different types of adhesive and charcoal combination needs to be studied. Crack study at low temperature for different samples (different adhesive and charcoal combinations) were carried out. After thermal cycling from 300K to 4K the conditions of the samples were observed from SEM and optical images taken before and after the experiment.

Development of Cryopanels : Cryopanel forms the heart of Cryopump. Development of the Cryopump targeted using cryopanels at 4K which acts as absorber for reactor relevant gases surrounded by shields and baffles at 80 K. Hydrofor-

Figure A.2.3.2 Developed Hydro-formed Cryopanels med cryopanels give efficient and uniform cooling. Thus technology to develop such panels also formed an important part of the project. The panels carry cryogen at 4K and 80K flowing at high pressures, undergo a number of thermal cycles and expected to exhibit complete leak tightness in Ultra High Vacuum. Task of indigenously developing the fabrication technology for hydroformed panels was taken up addressing all technological barriers. Various types of panels for different shapes conical, cylindrical, truncated etc. were fabricated and tested for the application of cryogenic radiation shielding and are categorized as (a) Bubbled Panels; (b) Embossed Panels; (c) Single embossed panel.

Development of Cryocooler Based Single Pellet INjector System (SPINS) : High speed hydrogen pellet injection technique provides the deep fueling of hydrogen particle in plasma core of a magnetically confined fusion devices. The technology to achieve efficient pellet injection has been demonstrated with SPINS. Hydrogen pellet is formed inside a barrel by "In Situ" technique with use of GM cycle based cryo-cooler. This injector is able to form a pellet up to 3.6 mm in Dia. (Max.) and 4 to 8 mm in length cylindrical solid hydrogen pellet at 7–8 K temperature. Pellets are dislodged and accelerated in pre-vacuumed guiding tube with high pressure helium gas injection through fast opening solenoid valve. Photodiodes provide signals for pellet speed determination under vacuum and the measured velocity of pellet is obtained up to 600 m/sec. Cryocooler, pellet former design and optimization of hydrogen fuel parameters are the most important parameter which extensively effect on the performance of the SPINS.

A.2.4. Test Blanket Module (TBM)

Background : The Indian TBM program is focusing on the development of Lead-Lithium cooled Ceramic Breeder (LLCB) (half-port size) which has the characteristics of both Solid Breeder and Liquid breeder blanket concepts. The Research and development oriented towards this concept covers major technologies development required for the future DEMO blanket. This blanket module will be tested in the ITER Radial Port no-2, the interface requirements between the TBM and the ITER machine are being worked out jointly with ITER organization, Cadarache France. The scientists and engineers from BARC, Mumbai and IGCAR Kalpakkam are actively involved in the design and development of the TBMs and the associated technologies such as, Fusion Neutronics, Fusion Engineering Design, Safety, Liquid metal

Figure A.2.3.3 Single Pellet INjector System (SPINS) technologies, Thermofluid MHD, Lithium Ceramics, Beryllium pebbles, Structural Materials, Fabrication Technologies for the TBM programme. In this regard, Memorandum of Understanding between IPR-BARC and IPR-IGCAR has been signed between the institute directors for development of nuclear technologies required for TBM delivery to ITER. For each area of development tasks and subtasks has been identified and the corresponding teams has been identified at both the centers. IPR scientists and engineers jointly working with the experts for the technologies development.

Synopsis of Work : In continuation of LLCB TBM design activities, neutronic performance of various variants of LLCB TBM design has been examined. For the parallel flow of Lead-Lithium the thickness of Ceramic Breeder (CB) zones were varied in order to get the optimal temperature distributions in CB zones. The reference ITER neutronic model Alite was used and LLCB TBM was placed at the equatorial midplane. Neutron flux, Nuclear heating and Tritium Production rate profiles were calculated for LLCB. A 1.2 meter thick shield block was placed at the back of LLCB TBM. Several geometry configurations of shield block such as homogeneous mixture, plate configuration including pipes were analysed and neutron flux and nuclear heating profiles were calculated. Indian Lead Lithium Ceramic Breeder (LLCB) TBM has both the features of solid breeder and liquid breeder blankets. Design of LLCB TBM is in progress. Different variants and their structural, thermal-hydraulic, flow analyses are being carried out. LLCB test blanket system consists of LLCB TBM and the shield block as shown in the Figure A.2.4.1. Neutronic safety analysis was carried out for the ITER safety report document. Cell averaged fluxes were estimated in all the zones of LLCB, such as Lead-Lithium, Ceramic Breeders, First wall, top plate, bottom plate side plates and TBM shield Module. The activation responses were calculated using the cell averaged fluxes and EASY-2007 code system for various ITER irradiation scenarios. Total Activation, Decay-Heat and Contact dose rates in Lead-Lithium, Ceramic Breeder, FMS structure and TBM Shield Module were calculated at various cooling times. The list of radio nuclides activity and Bq/A2 values for all the TBS materials along with Dose Rate from first wall were prepared as per the CEA, France guideline. Activation data was used to estimate the activity in components of the TBS. Several nuclear measurement diagnostics will be used in the LLCB TBM for the measurement of Tritium Production Rate, Neutron flux etc. It is important that the measurements are done at locations in the TBM where the nuclear responses have smooth profile and they do not vary with distance. Suitable neutronic model of LLCB TBM was constructed and nuclear responses in fine intervals were calculated and analysed for the appropriate locations of the diagnostics. In ITER equatorial port no.2, India will test Lead Lithium cooled Ceramic Breeder (LLCB) blanket concept along with Chinese Helium Cooled Solid Breeder (HCSB) blanket concept. TBMs will be placed vertically in port. Both TBM sets (TBM + associated shield Module) and port frame made of SS and water is integrated in TBM port plug. To ensure the maintenance criteria of dose rate in TBM port no. 2 at port extension area the shield assessment has to be carried out. According to ITER shield design limits, dose rate should not exceed 100μSv/hour 12 day after shutdown of ITER in port extension (maintenance) area. In present work, some issues related to inadequate shielding capability and possible solutions for improvements were addressed. The dose rate calculations were performed using direct one step method integrated with MCNP5. The analyses show that poor shielding at maintenance region of port is mainly due to lateral gaps between TBM sets and TBM Port frame and between Port frame and vacuum vessel extensions. The relative effects of these two gaps have been quantified. Some possible solutions for blocking the direct neutron streaming path i.e. doglegs in the frame design and mid stoppers in port plug lateral gaps are also examined and results show the improvements in shielding capability of TBM port. The dose rate at pipe forest maintenance area after blocking the all lateral gaps is 84 μSv/hr; while, in presence of all lateral gaps dose rate is around 156 times higher. The shielding were improved by making dogleg and mid stopper in TBM Port (case-6), in this case dose rate in pipe forest maintenance area is around 262 μSv/hr. Ceramic pebble development section is involved with the development of the Li_2TiO_3 tritium breeding material. The powder of Li_2TiO_3 is being prepared at IPR, from this powder Li_2TiO_3 pellets and pebbles are prepared followed by high temperature sintering. At every stage (powder, pellet and pebble preparation) extensive characterizations are also being carried out to meet the desired properties. Several instruments have been procured to set up the Li_2TiO_3 characterizations facility lab at IPR. Few of them have been installed and their training also have been conducted. The experimental setup for measurement of effective thermal conductivity of Li_2TiO_3 pebble bed has been built as shown in the figure A.2.4.2. The design of this setup and var-

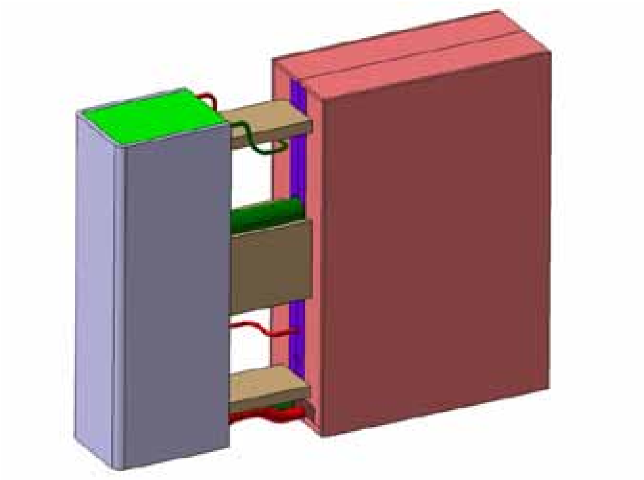

Figure A.2.4.1 Schematic of Indian Lead Lithium Ceramic Breeder (LLCB) Test Blanket Module (TBM)

ious components of this test facility like fabrication of the various reference blocks, components, were carried out. A liquid metal loop (Figure A.2.4.3) has been designed, fabricated and commissioned at IPR for testing and calibrating liquid metal diagnostics. Presently, pressure sensor and flow meter are being tested in the loop. Another loop is being designed for testing the performance of purification system for

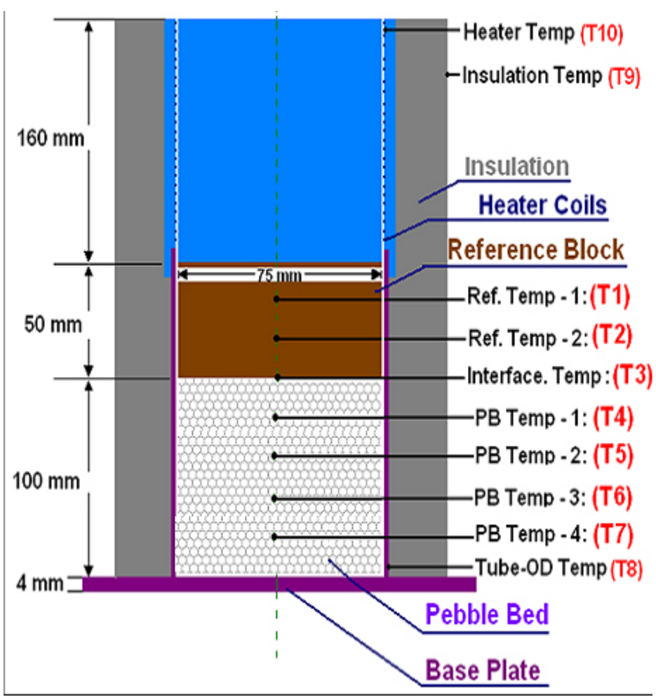

Figure A.2.4.2. Indigenously developed thermal Conductivity measurement for pebble bed

Figure A.2.4.3. Lead-Lithium loop for testing loop diagnostics

Lead-Lithium, namely the cold trap and magnetic trap. An electromagnet of ~ 1.4 T with the pole area of ~1000X400 mm^2 and pole gap of ~390 mm is presently under development for liquid metal MHD experimental studies. The MHD loop is currently under design at IPR. Significant progress has been made in 3D MHD computer code development. Presently the code is being used to benchmark liquid metal MHD experimental data. The up gradation of the code is also being made. An electromagnetic stirrer has been delivered to IPR for development of large scale (~75 kg per melt) Pb-Li eutectic alloy production system. The conceptual design for the complete alloy production set up is being performed. Efforts are also being made to develop oxygen sensor for Pb-Li liquid metal. Helium cooling system for IN LLCB TBM has been designed and its procurement plan is under progress. As an R&D program, an experimental helium cooling loop (EHCL) having similar operating parameters with small scale (0.4 kg/sec) design has been completed in IPR. The tender specifications are being worked out for procurement. The EHCL will be used to test the TBM mock-ups for its heat extraction efficiency and heat transfer performance. The development of structural material for the TBM which is facing the plasma is one of the challenges to realize the fusion power plant. The material shall satisfy the requirements of acceptable mechanical properties at high temperatures, low ductile to brittle transition temperature, corrosion resistance, compatibility with breeding materials, low residual activation and adequate resistance to neutron irradiation under ITER service conditions. The TBM Division of the institute, has signed a MoU with Metallurgy and Material Science Group of Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam for the indigenous development of structural material and setting up of required experimental facilities for the ITER fusion reactor project at IGCAR as well as at IPR. Extensive characterization of impact, tensile, creep, low cycle fatigue and thermo mechanical fatigue properties have been carried out to qualify the material, generate the design curves and model the mechanical behaviour. India specific reduced activation ferritic martensitic (IN-RAFM) steel has been developed from these extensive studies of mechanical properties. Materials modelling study is being carried out to study the atomic phenomenon occurring inside steel. Material modelling is helpful for simulation of irradiation which is difficult to obtain with experimental analysis. The structural material development and materials modelling section is responsible for the overall co-ordination of all the above mentioned R&D activities being carried out at various institutes and the activities at IGCAR, Kalpakkam, through its members who are working on these activities along with colleagues from IGCAR and BARC. The section is responsible for design database generation for IN_RAFM, new material development and mechanical behaviour modelling. Material selection and fabrication procedures selected for TBM shall be in conformance with the material specifications and fabrication practices approved for ITER components. As per ITER requirements, in the first wall that directly faces the fusion plasma, no welds are allowed. Further, it is emphasized that the weld zone (which includes weld metal and heat affected zone) shall be minimum in the components in order to minimize distortion during fabrication and embrittlement of the weld zone under irradiation. Accordingly, for fabrication of first wall of TBM, which directly faces the fusion plasma, diffusion bonding using Hot Isostaic Pressing has been chosen. Welding processes that are being considered for fabrication of other TBM components are electron beam welding (EBW), laser and laser hybrid welding (LW & LHW), and narrow gap tungsten inert gas (NG - TIG) welding. These welding processes produce narrow weld zones of very high quality. Institute for Plasma Research (IPR), through TBM Division, and Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam have taken initiative to develop these technologies indigenously in collaboration with various institutes in India such as Defence Metallurgical & Research Laboratory (DMRL), Hyderabad for diffusion bonding by HIP process to produce plate with internal channels as required for the first wall of TBM, Defence Research & Development Laboratory (DRDL), Hyderabad for optimizing procedures for EB welding of RAFM steels and dissimilar welds between austenitic stainless steels and RAFM steel and International Advanced Research Centre for Powder Metallurgy and New Materials (ARCI), Hyderabad for LW & LHW of RAFM steel. Filler wire development for RAFM steel and consumable qualification of filler wire is under progress at IGCAR. IGCAR is also working towards the development of non-destructive examination and testing procedures for the fabricated components. NDE of TBM components requires special techniques to be developed due to the complex geometry of TBMs. As the TBM components are made of ferritic steel, ultrasonic based NDE techniques are most suitable. To this end, phased array based ultrasonic techniques was conceived to be useful for the inspection of TBM welds. In this context, a simulated box structure of stainless steel, serving as a mock-up to resemble the reduced activation ferritic martensitic (RAFM) steel channels in the TBM first wall structure, was fabricated by electron beam welding using 6 mm thick plates. In the weld region of the box structure, notches having depths of 10 %, 5 % and 2.5 % of wall thickness were fabricated at both outer side and inner side of the box structure. Phased array utilizing 16 elements transducer of frequency 10 MHz was used at an angle of 55º to scan the weld zone of the box structure. It was observed that both ID and OD notches were detected with good sensitivity. However, the sensitivity showed a dependence on distance between the transducer and the weld bead. Towards this, optimization of the scan distance between the weld centre and the phased array transducer was carried out in ray based simulation software 'CIVA'. It was observed in the simulation that optimum distance between the transducer and the weld centre should be 30 mm. Subsequently, it was validated with the experiment. The results from the experiment show that the entire weld bead can be inspected from the optimum distance of 30 mm by making longitudinal scans along the weld. Development of NDE methodologies for other complex TBM components is being conceived using ultrasonic guided wave and optical methods such as video scopy. Preliminary Safety Report (RPrS) for LLCB Test Blanket System (TBS) has been prepared and submitted to IO for review. Safety functions, signals for various accidental scenarios to be reported to Central Safety System (CSS) of ITER have been defined with flow charts of development of accidental scenarios, detection signals, mitigation measures and actions to be performed after the accident for each accidental scenario. Detailed logic diagrams for few main accidental scenarios have been worked out and submitted to IO for review. Detailed Project Report (DPR) of collaboration with BARC, Mumbai for safety analysis and requirements towards LLCB TBS safety licencing is prepared and is under finalization. Modification of RELAP5 code for safety analysis is under progress through a MoU with IIT, Kanpur. Experiment for transient measurement of hydrogen produced during PbLi-water reaction is at the stage of functional testing of its various parts. Preliminary design of the experiment for validation of modified RELAP5 code has been carried out. Development of neutron diagnostics for use in LLCB TBM has been taken up through collaboration with BARC, Mumbai. DPR of this collaboration is prepared and is under finalization. MCNP and SAND-II simulation of neutron activation system for measurement of neutron flux and spectrum at laboratory scale is on-going. Host state (France) check lists for rad-waste estimation from LLCB TBS and TBM transportation have been prepared including detailed physical dimensions, chemical compositions of materials, detailed radiological data of the irradiated and contaminated components, tritium inventory in various TBS materials and components, tritium outgassing from TBS components and materials after decommissioning, A2 values for all radionuclides present in the rad-waste from TBS. These reports are submitted to ITER Organization and CEA France authorities for review. Aluminide coating is one of the potential coatings which can address the issues of corrosion of structural material with Lead Lithium, Tritium permeation through the structural material and MHD pressure drop.Therefore Aluminide coating is tried on Indian RAFMS material through hot dip aluminization method. This method involves two steps, first is "Dipping" and second is "Heat treatment". During dipping of samples in (Al+Si) melt, hard and brittle inter metallic phase Fe_2Al_5 layer forms and this can be transformed into softer phases by further heat treatment. RAFMS coupons are dipped into Aluminium melt, with three different Silicon concentrations, at 750 °C for 30 seconds. Two types of heat treatments were given to the above samples. (1) 980 °C for 0.5 hours and 760 °C for 1.5 hours and (2) 760 °C for 30 hours. Width of Fe_2Al_5 layer, on hot dipped samples was less than 10 µm in all the cases. In case of 3% and 5% Si concentrations, Fe_2Al_5 layer got completely transformed into intermetallic layers. Band of pores were observed between FeAl and α-Fe(Al) layers. In the case of 7% Si concentration, Fe_2Al_5 layer could not be completely transformed into intermetallic layers, in both the heat treatments. Out of the two heat treatments, the heat treatment II seems to be better as compared to heat treatment I, for achieving thinner intermetallic layers. The transition zone widths were also less in heat treatment II. Hardness of $FeAl_2$, FeAl and α- Fe (Al) layers were found to be (972-1089) HV, (324-384) HV and (200-270) HV/0.05 respectively. RAFMS samples are exposed to flowing Lead Lithium at 550 °C and at a velocity of 30 cm/sec, with and without the presence of magnetic field (1.7 Tesla). The samples from the loop are taken out after 2700 hours and analysed. In the presence of magnetic field, Corrosion rate increased by 1.5 times as compared to nonmagnetic field region. Corrosion rate of ~220 µm/year and ~360 µm/year is observed for the samples located in nonmagnetic and magnetic field regions. Tensile strength and ductility of the samples reduced after exposure to Lead Lithium as compared to the unexposed samples. To study the corrosion of RAFMS with static PbLi eutectic, RAFMS coupons are dipped in static Lead Lithium at 550 C. One set of samples, flat and tensile were removed from the system and they are being analysed to study the microstructure and corrosion rate. To study corrosion of RAFMS samples with Lead Lithium (PbLi) eutectic, this loop is being run with hot leg temperature at 550 °C and cold leg temperature at 450 °C. Samples would be taken out after 3500 hours to study the effect of corrosion on microstructure and to estimate corrosion rate. DG set is bought to run the pump driven loop continuously. Ground preparation is done to keep DG set and fuel tank. Cabling from the DG set to the loops is being planned. Temperature control panels were procured and installed at TBM lab. The panels can maintain temperatures of up to 10 heating zones per panel by varying the power supplied to electrical heaters. The panels are being used for various experiments in TBM lab such as Liquid Metal Buoyancy loop, Liquid Metal Pump Driven Corrosion Loop and Liquid Metal Diagnostics Loop. Electromagnetic stirrer was tested at TBM lab. The purpose of this equipment is to stir/mix liquid metal for the process of alloy development. For testing and operation of this electromagnetic stirrer, a three phase variac was procured to supply variable voltage input to the stirrer. The testing was carried out successfully.

A.2.5. Large Cryogenic Plants and Cryo-systems (LCPC)

Under this project new initiatives have been taken to indigenously build a kW class helium liquefier-cum-refrigerator (HRL). This HRL is planned to have modularity so that it can be upgraded easily up to ~2kW cooling capacity at 4.5 K. This endeavor of indigenously building large HRL is to achieve the cryogenic technology required for making HRL of high cooling capacity for ITER like tokamaks aimed to commercially generate power from fusion reaction. HRL involves state-of-the-art cryogenic technology. In the field of HRL development work, this is the biggest one in the country, planned to involve latest cryogenic technologies like gas

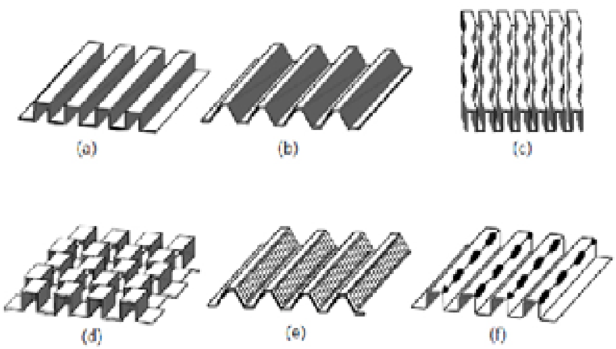

Figure A.2.5.1. Different type of fins used in the plate fin heat exchanger: (a) Plain rectangular (b) Plain trapezoidal (c) Wavy (d) Serrated or offset strip fin (e) Louvered (f) Perforated

bearing (contactless bearing) based turbo-expanders, vacuum brazed aluminum plate-fin heat exchangers, turbo-expander to handle high density helium at temperature less than 10 K. This will have also possibility to produce liquid helium below 4 K. Design, analysis, optimization and industry study related to some long lead components have started and few results are as follows:

Plate-fin Heat exchanger design and development: Heat exchangers are essential components in any refrigerator and liquefier. Here, in the HRL, this is even more important and heat exchanger effectiveness required is pretty high up to

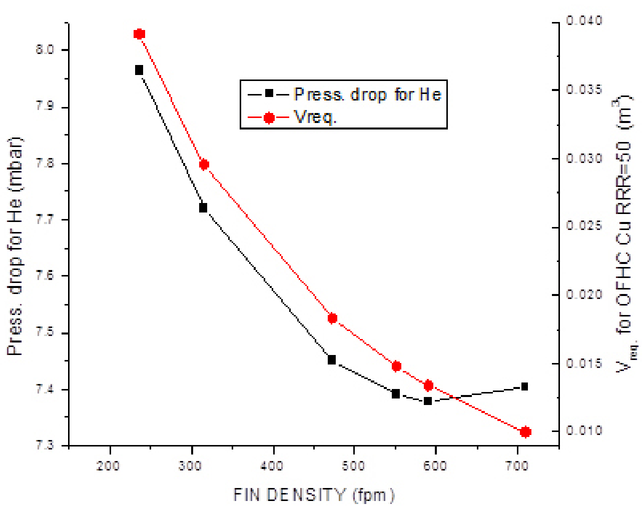

Figure A.2.5.2. Liquid nitrogen precooling heat exchanger volume and pressure drop optimization for different fin density using serrated type fins and for Al3003 and OFHC copper.

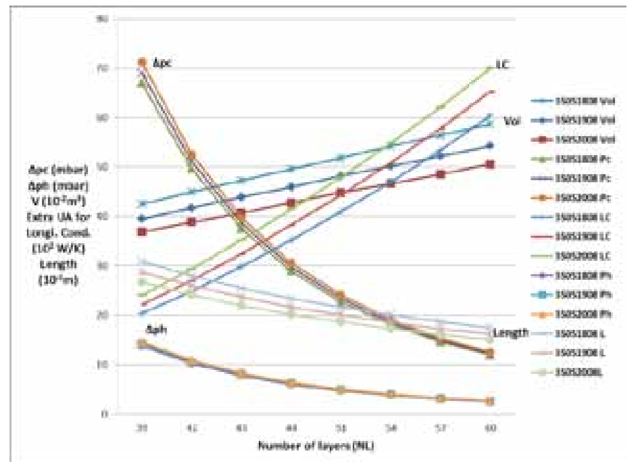

Figure A.2.5.3. Effect of different design parameters for the plate-fin heat exchanger operating between ~300 to ~80 K in the indigenous helium plant. Here international standard fins have been used.

~98% which can be met by only plate-fin heat exchangers (PFHE). Cryogenic plate-fin heat exchangers of such high effectiveness has not been fully successful yet, although some attempts for design and manufacturing have been made recently by BARC and NIT, Rourkela with M/s. Apollo Heat exchanger manufacturer, Mumbai. Besides complex geometry design and optimization procedures, there are practical problems like flow mal-distribution, axial conduction, inter-stream leakage, limitation of size of vacuum brazing furnace. The design and analysis work involves many non-linear material and fluid parameters and empirical correlations which can lead to some uncertainty in the real performance. This calls for wise analysis approach along with appropriate design margin. Different types of fins, used in the plate-fin heat exchanger, are shown in Figure A.2.5.1. Serrated or offset strip type provides highest heat transfer ability but it also provides highest pressure drop which is not good for process cycle efficiency. Hence a design analysis and optimization study have been done for two heat exchangers in the HRL process cycle: two-stream (Helium/liquid nitrogen) liquid nitrogen precooling heat exchanger having temperature range between 100 to 80 K and 3-stream (Helium/helium/gas nitrogen) heat exchanger having temperature range between 300 to 80 K. The variation of volume requirement and pressure drop for different fin density and for different material (Aluminium-Al3003 and OFHC (oxygen free high conductivity) Copper with RRR (residual resistivity ratio) = 50). The industrially and widely used material for plate-fin heat exchanger is Al3003 compared to copper mainly due to high

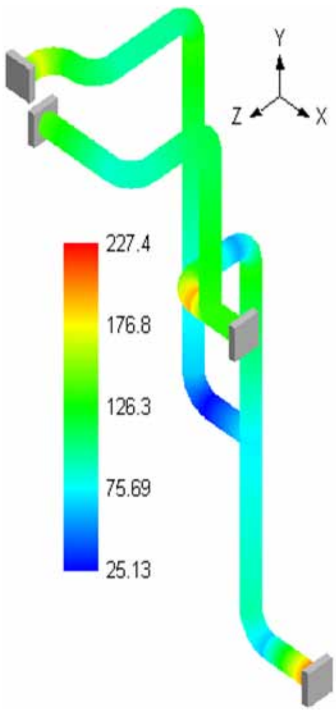

Figure A.2.5.4. Piping stress analysis results. Numeric values in the stress scale, correspond to the stress in MPa. Material used is SS304L and allowable thermal stress limit is 280 MPa.

density and high price. The density of copper is more than 3 times of Al3003 and further price of copper is about 3 times that of aluminum. From the figure 2.5.2 it is also clear that, volume requirement for copper is slightly less than that for Al3003 which can't compensate high price and high density and hence aluminum is more attractive to use. This figure A.2.5.2 further shows that the volume of the heat exchanger is pretty small with pressure drop less than 10 mbar for helium stream which are meeting the design requirement. Here, heat conduction along the flow direction of the heat exchanger is zero as one of the two streams is in two-phase region and temperature of this stream is nearly constant. Figure A.2.5.3 gives the variation of different aluminum PFHE parameters for 3-stream heat exchangers. One can see here that the length of the PFHE can be more than 2 m, which implies the need of such big vacuum brazing furnace, which is not available now in India. When header tank and distributors will be added its length could be about 3 m. This is an issue, which may need to change the design requirement. Analysis uses the international standard fins. These are named like '350S1808', as an example and this naming is based on the fin type, dimensions and fin density. Here, longitudinal conduction effect is significant and increases if the cross-section of the heat exchanger is increased. The pressure drop in the cold stream is significantly high compared to that of hot stream as the cold stream has low operating pressure and hence high volumetric flow-rate.

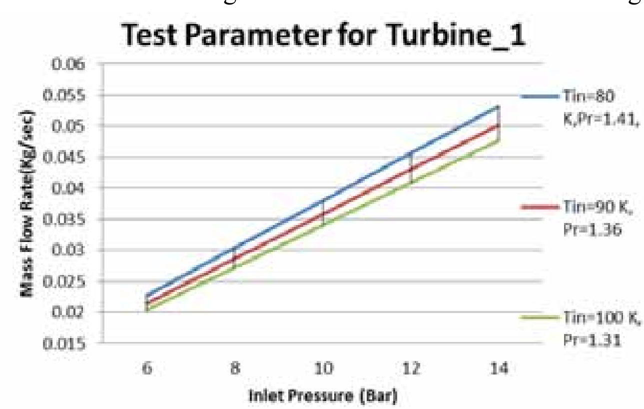

Figure A.2.5.5 Variation of mass flow rate vs. inlet pressure for different inlet temperature and pressure ratio (Pr) between inlet to outlet

Cold Box design and development: As a part of design study of the cold box internal component layout, many aspects like layout orientation of each components, maintenance feasibility, fabrication easiness, thermal stresses due to low temperature thermal contraction etc., have been analyzed. A part of the piping stress analysis result has been shown here in Figure A.2.5.4. This piping is a part of cold box internal component layout between heat exchangers and third turbine which are at temperature about 10 K.

Design and development of Turbine test facility: As a part of indigenous turbine development work, requirement for testing of turbines have been studied in-depth knowing the turbine operating parameters tentatively for helium plants. For measurement of performance of turbines using different process fluid parameters, following equivalent conditions must be met. This is required to find ways of testing turbines at or above 80 K temperature which can be easily created using liquid nitrogen cooled heat exchanger, although the design (or operating) temperatures are pretty below 80 K. To provide the similar velocity triangle at the turbine impeller tip for ensuring similar performance, following non-dimensional flow coefficient equation has been used. $(m*sqrt(T_{in})/P_{in})_{Design} = (m*sqrt(T_{in})/P_{in})_{Test}$ where, m is the mass flow rate through turbine, T is the temperature and P is the pressure of the process fluid. Here if temperature of test fluid is high, mass flow can be less, which is an advantage as it will need less capacity compressor for test set-up. For equivalent performance test of turbines, another non-dimensional velocity condition has been used. $(U/C_o)_{Design} = (U/C_o)_{Test}$ where, turbine impeller tip speed (U), having diameter, D_{imp} and rotational speed N, is given by, U = pi*D_{imp}*N and Spouting Velocity, C_o = SQRT(2*ΔH), where ΔH = enthalpy difference between the turbine inlet and outlet process flow. ΔH can be found based on the outlet and inlet temperature from the following equations only when process fluid is ideal. Here for first turbine (Turbine_1), where, the inlet and outlet temperatures (T) are between 35 to 25 K and pressures (P) are between 14 to 5 bar, the deviation from ideal gas behaviour is considered negligible. The relation between inlet and outlet temperatures of fluid in the turbine, assuming 100% isentropic efficiency, is given by $T_{out}=T_{in}/(P_{in}/P_{out})^{(\gamma-1)/\gamma}$. And enthalpy difference is given by $\Delta H = C_p T_{in} [1- (P_{in}/P_{out})^{(1-\gamma)/\gamma}]$. Based on above similitude procedure, analysis results have been shown in Figure A.2.5.5 which gives the turbine test parameters tentatively. This gives the region of operation in the test stand based on which further the test facility can be sized.

A.2.6 Remote Handling and Robotics Technology

With India establishing itself as a key player in the fusion community, development in indigenous Remote Handling is essential. In order to maintain and repair the thermo-nuclear fusion reactor, as well as reconfigure it with new components before any new series of fusion experiments, a bespoke Remote Handling system needs to be developed that can sustain nuclear environment challenges like ultra-high vacuum conditions, radioactive environment, tritium contamination effects. The primary role of the RHRTD division is to lay down a versatile base for accelerating the developments in RH systems and related activities for Indian fusion devices. The division aims at the design and development of SST-1 Scale Inspection system, Virtual Reality lab for system development, testing, operation and control along with scaled test facilities. In the present year the foundation in various fields of robotics was laid down for development of large scale systems. A major breakthrough was achieved with the development of an interfacing technique for control of manipulators with DELMIA. This simulation software provides the virtual environment to import the manipulator and the working environment CAD data from CATIA and study the path planning and obstacle avoidance. 3D simulation with real time hardware in field application using Inverse Kinematics was carried out. This methodology is usually followed for Remote handling in JET machine operations. The interface was designed in Lab-VIEW such that the robot can read XML file created by DELMIA. This can work with robots having any number of degrees of freedom. Assembly sequencing can performed using 3D-Via. Clash Avoidance Techniques were implemented in robotic system with the FPGA platforms. Multiple communication networks were established to achieve long wireless control range. Inverse Kinematics Algorithms were programmed in Lab-VIEW to navigate the robotic system wirelessly to the desired position coordinates avoiding all the static as well as moving obstacles in its path. The developments will be further worked up on and interfaced with more robust systems that are being manufactured presently.

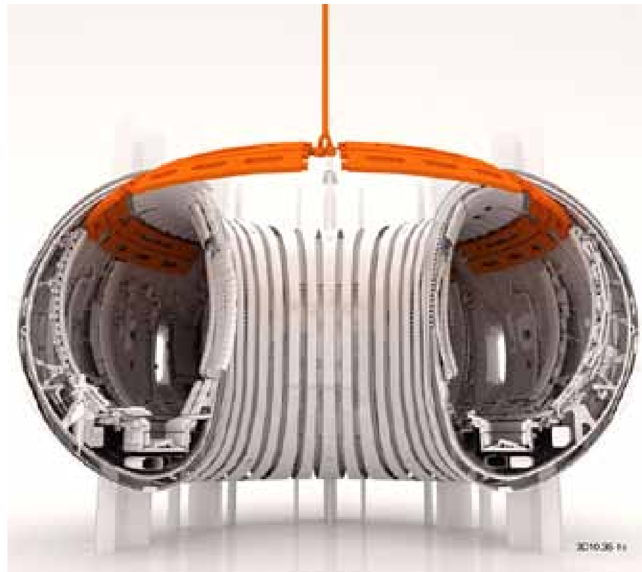

Figure A.2.6.1. A computer generated impression of the ELM control coils mounted inside of the JET vacuum vessel.

Conceptual Design of ELM Control coils for Joint European Torus (JET): The RHRTD division was also actively involved in the conceptual design of the remote handling compatible ELM correction coils for the Joint European Torus, UK under the international collaboration. A team of 6, including the RHRTD project leader was deputed at the JET for a period of 6 months for the conceptual design of the in - vessel ELM correction coils support systems and other associated in-vessel components for the JET tokamak. With JET being adapted as close as to a mini-ITER, the next step is to experiment the possible control schemes of the Edge Localized Modes (ELM) in plasma. The confinement in the H-mode leads to pressure build ups inside the plasma until an ELM develops: a burst of turbulence that spews out particle and energy, much like a solar flare. ELMs are common with the H-mode plasmas. Depending on the amount of energy ejected these ELMs can damage components and erode or melt wall tiles. The proposed JET ELM control coil configuration comprises 8 sets of one large coils and three small coils that run toroidally within the JET machine at the location of the present upper saddle coils and mushroom tiles. The coils will be held in position with stout support structure that are attached to the JET vacuum vessel. The JET uses extensive RH techniques for all its in-vessel installation and maintenance task. The major RH requirements are defined as – the allowable support structure weight to be below 160kG, design with assembly sequences for installation and removal, minimum RH operation time per ELM coil installation. It also includes the Virtual reality sequencing for coil installation along with the interference issues with other in-vessel components while material transportation inside the vessel. The ELM coil support structure, base supports and coil lead connector design are designed with these requirements. Size and topology optimization was carried out to bear the electromagnetic loads due to normal operation of coils and for disruption scenarios like Eddy current loads and Halo current Loads and achieve a structure weighting less than 160kg. The assembly sequencing also resulted in conceptualizing minimum RH requirements by installation of three coils simultaneously with a front plate and electrical connections being made outside the vessel. More than a hundred in vessel system interfacing issues were resolved with structural modifications only to avoid any disturbance in the existing JET in vessel configurations. RH compatible base supports, electrical jumpers, halo current earth straps were also designed as a part of the project. The JET ELM control coil design project has further boosted the capability of the IPR RHRTD team to design and analyse active and passive components for in-vessel tokamak applications which can withstand the plasma disruption loads and are compatible with RH installations and maintenance procedures. The experience and expertise achieved with this project can be employed for indigenous fusion programs and other in house R&D projects.

A2.7. Negative ion Beam Source

ROBIN experiments: The extraction system of negative ion source at IPR has been assembled, installed (Figure A.2.7.1) and commissioned in negative ion source test bed, ROBIN successfully. The extraction system has been successfully tested for high vacuum and high voltage compatibility upto 10 kV. The negative hydrogen ion beam experiments in volume mode (without cesium) have been started in ROBIN using a 10 kV, 400 mA power supply. The plasma grid has been masked (extraction area: 2 cm^2) to limit the extracted negative ion and co-extracted electron current upto 400 mA due to the limitation from presently used power supply. Soon the full rated power supplies will be available and then extraction area would be increased to extract large current beams. In present configuration, a negative ion beam with >9 mA/cm^2 current density has been extracted at a source pressure of 1.2 Pa in volume mode. This is an exciting result as an extracted negative ion beam of 3 -4 mA/cm^2 is expected with larger extraction area of about 100 cm^2 in volume mode. The source is being fully characterized for all parameters including source pressure, input power, extraction voltage, grid bias voltage etc. New diagnostics like laser photodetachment for negative ion density measurements, Doppler shift spectroscopy for beam divergence measurements, water cooled calorimeter for beam profile measurements, etc. are being introduced.

Figure A.2.7.1. Negative ion source test bed, ROBIN, with assembled extraction system

Cesium experiments: A full scale experiment of proposed long stem cesium delivery system for DNB has been successfully carried out in negative ion source lab at IPR. The cesium metal vapor was successfully transferred over a long length

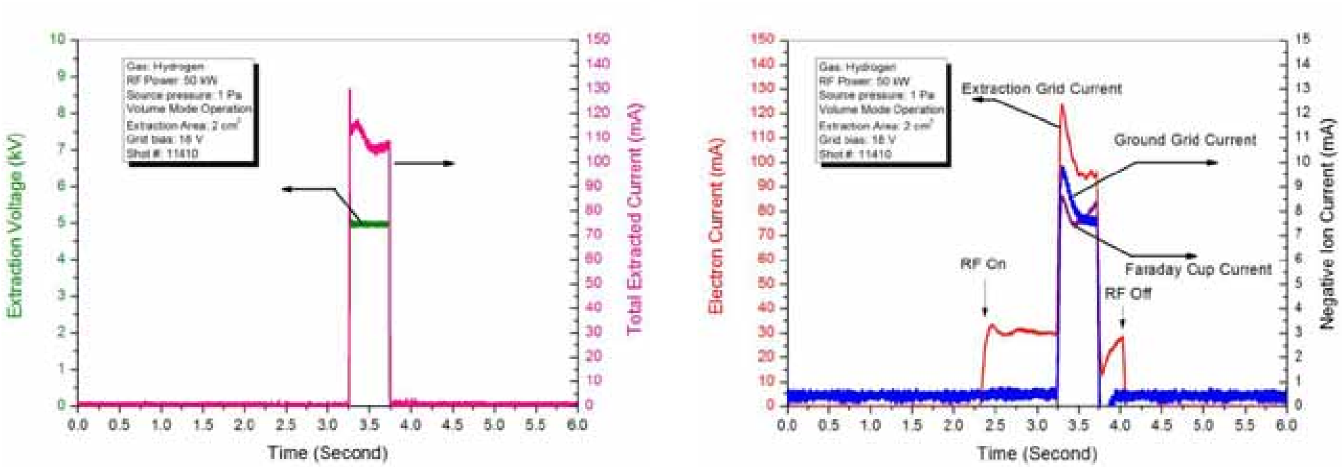

Figure A.2.7.2. An example of 5kV beam extraction. Extraction grid current is the co-extracted electron current. Ground grid and Faraday cup currants are total extracted negative ion currents

of 6 m first time in the world. A long stem cesium delivery system has been proposed for DNB to reduce the stop time of DNB due to the maintenance in the cesium ovens. In the proposed design, the cesium oven is kept outside the vacuum envelop of the DNB where remote handling manipulator can easily access the oven and do the maintenance. During maintenance, the primary vacuum of the DNB need not to be broken which is the most important aspect of this design. Cesium distribution from a multiple nozzles distributor was also tested successfully. The multiple nozzles distributor helps to spray cesium over a wide area in large ion sources like ITER and reduces the need of having multiple cesium ovens. A new alternative method to inject cesium into large ion sources has been proposed. In this method, the plasma grid is modified into a box like structure in which the cesium vapor is injected. This cesium vapor comes out through small holes made in the extraction apertures of the plasma grid and then sprayed over these apertures where it matters the most for negative ion production. Generally, in ion sources, the cesium is injected from the back plate of the source which then flows with plasma and reach the plasma grid, however, it is observed that more than 90% of the cesium is ionized with plasma and goes back to the plasma source walls rather than going to the plasma grid and therefore only less than 10% of the injected cesium is utilized to cover the plasma grid. In new proposed technique, the cesium is sprayed directly on the plasma grid apertures and therefore, the required cesium quantity is about 10 times less than normal injection technique and hence, the same cesium inventory can be used for 10 times longer duration without refilling. Due to less cesium used in the source, the maintenance requirements also reduce significantly. A prototype small scale experimental setup has

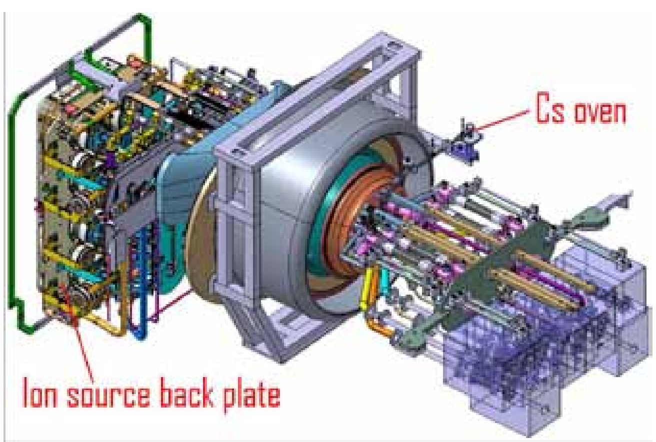

Figure A.2.7.3. Layout showing the position of proposed cesium oven outside the vacuum envelop of DNB

Figure A.2.7.4. Experimental setup to investigate the alternative cesium injection technique.

been developed in the negative ion source lab to validate this alternative cesium injection method. The experiments are going on at the moment.

ROBIN integration : A 100kV, 100mA Hi-pot tester has been procured for performing the HV testing various electrical systems / components at high voltage. The device will be mainly used for the HV testing of 180kW RF generator for Twin source, HV bushing for DNB etc. The tester has facility to set the break down current continuously from 0 to 100mA. The tester can be used for 0 to 100KV AC, 0 to +100kV DC and 0 to -100kV DC testing. The PDI of the device is successfully performed at M/s Ajit Electronics Mumbai.

Integration and testing of Extraction Power Supply System (EPSS): Various components of the 11kV, 35A Extraction Power Supply System are tested for the specified performance before doing the final integration of the power supply system. The power supply is presently under the advanced stage of final acceptance testing at M/s Veeral Control Pvt. Ltd. Gandhinagar. Following main tests have been performed :(a) Heat run and HV testing of 30nos. of 20kVA, 50kHZ, 100kV DC isolated transformers; (b)Electrical and HV testing of 550kW continuous duty resistive dummy load; (c) Testing of passive breakdown circuit (RL snubber); (d) Testing of 35kV ignitron system for performing simulated break down tests; (e) HV Testing of HVDC cable; (f) Testing of Remote monitoring and control Rack (RMC) and Local control unit Rack (RMC); (g) Testing of HV isolators and earth switches; (h) Testing of LT and Rectifier panel; (i) Testing of high voltage and current feedback system; (j) Testing of HVPS in open loop and close loop; (k) 10J Wire-test across the HVPS terminals; (l) Repeated breakdown tests (200nos.) at the HVPS terminals; (m) Testing of fiber optic (FO) based remote interface; (n) EMI / EMC testing of modules at ERDA Baroda.

Cable trench for HVPS building: For receiving the 11kV HT cable and control cable for the 2MVA 11/0.433kV transformer, a cable tray system has been designed. A 2 tier arrangement has been adopted where GI ladder trays have been installed. The trench is now connected with the existing 11kV trench of the main switch yard for which 6 inch through holes have been drilled in the new trench using diamond cutter.

11kV, 400mA High Voltage Power Supply (HVPS) for low current extraction experiments: The -11kV, 400mA HVPS has been successfully site tested and commissioned with the negative ion source (ROBIN). The central data acquisition & control system (DACS) has been successfully integrated with the remote interface of the power supply. The power supply has been tested on site for all critical parameters including the 100 nos. of simulated breakdown tests. The power supply is procured from M/s Ionics Hyderabad.

Data Acquisition of ROBIN: In ROBIN, High Voltage power supply (HVPS) of rating 11kV, 400 mA is successfully integrated with the ROBIN DACS system though fiber optics links and Beam Operation champing has been successfully completed.

In-house Design and Development of FO (Fiber Optics) link based on FPGA (Field Programmable Gate Array) technology: For cater the requirements of fibre optics links for upcoming two test-beds viz. (1) Twin source and (2) INTF (Indian Test Facility), new in- house development of fibre optics links, based on advanced FPGA technology and digital communication technique has been initiated. FPGA has an advantage of easy and fast Re-Programmability, configurability and upgradability of the design. As a part of the development, two types of prototypes links as described below has been in-house design and successfully tested for below mentioned specifications.

(A) *FPGA based, Prototype of fiber optics serial data links for digital signals (8 Channel and 16 Channel)*: The FO links comprises of transmitter module, receiver module, power supply module and fibre optics cable. Specialty of the link is that it can transmit 8 or 16 nos. TTL signals, having a bandwidth DC- 20 KHz, up to 300 meter distance via single HCS fiber cable. Specifications of the link: (a) Input signal level – TTL; (b) Output signal level – TTL; (c) Rise and Fall time - 368 nS and 87 nS (respectively); (d) Delay – 4.2µS; (e) Jitter - 1.2 µS; (f) FPGA - XILINX SPARTAN-3E, 32 MHZ Onboard Oscillator; (g) Technique - Digital Communication; (h) Synchronization Technique - 8B/10B block coding and Unipolar NRZ Line Code (i) Prototype board - Papilio One Butterfly FPGA board

(B) *FPGA based, Prototype of 1 channel fiber optics link for transmission of analog signal:* The FO link comprises of transmitter module, receiver module, power supply module and fiber optics cable. Specialty of the link is that it can transmit single analog signal, having a bandwidth DC-1 KHz, with accuracy and linearity of 0.05 %, up to 300 meter distance via single HCS fiber cable. Specifications of the link : (a) Input signal level - +/- 10V; (b) Output signal level - +/- 10 V; (c) Accuracy and Linearity - 0.05 %; (d) Resolution - 14 bit;

FPGA - XILINX SPARTAN-3E, 32 MHZ Onboard Oscillator; (e) Technique - Digital Communication; (f) Synchronization Technique - 8B/10B block coding and Unipolar NRZ Line Code; (g) Prototype board - FPGA development kit

TWIN Source

Experiment: TWIN source (TS) has two RF driver (figure A.2.7.5. It is the intermediate step between single driver ROBIN and eight driver INTF. The objectives of this experiment are to gain experience to operate a multi-driver source with single RF generator (RFG) in vacuum immersed condition with remote impedance tuning mechanism through CODAC based control and data acquisition platform. The source is designed to study also the plasma grid (PG) current filter field operation. In this TS program the conceptual design for two driver source finalized and procurement activities related to plasma phase experiments initiated. The conceptual designs for Vacuum vessel have been carried out by identifying the functional and operational requirements. Related pumping requirements for vacuum chamber based on the operational requirement have been established. To house the TS, a mezzanine floor is being erected and designed within INTF lab area at ITER-India building. Contract has been placed for 180kW RF Generator. Procurement process is ongoing for electrical distribution panel with cables, PG bias power supply, Filament heating and bias power supplies, PG filter field power supply. In DAC system, Workstations, Fibers for communication are received and indents are raised for DAQ and Control hard wares.

Development of Control System based on ITER CODAC Core system for Site Acceptance Testing of Radio Frequency Generator (RFG) with Dummy Load: For the Site Acceptance Testing of RFG (180 kW, 1MHz) with the dummy load for Twin source experiment, a standalone control system has been design based on ITER CODAC Core system (CODAC- Control, Data Access and Communication is the central control system responsible for operating the ITER device and CODAC Core System is a software suite for control system development), developed and successfully tested with the dummy signal (as RFG and its related sub-systems are presently not available). Mainly it performs the following task:

- Remote operation, control and monitoring of RFG system through total 34 nos. signals
- Operation of RFG in three different Mode viz. (1) Continuous, (2) Pulse and (3) Modulation
- Protection of RFG through interlocks signals l
- Supervision of other sub-systems

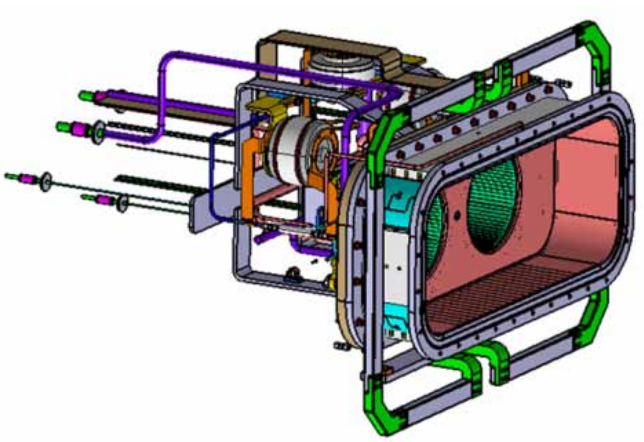

Figure A.2.7.5. Schematic of the Twin Source

The control system is mainly consisting of the Siemens PLC S-7 300 system and ITER CODAC core software. The communication between the S7-300 PLC system and the central control room computer is done through Industrial Ethernet (IE). The control program is developed in Siemens Step7 PLC programming software and downloaded to the PLC system. The HMI is developed in CODAC Core 3.0 System.

A.2.8. Fusion Reactor Materials Development and Characterization

This division has planned the activities for the development of structural and functional materials for the near-term and future requirements of reactors to be built and setting up of characterization facilities useful for the developing these materials. R & D on Ion and Neutron irradiation of various materials is also a part of this programme.

Materials Development

IPR-IGCAR MoU has been signed and Oxide Dispersion Strengthened Steel (ODS) plates for future fusion reactors are being developed jointly by IGCAR and IPR in collaboration with International Advanced Research Centre for Powder Metallurgy and New Materials (ARCI) and Defence Metallurgical Research Laboratory (DMRL) under this agreement. ODS have microstructures with a ferrite/martensite matrix containing dispersions of fine Y_2O_3 particles which are known to act as strong barriers for mobile dislocations even at elevated temperatures and also act as sinks for radiation induced defects making these ODS steels a candidate structural material for fusion reactor applications with higher strength and creep resistance at elevated temperatures. Realisation of products of ODS steels involve powder metallurgical routes to develop and produce ODS-9Cr RAFM and ODS-14Cr RAF steel powders and to process these powders by hot isostatic pressing and subsequent hot forming operations like hot rolling to plates. Extensive characterisation of the products formed at various stages of production to finalise the processing route and generation of material property data is also part of this programme. Planning for the SiCf / SiC composites R & D program is in progress. The development of functional materials and coatings has been taken up. Samples of proton conducting oxide $LaNbO_4$ have been prepared, by using three different synthesis methods, with the primary objective of developing hydrogen isotope separation membrane. Characterization of samples using XRD, SEM, EDX and the Dielectric measurements were carried out. From data analysis, it was observed that all samples prepared by Molton Salt Method, Sol-Gel and solid state method show single phase and stoichiometry. However, sample preparation by molten salt method shows preferred orientation of grains indicating that microstructure and electrical properties of $LaNbO_4$ samples are strongly dependent on synthesis method. In order to optimize Molten Salt synthesis method, samples were prepared by doing variation in calcinations time (1-3hr) and Oxide to salt ratio (1:1;1:2,1:0.8). Best conditions were used to prepare doped samples of $LaNbO_4$ by doping Ti as dopant at Nb site according to its valence state; close matching of ionic radii and electronegativity with Nb. XRD, Raman, and Dielectric measurements were carried out.

Tritium barrier coating by sputtering technique : Activity on development of Er_2O_3 (Erbia) as a tritium permeation barrier coating has been going on and it is further extended by carrying out a series of deposition optimization experiment using the upgraded magnetron sputter coating set-up to enable high substrate temperature (360 ^{o}C). The substrate temperature capability will be further increased to 700 ^{o}C by integrating the new substrate heating system, which is being procured. At the optimized sputtering power, a series of depositions as a function of substrate temperature show that the coatings are largely amorphous at room temperature and becomes partially crystalline with increase of the temperature to 360 ^{o}C. By comparing simulated patterns with the experimentally observed crystalline phase pattern, it has been deduced that the coating at 360 ^{o}C temperature is formed in the metastable monoclinic phase [Figure A.2.8.1]. In another series of experiments carried out at different O_2/Ar gas flow ratio showed the formation of cubic phase in a very narrow window of the flow ratio parameter. However, the process is extremely sensitive to variation in this parameter and depending on slight variation in the parameter on either side, cubic Erbia mixed with pure Erbium or monoclinic Erbia has been formed.

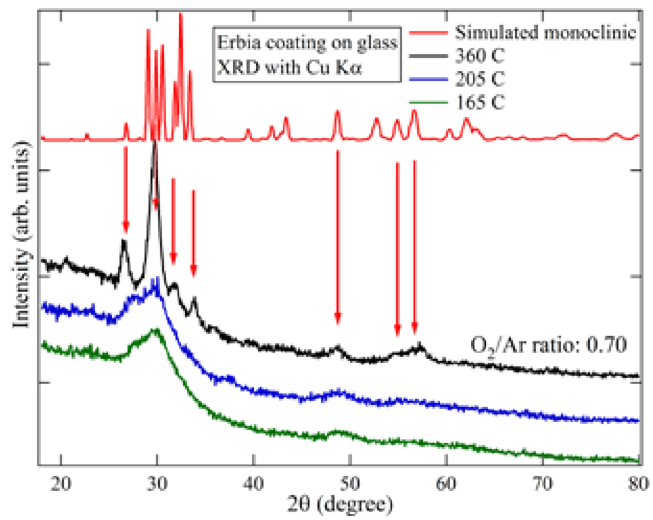

Figure A.2.8.1. Development of Er2O3 (Erbia) as a tritium permeation barrier coating

Tritium permeation barrier coating by wet method : A new set up installed for the development of Erbia coating through an alternate route of wet method. This method has an advantageous ability of coating surfaces of odd shape and size.

Materials Characterization Activities

X-ray Diffraction : Powder mode and Grazing incidence mode XRD measurement and data analysis was provided for the various research activities of different groups of IPR, such as SnO_2 and Er_2O_3 coatings for FRMDC division, Li_2TiO_3 characterization for TBM group, heat treated CuCrZr Magnet Division, Tungsten powder and pellets, Ti coated and cladded Carbon Fiber Composites analysis for Diverter group, tungsten coatings for Aditya vacuum group, nitrided steels for Nitriding group at IPR and FCIPT, nano powders, air plasma treated brass, titanium films, depth dependent phase analysis of plasma nitride SS304, ZnS films, for FCIPT, etc. Apart from this, XRD analysis services were provided on commercial basis to various users from outside IPR, including industries, research institutes and universities.

R & D of fabrication Technology for Austenitic Steels: Multipass TIG welding of the 40 mm and 60 mm thick 316 L plates used for Vacuum Vessel applications have been done and the welds have been characterized with Non Destructive Examinations. Mechanical properties characterization (Tensile, Bend, Hardness, Impact fracture, Impact Fractograph analysis) and microstructural studies have been carried out. It was found that in most cases the joints have shown higher Tensile properties than base metal indicating good joint quality and have shown higher hardness in weld zone where as in case of impact properties, WZ has shown significant reduction (around 50%) in WZ compared to Base metal. Electron Beam welding of 60mm thick SS 316L was fabricated and characterized for mechanical properties and microstructures. It was found that Tensile strength of the EBW joints are slightly lower than the base metal and softening is observed in the weld zone where as the other test for weld joints were passed successfully. Laser welded 8 mm thick SS 304L and SS 316L samples were fabricated and characterized. Fracture analysis of Base Material, Heat Affected Zone and Weld Zone has been carried out and it was found that the joints have exhibited tensile properties comparable to the base metal. Microstructures at HAZ and WZ found to be having dendrites with combination of ferrite pool in austenite matrix. Design of experiments and TIG process parameters optimization with 10mm thick SS 316L materials and activated GMAW and GTAW process development work for Austenitic Stainless steels have been done.

Hydrogenated Silicon (Si:H) Thin Film Deposition by Very High Frequency Plasma Enhanced Chemical Vapour Deposition and their irradiation study : Thin layers of hydrogenated amorphous silicon (a-Si:H) with 0.5-2 µm thickness have found extensive application in solar cells and in thin film transistors (TFT). While thick film (>30µm) a-Si:H p-i-n diodes are used for detecting and recording the spatial distribution of charged particles, X-rays and γ rays. Thick Si:H films by Plasma Enhanced Chemical Vapour Deposition (PECVD) have been grown using novel multi-hole cathode shower geometry to achieve high growth rate.The damage study of these films by deuterium ion (D+) bombardment at different ion energies ranging from 50-70 keV have been done from detector application point of view. The Scanning Electron Microscopy (SEM) analysis done after irradiation of D+ ions revealed that the micro-crystallites embedded in amorphous matrix, transformed in to small clusters of crystalline phase for energy range of 50–60 keV. Whereas at 70 keV D+ beam bombardment, more amorphization of micro-crystalline structures has been observed. At the same time, D+ ion bombardment drastically reduces photoconductivity due to localized defected and hence carrier mobility. Further investigation for D+ ion bombardment effect on these films has been going on.

Antimony doped tin oxide thin film preparation by co-evaporation of Sn and Sb using plasma assisted thermal evaporation technique : Tin oxide (SnO_2) thin films are having promising properties such as high visible transmittance and low electric resistivity, which make them very important transparent conductor in a variety of optoelectronics devices. Further, doping with pentavalent impurity such as Antimony (Sb) enhances its conductivity considerably. In order to study the effect of Antimony doping, Antimony doped tin oxide (SnO_2 : Sb) thin films have been prepared by the co-evaporation of Sn and Sb using Plasma Assisted Thermal Evaporation (PATE) in oxygen (O_2) partial pressure at various doping level from 4% to 25%. The influence of various Sb doping levels on the compositional, electrical, optical and structural properties have been investigated using Energy Dispersive X-ray (EDX) spectroscopy, Ultraviolet-Visible (UV-VIS) transmission spectroscopy, four-probe resistivity measurement and X-ray Diffraction (XRD), respectively.

A.2.9. Neutronics Diagnostics

Design of Compact Electron Cyclotron Resonance (ECR) Ion source for accelerator based 14-MeV neutron Generator : An indigenous compact 2.45 GHz, 1200 Watt, CW ECR ion source has been designed by using WR340 wave guide section and OPERA 3D code. The major components of the ECR ion source are microwave system, magnet system, plasma chamber and vacuum system. The magnetic field of the source will be generated by using coaxial NdFeB permanent magnet ring, which have a high temperature coefficient. Three typical axial magnet structures will be used to produce axial magnetic. The aim of the source is to produce 50 mA CW ion beams at up to 50kV operation voltage. Design Parameter of the ECR ion source : (i) Microwave Power - ≤ 1200 watt; (ii) Microwave frequency - 2.45 GHz; (iii) Ion species – D+ ; (iv) Extraction Aperture – 6mm; (v) Beam Intensity - ≤50 mA; (vi) Extraction Voltage - <50kV; (vii) Operation pressure - ≤ 10^{-6} mbar; (viii) Plasma Chamber - 50 X 50Φ mm2 ; (ix) Emittance - < 0.2 *pi* mm mrad. In order to reduce the beam divergence and obtain low emittance a tri-electrode extraction system with electrode of 450 angle has been designed to extract the ion beam. Opera-3D simulations are carried out for various apex angles (450, 600, 67.50, 700, 800, 900) of electrode. The aperture diameter of plasma electrode is 6mm and of suppressing electrode and ground electrode are 8mm. The acceleration gap and deceleration gap are 12mm and 3mm, respectively. In figure A.2.9.1 shows the design of ECR ion source and extraction.

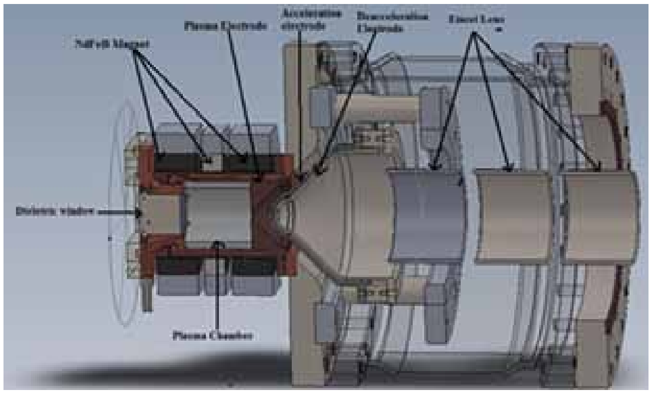

Figure A.2.9.1 The design of ECR ion source and extraction.

Neutron Irradiation of tungsten carbide composite : In this experiment we have studied the effect of 14MeV neutron irradiation on different sample of carbide composite like (WC, WC+B_4C and WC+TiC). The composite samples were placed at the top surface of the neutron generator tube and one Fe foil (activation foil) was placed over it and another Fe foil was placed at one side of the source tube in such a way that its distance from the tube surface is equal to the thickness of melt-cast sample. Time of irradiation of the samples was 600-660 sec. After irradiation, neutron activations were counted in the foils employing well calibrated high purity germanium detector and multi-channel analyzer to measure neutron induced gamma activity.

Figure A.2.10.1 Picture of the fabricated PSA system

Deuterium ion implantation on SS316L sample : In this experiment we studied the effect of deuterium ion beam irradiation on the SS316L sample. The ion implantation of deuterium ion was accomplished with an accelerator. SS 316 L samples were subject to an ion implantation of energy level of (40-70) keV, dose (7.076 – 68.92)×10^{17} ions/cm^2 at room temperature. Ions were accelerated in a linear accelerator. This implantation process is a line of sight process. The samples were mounted on the back plate of end flange of the accelerator. When the vacuum level was achieved, accelerator was started and implantation was done for 30 minutes. Implantation was carried out at room temperature. Above process was repeated three times to irradiation all the four samples.

A.2.10. Fusion Fuel-Cycle Development

In this activity, developing of Tritium Extraction System (TES) for Lead Lithium cooled Ceramic Breeder - Test Blanket module (LLCB-TBM) and its analytical system are undertaken. Complete fuel cycle consists of fuel system, NBI system, TES, Tokamak exhaust processing system, vent de-

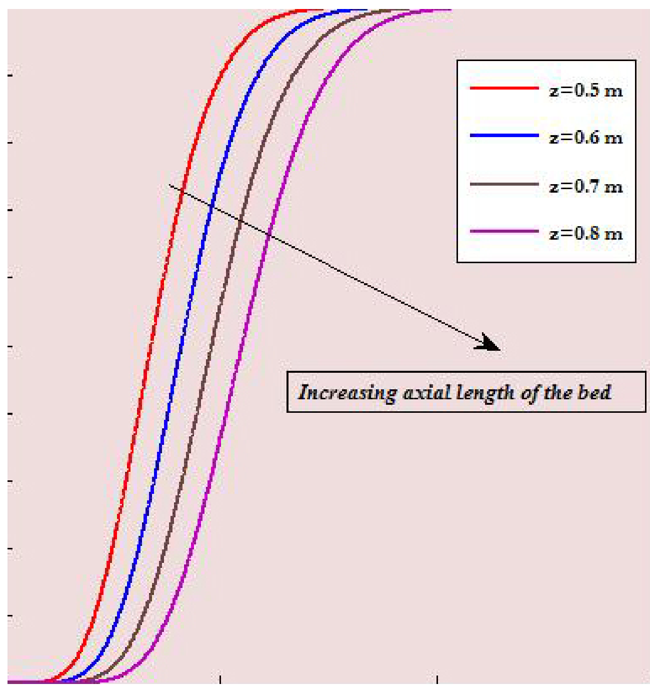

Figure A.2.10.2 Breakthrough curves by varying axial length of AMSB tritiation system, isotope separation system (ISS), water detritiation system, storage & delivery system, and analytical systems. During XII plan some of the abovementioned R&D activities are taken up in the XII plan, which are mentioned below in brief. Tritium being radioactive, it is decided to establish all the processes using its isotopes, hydrogen and deuterium. Tritium will be used in the coming five year plans. In this (XIIth) five year plan the following activities are planned : (i) hydrogen isotopes removal from He purge gas, (ii) hydrogen isotopes extraction from liquid PbLi, (iii) isotope separation system, (iv) hydrogen isotope permeation studies to qualify tritium permeation barrier (TPB) coating developed at IPR and (v) hydrogen isotope sensor in PbLi.

Activities towards development of laboratory scale hydrogen isotopes removal system (HIRS) for He purge gas: In LLCB-TBM, helium gas with 0.1% of hydrogen is used as purge gas to sweep tritium from solid Ceramic Breeder (CB) and liquid PbLi. We have plans to develop a laboratory scale hydrogen isotope removal system for He purge gas. The complete system consists of atmospheric molecular sieve bed (AMSB) column (for removal of moisture from He), which would be regenerated using pressure swing adsorption (PSA) and cryo-molecular sieve bed (CMSB) column, which would be regenerated by heating the bed. The design and fabrication of the PSA system containing AMSB is complete.

Figure A.2.10.1 shows the fabricated PSA system. High purity hydrogen generator and deuterium generator are also procured for this experiment and the have been delivered to IPR. Some diagnostics, like, trace moisture analyzer, gas chromatograph etc. are expected to arrive shortly. Once they are delivered, experiments for finding breakthrough times at different process parameters would be performed. However, theoretical estimation of breakthrough curves is done and they are shown in figure A.2.10.2.

Activities towards development of hydrogen isotopes extraction system (HIES) for liquid PbLi: The HIES sweeps tritium (or hydrogen isotopes) from liquid PbLi in a gas liquid contactor. Two of the main components of this experiment are detritiation column or extractor (consisting of structured packing bed) and electromagnetic pump (EMP). Estimation of pressure drop is done to decide about the height of packed column dimension. Specifications for extractor and EMP are generated and would be procured through budget for the next year.

Activities towards hydrogen isotope permeation study to qualify TPB coating : Tritium present in different streams of blanket system has a tendency to permeate through the metals at high temperatures. Therefore, TPB coating on the structural materials is essential to reduce loss of tritium through permeation. So, an experimental setup to study hydrogen isotope permeation to qualify the TPB coating developed at IPR is designed. The setup would be fabricated by M/s Vacuum Technique, Bangalore. They are in the process of preparing fabrication drawings at present

Activities towards development of hydrogen isotope sensor for PbLi: Hydrogen isotope sensor for PbLi is not readily available. However, measurement of hydrogen isotope is a must for all the systems of blanket involving PbLi. So, permeation based hydrogen isotope sensor is designed. In its simplest architecture, this sensor can be considered as a hollow capsule permeable to hydrogen isotopes, immersed in liquid PbLi where hydrogen isotope is dissolved at certain concentration, C_0, in equilibrium with a partial pressure Peq. Measurement of permeated gas pressure inside the capsule can be correlated with the concentration/pressure of the hydrogen isotope dissolved in liquid PbLi. The capsule is connected, through a small tube, to an external pressure gauge or to a vacuum pumping system and a Quadrupole Mass Spectrometer (QMS) depending on its mode of operation, i.e. equilibrium mode or dynamic mode. The capsule would be made with iron foil coated with palladium on the inside surface to enhance permeated flux. The palladium targets for coating have been procured and orders for iron foils have been placed and once they arrive, fabrication of the sensor would be initiated.

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A.3. Basic Experiments

The institute has a very strong experimental program on fundamental plasma sciences. This exciting programme caters mostly to the requirements of Ph.d. student programme. The current programme has experiments under the following heads:

A.3.1. Large Volume Plasma Device (LVPD)

The most significant role in the success first unambiguous laboratory observation of Electron temperature Gradient (ETG) is played by a piece of instrument called, Electron Energy Filter (EEF). This is a variable aspect ratio solenoid whose magnetic field can be controlled over the entire cross-section of device externally without affecting a vacuum break in LVPD. Using this instrument it has become possible to control cross field diffusion through EEF and thereby control plasma profiles. We believe that by making use of EEF, not only controlled studies can be carried out on ETG turbulence but also other important processes involved like plasma transport, study of non-linear coherent structures, scaling of plasma transport etc., in the background of ETG can also be explored extensively. The presence of EEF has divided LVPD plasma into three distinct regions of source, filter and target plasmas. The three regions of plasma exhibit different characteristics. The source plasma is rich in energetic electrons and shows presence of electromagnetic turbulence, the EEF plasma exhibits electrostatic turbulence whereas the target plasma which covers most of the experimental area within LVPD shows presence of ETG turbulence which is electromagnetic in nature. Here the results from experimental inroads made through a set of observations in three fronts are presented. The three regions are 1) ETG turbulence; 2) sandwiched plasma and 3) system up gradation.

Electron Temperature Gradient Driven Turbulence : The EEF has made LVPD plasma in target region free of energetic electrons, a major source for the introduction of ambiguity in the measurement of electron temperature and secondly in making suitable case for the excitation of a pure ETG turbulence. We have mentioned that EEF is capable of producing different plasma profiles for its different fields of EEF but for the excitation of ETG and its confirmation we have chosen only two extreme possibilities in which 1mx2m extent of EEF is energized and in another where EEF remains unenergized. The plasmas in the two cases are defined as one having flat density and gradient in temperature (FneGTe) and second hollow density and flat temperature (HneFTe). We have presented mean plasma profiles for both cases and it can be seen from the figure that active EEF produces profiles suitable for ETG turbulence whereas, the inactive EEF, produces almost a flat electron temperature profile in the core of LVPD plasma. The calculated electron temperature profile for both the cases shows that it is the FneGTe case where both the ex-

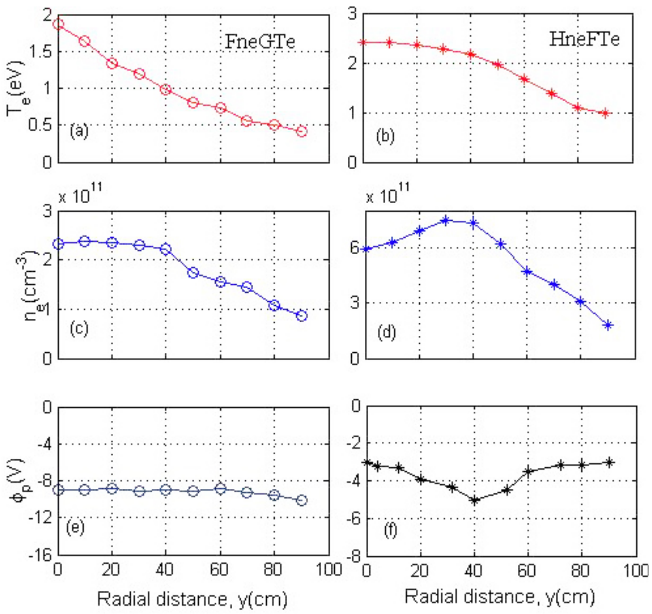

Figure A.3.1.1: Radial profiles of mean plasma parameters, (a-b) electron temperature, Te, (c-d) plasma density, ne and (e-f) plasma potential in two configurations of EEF active and inactive respectively.

perimental and calculated values are in close agreement thus ruling out presence of energetic electrons whereas in HneFTe no such agreement is seen. In the later case no transverse field of EEF is present, the deviation between the two profiles of temperature becomes visible and reason for this owes to the presence of energetic electrons. Also it should be noted that,

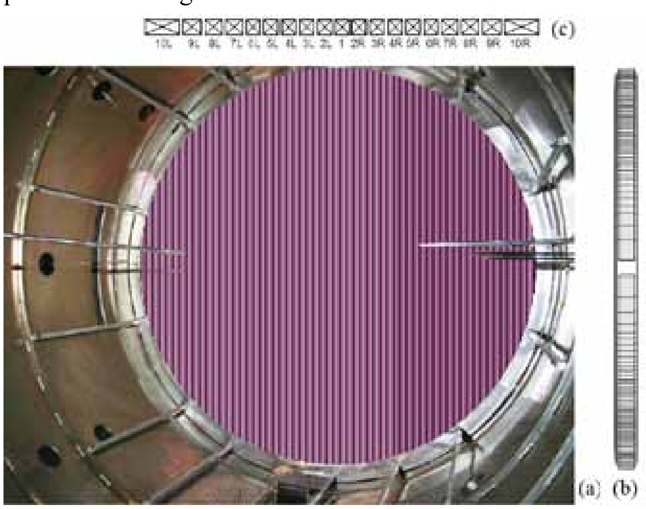

Figure A.3.1.3: Shows (a) photograph of the installed EEF in LVPD, (b) the side view of its cross-section and (c) the top view showing the extent of respective coils

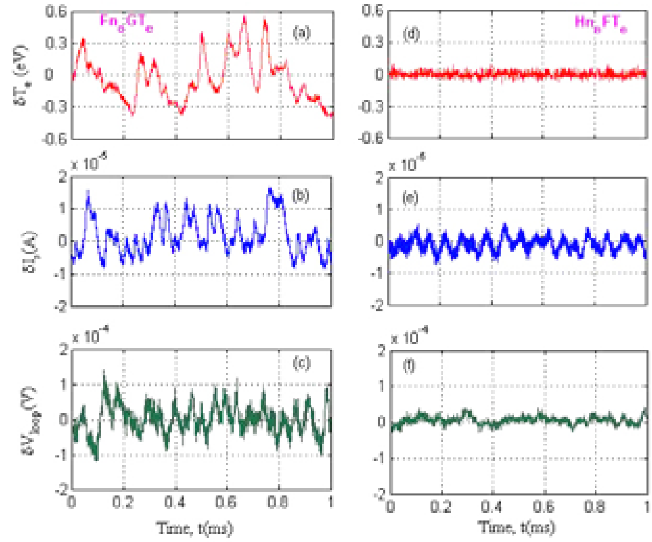

Figure A.3.1.2: Time series for fluctuations is shown for the EEF active (a-c) and inactive (d-f) cases.

ETG turbulence is excited only in the case of FneGTe and remains absent in HneFTe. A successful excitation of temperature fluctuations in FneGTe and their absence along with density and potential fluctuations in HneFTe case is the hallmark of our investigations. This is a wonderful proof for the excitation and validation of the observed turbulence as ETG in any laboratory device [See Fig. A.3.1.1 and A.3.1.2]. This time we have attempted to present through our measurements various scales of plasma density and electron temperature possible in LVPD by varying spatially the activation area of EEF [See Figure A.3.1.3]. A large number of gradient scale lengths are excited which are suitable for carrying out ETG study. We have thus successfully demonstrated that various

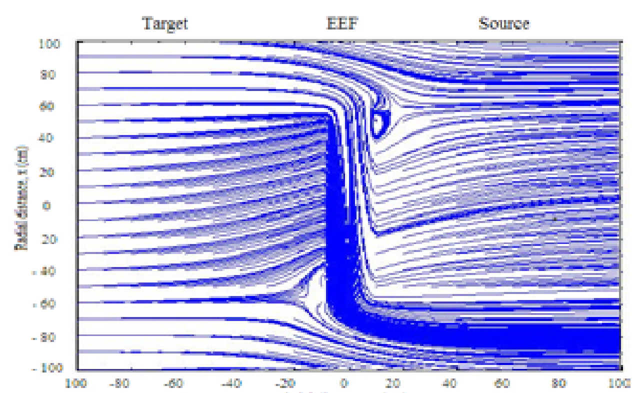

Figure A.3.1.4. The magnetic field pattern in LVPD after the installation of EEF is shown combinations of plasma profiles are excited for carrying out ETG turbulence study. These can be utilized in providing a scaling law to the observed ETG turbulence and carrying out plasma transport study. Investigations for the plasma transport in the background of ETG turbulence are presently initiated and initial efforts toward investigations of non-linear structures in LVPD is already made. Results from these investigations are yet to be consolidated.

Sandwiched Low Beta Plasma between two High Beta Plasmas : The experiments are carried out aiming to understand the plasma transport and turbulence in the vicinity of the EEF region. As described, the EEF divides LVPD plasma into three distinct experimental regions, namely, source, filter and target regions. It is observed that the plasma parameters largely remain unchanged in these three regions when EEF is not activated. On the other hand, activated EEF, produces a strong transverse magnetic (Bperp ~ 160G) field against axial magnetic field (Bz ~ 6.2G)of LVPD. The plasma parameters like plasma density, ne, floating potential, Vf, plasma potential, Vp, and electron temperature, Te measured on the axis of the system have shown sharp gradients axially in the EEF region. Major inferences are concluded from these measurement of floating potential, an indication for electron temperature: 1) strong EEF field selectively stops the energetic electrons in the source region from passing through the EEF region to target region. 2) The energetic electrons are more visible in the source region. 3) The target region is devoid of energetic electrons and is filled with thermal cold electrons. These observations has given speculations over the energetic electron loss path and involved loss mechanism. The simulation for the EEF magnetic field has shown that the magnetic field lines enter the EEF from the source region and after traversing a distance within EEF leaks out in the target region [See Figure A.3.1.4]. We believe that thermal as well as the hot electrons must follow the magnetic field lines from the source region and should get transported to the target region through EEF. The loss mechanism involved of energetic electrons in the presence of EEF field becomes an

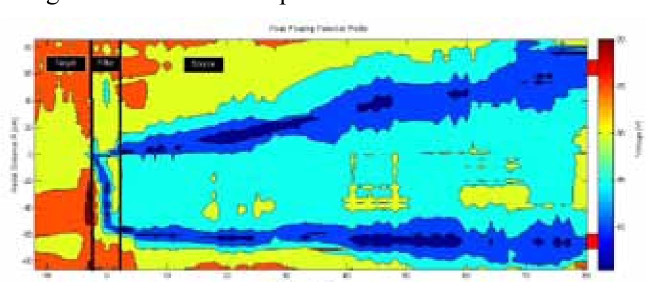

Figure A.3.1.5 The tracing of energetic electrons present in the plasma of LVPD in the presence of activated EEF field

interesting problem for understanding of physics of electron energy filter. This has encouraged us to trace the pathways of these energetic electrons, the experiments were carried out to scan the entire X-Z plain in the source, EEF and target regions by employing Langmuir probe arrays. The peak values of floating potential are chosen as the basis for the detection of the energetic electrons. Figure A.3.1.5 shows the tracing path of the energetic electrons in the LVPD system. The red boxes show the filament locations in the system. The observation shows that 1) these energetic electrons are not getting lost to the walls in either direction of the LVPD system. 2) the energetic electrons remain in a band in the source and EEF region and clearly indicate the filament locations as the source of their origin. 3) target region didn't show any traces of energetic electrons. 4) the loss path is still not clear to us. The outcome of these observations has not led us depict exact path of energetic electrons. The experimental observations offer altogether a different scenario. No leaking of energetic electrons is taking place to the target region. Whereas the loss path as speculated on the basis of magnetic field lines supports the cause that these energetic electrons should get lost to the device or should at least try to reach target region from the periphery. Further, attempts are made to carryout measurements over the entire (X, theta) plane so that leaking tracks for these energetic can be established. The measurements were then carried out in the azimuthal plane of the LVPD system to find out exact loss mechanism and path of these energetic electrons. An array consisting of 32 Langmuir probes mounted on an axial probe shaft and rotated through

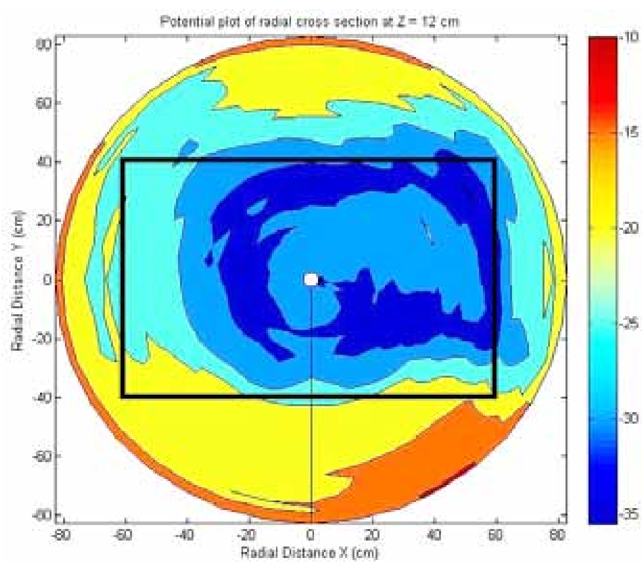

Figure A.3.1.6 The tracing of energetic electrons present in the complete azimuthal plane at z=12 cm from filamentary source

360 degrees in azimuthal plane in steps of 10 degrees, to trace the pathways of energetic electrons [See Figure A.3.1.6]. The measurements were carried out at several z locations in source region, EEF region and target region. Interestingly, we have found out that the energetic electron reside within a band in azimuthal plane and does not show any loss path leading to the walls of the device in any direction. The observations are summarized as 1) the energetic electrons may not be getting lost to the system wall at all; 2) turbulence in the energetic belts may provide a channel for the loss of energy for these energetic electrons. These are just speculative conclusions and needs further investigations by making use of more accurate diagnostic tool called energy analyser. We are presently developing these in the laboratory. We are also carrying out investigations on plasma turbulence in the energetic belt region of the source plasma to unfold the mechanism of exciting turbulence by these energetic electrons.

System upgradation : During last year a major system up gradation activity in LVPD is undertaken towards developing an automatic probe drive system for the probe movement. We have successfully developed An automated computer controlled linear probe drives capable of taking measurements over a of 1.5 meters length was developed. These are now an integrated part of LVPD system and are installed on several radial ports. These probe drives operate are operated remotely by computer through a Lab-VIEW based GUI interface. This facility is capable of providing movement to a single or multiple linear drives at a time. This has facilitated the device in making measurement by smooth operation, exact probe positioning, and measurement accurately within 1 mm of spatial resolution. This will substantially reduce the experimental time and reduce manually imposed deformations to the probe shafts. Future plans include making this facility for all 14 radial ports of the LVPD.

A.3.2. Basic Experiments in Toroidal Assembly (BETA)

Experimental study of generation of fluctuations-driven flow in and mean profile sustenance in BETA : Major part of the experimental campaign in BETA during this period was continuing the studies in Fluctuation-Flow cycle and generation of self-consistent poloidal flows. A manuscript on the role of ion mass in the fluctuation and intrinsic flow generation got accepted during this period. The observations and new findings in BETA were presented in posters and seminars at reputed institutions and international / national conferences. With the use of advanced data analysis techniques, nonlinear aspects of observations made in BETA plasma were investigated. The results of this analysis indicating nonlinear phenomena were summarized into a manuscript and submitted to an international journal recently. In order to begin a fresh experimental campaign using vertical magnetic field to control parallel wavenumbers, extensive maintenance activities such as necessary repairs were performed.

A.3.3. Interaction of Low Energy Ion and Neutral Beams with Surfaces

A new electromagnet was designed and got fabricated in a local company. The new electromagnet is energy efficient and more powerful compared to the earlier one. It has been designed to produce 3.2 times more magnetic field for the same electrical power (8 KW). Magnetic field was measured along the central axis from one end to the other. In the Helmholtz regime, i.e. from -5cm to 5cm a minimum of 1.2 KGauss was obtained with a maximum of 5% variation at both ends. Figure A.3.3.1 shows the complete profile of the magnetic field for 60A coil current. It is expected that when tested at its full capacity, i.e. 70A coil current a minimum of 1.4KGauss magnetic field will be produced at the centre which will be 3.2 times the magnetic field (436 Gauss) obtained with the earlier electromagnet with a maximum of 200A coil current (electrical power 8KW). Since the ion current varies as the square of the magnetic field for such plasma sources plasma density is expected to increase ten-fold. The ion current to the biased plate is found to be 500mA which is 8.33 times the previously measured ion current of 60mA. When tested at its full capacity, i.e. 70A coil current it can be extrapolated that ion current will see ten-fold increase to 600mA in line with the design of the new electromagnet.

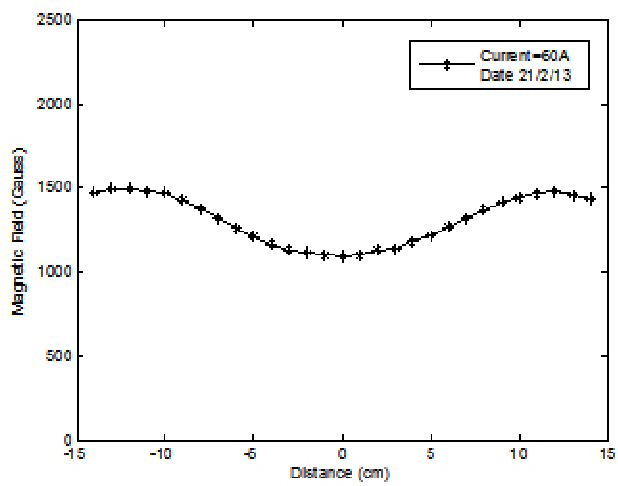

Figure A.3.3.1. Magnetic field profile with the new electromagnet.

A.3.4. System for Microwave Plasma Experiments (SYMPLE)

This project aims at studying the interaction between plasma and high power microwave (HPM). The basic objective is to delineate what causes the low frequency (microwave frequency << plasma frequency), but highly intense, electromagnetic waves to get absorbed in the plasma, as it is well known that plasma does not support propagation of low frequency waves as long as their intensity lies within the conventional level where the wave energy density is less than the plasma particle pressure. For the last four years, the investigations planned included study of extremely intense microwaves with plasma. For this, we have been developing a VIRCATOR based high power microwave source, potentially capable of yielding ~ 1GW microwave power, which can drive the plasma electrons weakly relativistic, upon their interaction with the HPM at the critical layer. The work carried out in this direction includes, development of an initial version of VIRCATOR constituting a compact, input pulse power (~18 GW) driving a diode that gives out microwaves in a broad band frequency, with integrated power of about a few Mega Watts, development of a washer gun plasma source satisfying the critical criteria in terms of density ($\sim 1\times10^{12}/cm^3$), about 1 m axial uniformity, ~10 cm radial uniformity and a sharp gradient of ~10 cm. While efforts are on to carry out simulation and appropriate design modifications on the VIRCATOR so that required power level, to study relativistic effects, is achieved, we have now taken up investigations on waves having moderate power levels, so that wave plasma interactions involve parametric effects leading to formation of ion density depressions which trap the wave, followed by growth of the wave field and the cavity by mutual enhancements. The HPM power required for these studies is ~ few Mega Watts. Investigations in this regime would now help widening the physics issues that can be addressed with regard to HPM plasma interaction, ranging from linear, through weakly nonlinear to relativistic effects. The work carried out in this direction include parameter estimation for wave-plasma interaction studies under weakly nonlinear regime, where the HPM requirement is not that stringent as in VIRCATOR and conceptualization of a scheme to study weakly nonlinear wave-plasma interaction. We are developing a magnetron based, narrow band (3 GHz), pulsed (4 micro-s) microwave system, the output of which would be coupled to a washer gun plasma source. Apart from adding a new arena of investigations as discussed above, continued experiments in the direction of additional plasma and microwave diagnostics include carrying out optical measurements to cross check density and temperature of plasma, characterization of the HPM output by splitting the power of single shot outputs to various channels and detecting the output resolved to different frequencies, using appropriate detectors of various frequency bands.

A.3.5. Plasma Wake-Field Acceleration Experiment (PWFA)

The absorption and emission spectroscopy experiments for the characterization lithium vapor and plasma were initiated using the new 0.01 nm resolution spectrometer and confirmed the low resolution measurements made earlier. The emission spectrum of Li-I at 610 and 670 nm shows a dependence that could be correlated to the vapour density and hence the electron density in the plasma. Studies are being continued for different configurations of heat pipe oven profiles which were arrived at and investigated theoretically by both ANSYS FEM analysis. The heat pipe oven was analysed with 3 mbar to 10 mbar of helium buffer gas pressures at which the normal PWFA experiments would be carried and the temperature profiles found to be not much different from the earlier observations at buffer gas pressures at 200 bar to 600 mbar. The low pressure studies incorporated additional precautions that needed to be taken care to protect lithium stock inside the chamber from impurity and from oxidation. The experiments were also carried out over an extended length of SS mesh pipe to ensure proper condensation of lithium well inside the cold zone and higher quantity of lithium as compared to earlier experiments. A total of 50g of Li was used in the current experiments to ensure that adequate Li is available to coat the entire length of the extended mesh. FEM studies also indicated that higher quantity of lithium was required for the extended mesh. FEM study with a three section heater segments was also initiated. By using a 3-segment heater, it would be possible to control the oven temperature more precisely as compared to a single heater system. Results show that the length of the column over which the temperature remains constant could also be extended using this configuration and also the temperature profile at the transition from hot to cold sections can also be modified. This heater has been designed and is under fabrication. Special experimental setup to demonstrate lithium neutral as well as plasma absorption and emission lines was arranged for the DST SERC School on Tokomaks and Magnetized Plasma fusion held at the Institute from 25th February to 15th March 2013. Eight batches from the participants were introduced to excimer laser system and the experimental setup and given hands on experience with spectroscopy and related measurement and analysis of the laser photo ionized Li plasma. The heat pipe oven heaters were replaced twice after burn out with new and improved versions by way of insulation and in the number of temperature sensors. This has contributed better temperature profiles. Major components for interferometry experiment, viz., CO_2 laser and associated optical components, and opto-mechanical components have been received during this period and steps are being taken to incorporate these into as is required in the further advancement of the experiment. An important addition to the equipment is the newly procured pico-second streak camera which was taken to the Raman Research Institute at Bangalore for acceptance tests as well as for operational training. Some experiments are being planned to be undertaken in collaboration with RRI Bangalore in the coming months, with picosecond laser.

A.3.6. Experimental study of non-linear plasma oscillations

The primary aim is to study non-linear plasma oscillations and other nonlinear modes experimentally. For this purpose an experimental set up has been designed and fabricated in house. The fabrication is being been done in two phases. The vessel consists of a source chamber of diameter 0.5 m and length 0.5 m and a main chamber of length 2.1 m and diameter 15.5 cm. Initially 10 wire wound handmade magnets are used. These magnets can produce a magnetic field of 100 G to 130 G under normal operation. The first plasma in the present system was produced in June 2012. Since then a number of experiments have been carried out. The variation of plasma density and temperature has been studied by varying the discharge voltage, filament heating current and background pressure. In the process primary diagnostics have been developed that will be useful in the main experiment. Proof of principle experiments were carried out in this device. The results have been encouraging. The major achievements in the current system include achievement of base pressure of 6 X 10^{-7} mbar using Diffstack, production of electron impact ionization plasma in a linear magnetized vessel at a low operating pressure of 3 X 10^{-5} mbar and the quiescence of the plasma produced was found to be around 1%. A large variation of plasma temperature and density has been achieved in the vessel. Temperature has been varied from 5 to 11 eV. Density has been varied from 10^8/cc to 10^{10} /cc. The magnet system will be upgraded in the near future. The wire wound magnets will be replaced by ETP copper tubes magnets fabricated in house. These new magnets will be capable of producing 1.8 kG using the current facilities in the lab. With a bigger power supply greater values of axial magnetic fields can be produced. A new extension of the vessel will also be added. The total length of the vessel will become ~ 3.2 m. With the new system, the range of magnetic field over which the experiments can be conducted will increase drastically. A lowering of the lowest operating pressure is expected. A greater variation of the plasma density and temperature is expected in the upgraded set up.

A.3.7. Experiments on Dusty Plasma

Dusty Plasmas contain solid particles (dust) of nano- or micron-sized which when inserted in plasma get charged. Because of the high mobility of electrons, these particles generally get negatively charged. The charge on dust particles can be of the order of 10^5 e. After getting charged, these dust particles can levitate in the sheath and show various interesting phenomena. Till now it has been found that under the effect of a strong external magnetic field, the levitated dust particles can act as rigid rotors and show rotations in a direction perpendicular to the plane containing the electric field and the externally applied magnetic field. It has also been found before vertical dust rotation in the presence of temperature gradient of neutrals (due to thermo-phoretic force). But in all these cases of dust rotation, they have applied either external magnetic field or temperature gradient. We have used both parallel plate RF and DC glow discharge techniques to produce dusty plasma. Dust rotation has been observed in DC glow discharge and this rotation is not the result of any type of external magnetic field or thermo-phoretic force. The exact cause of this type of dust rotation is not known. The probable causes of this phenomenon are being investigated experimentally. This dust rotation has been found to be very sensitive to the applied discharge conditions as well as to the boundary conditions of the discharge producing system. Thus to measure these potential structures, we have developed a Langmuir probe with translational as well as rotational arrangement which is operational. Since we need to determine the XY profile of the potential, another Langmuir probe system with Rack-n-pinion arrangement has been developed in-house.

A.3.8. Multi-Cusp Plasma Experiment

The vacuum chamber has been delivered to the institute and has been commissioned successfully. The chamber was integrated with the already procured pumps and the gate valves. A base vacuum of 5E-7 mbar has been achieved without any baking. It is expected to improve once the cathode is heated for required temperature. After this the integration of the system has been commenced. The interface flange to hold the hot ionizer cathode has been fabricated. The core material for the electromagnets has been arrived and the purchase order for the winding has been issued. The cesium oven is being redesigned to accommodate the cesium capsules acquired and also incorporating the experience gained from the testing of the oven at Negative Ion-Beam experiment system. The indirectly heated probes for the diagnostics of the plasma is getting readied.

A.3.9 Non-Neutral Plasma Experiment (SMARTEX-C)

The non-neutral plasma system (SMARTEX – C) is going through a major upgrade from low field (200G), short pulse (30ms) and moderate vacuum levels (10^{-7} mbar) to high field (1kG), long pulse (1s) and ultra high vacuum levels (10^{-8} mbar). While the up gradation process is going on in full swing, some of the test experiments that have their own vital importance and fulfill the essential prerequisites for final upgradation are being done. Some of the experiments that have been carried out and other developmental steps taken so during the period have been listed below:

Injection characterization of filament – Observations : Electron injection studies under various conditions in DC mode are carried out. Emission current from filament, depends on different parameters i:e: bias voltage on grid, filament current, magnetic field, and pressure. Richardson-Dushmann's equation gives the relation of space charge limited emission current from the filament as a function of temperature (filament current). As the bias voltage applied on injector grid is increased, emission current increases in accordance with Child's law and at a certain voltage all the electrons from the filament are extracted and emission current gets saturated. This saturation bias increases with the filament current. Toroidal magnetic field applied causes electrons to undergo EXB drift along the direction of filament curvature and reduces the emission current. This results in higher saturation bias voltage needed to extract all the electrons under the influence of magnetic. As the transparency of the grid decides the amount of electrons being sent into the trap, transparency of the grid in above case has been studied and found that physical transparency of the injector grid is 60–65%. Magnetic field changes the transparency of the collector grid, which depends the Larmor radius of the electrons. This needs further work to investigate in detail. Collector gird condition matters during the experiment, if one keeps the collector grid floating, then one develops the space-charge build-up inside the trap which stops further pumping of electrons, once the space charge equivalent to grid-filament potential is developed. While if one grounds the collector grid continuous electron beam is formed, but this scenario is different to the experiment one. Hence, pulsed injection experiments are further needed to be done.

New Procurements : Procurement of a new rotary pump, design and fabrication of the integrated support structure for the rotary – turbo - cryopump combine have been done. The new Pfeiffer-make Penta – 35 rotary pump has been installed, tested, and integrated with SMARTEX-C. Activation of various preventive interlocks has also been performed and successfully tested.

Improvement of Charge Collector Diagnostics : With improved displacement current cancellation scheme, the charge collector diagnostics has been tested on to a model that simulates the vessel and electrodes. As can be seen below, the cancellation of displacement current is observed up to 40-50 mA which is an improvement in noise by a factor of two.

Re-commissioning of SMARTEX-C, which include the following steps: (i) New Tungsten filament mounted; (ii) Wireseal for top flange of vacuum-vessel fabricated and commissioned; (iii) Baking of the vacuum vessel at 200 degree C; (iv) Winding of Toroidal Field coil ; (v) Base vacuum achieved up to 1.1 x 10^{-8} mbar and 4.5 x 10^{-8} mbar when filament was 'ON'.

Rigorous analytical calculations : Solution of three dimensional Laplace equation to estimate the potential profile due to an insulated electrode having racetrack geometry placed inside a grounded box have been performed.

Development of the primitive version of a charging and control circuit for PFN : With the provision of 'Fail Safe Charging' the control circuit has been designed, fabricated and successfully tested on the PFN (Pulse Forming Network)

A.3.10 A Linear Helicon Plasma Device with Controllable Magnetic Field Gradient

A linear helicon plasma source with diverging magnetic field is designed and installed at IPR. Helicon antenna produced plasma has been characterized and evidence of helicon waves has been reported earlier in a linear helicon plasma device with a variable magnetic field gradient. The special feature of this machine consisting of two chambers of different radii is its capability of producing different magnetic field gradient near the physical boundary between the two chambers either by sending current in one particular coil in the direction opposite to that in other coils and/or by varying the position of this particular coil. Although, the machine is primarily designed for CFDL experiments, however, it is also capable of carrying out many basic plasma physics experiments such as wave propagation, wave coupling and plasma instabilities in a varying magnetic field topology. In a Helicon plasma the density increases linearly with magnetic field but at low magnetic fields typically below 100 Gauss, many research-

Figure A.3.10.1 Experimental set-up of the linear Helicon plasma device

ers have observed the density not behaving linearly rather peaks for a certain magnetic field. We have observed the same phenomena in our experimental set up at 25 Gauss and additionally observed another density peak around 50 Gauss.

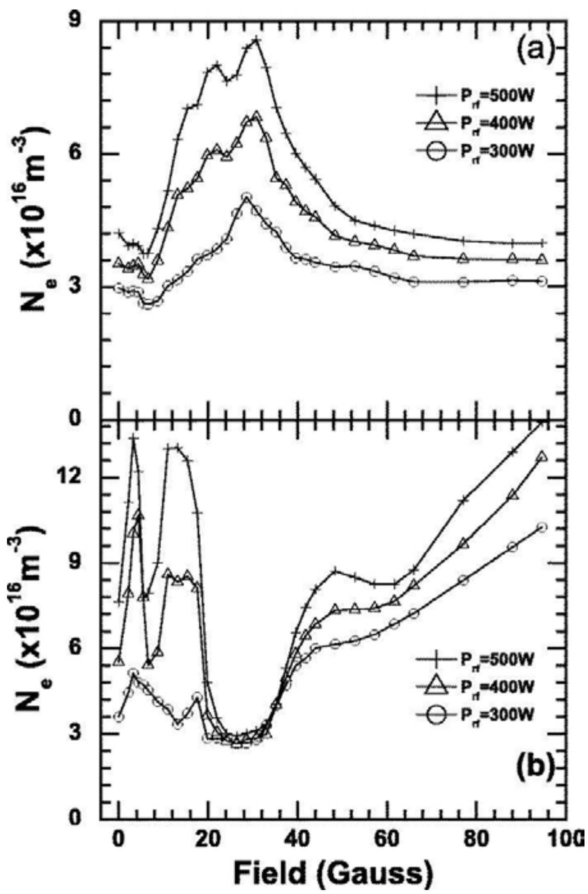

Figure A.3.10.3 Variation of electron density (n_e) with magnetic field (a) n_e at +18 cm and (b) n_e at –18 cm

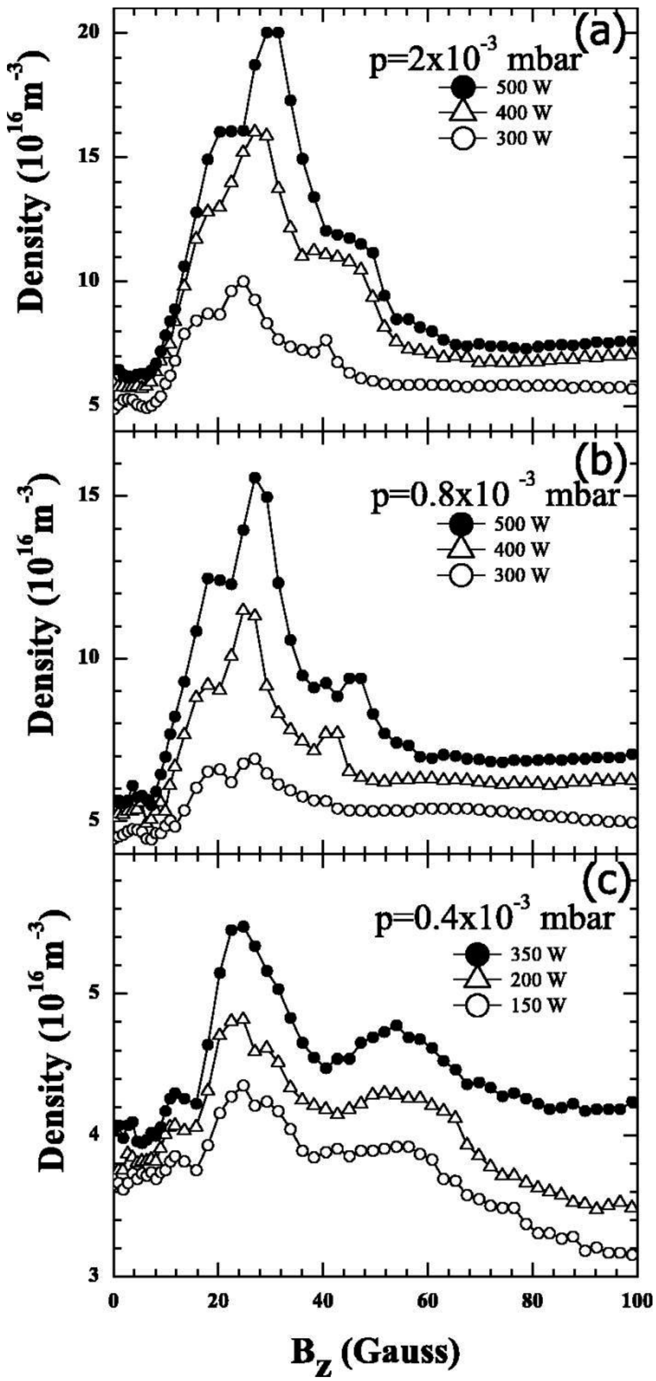

Figure A.3.10.2 Plasma density on axis at z=20 cm versus magnetic field. (a) 300 W, 400 W, and 500 W RF powers, p=2X10^{-3} mbar, (b) 300 W, 400W, and 500 W of RF powers, p=0.8 X10^{-3} mbar, and (c) 100 W, 200 W, and 350 W of RF powers, p=0.4X10^{-3} mbar.

The results are explained on the basis of oblique cyclotron resonance of right circular polarized helicon waves. With an experimental set up where the radial plasma dimension is less than the axial dimension, finite perpendicular wave number exists, which forces the helicon wave to propagate at an angle to the magnetic field defined by the ratio of parallel and total wave number. The wave propagation angle coincides with the resonance cone angle for magnetic fields of 25 Gauss and 50 Gauss. When the wave propagates in a resonance cone, the wave can have large electrostatic components which can trap and amplify any normal mode of the plasma. We have observed increased potential fluctuations at these resonant magnetic fields and explained the density peaks as a result of potential fluctuations depositing energy in the plasma. Right circularly polarized helicon waves can have a resonance but left circularly polarized helicons are not supposed to have cyclotron resonance. To see this experiment is carried out on both sides of the antenna and also by changing the magnetic field direction. In both cases it is found that the peak around 25 Gauss on the m = +1 side is absent in the m = -1 side. Additionally two peaks are observed on m = -1 side for 5 Gauss and 12 Gauss which have higher density as compared to the density on the m=+1 side for the corresponding magnetic fields. The peaks on the m = -1 side are explained on the basis of polarization reversal mechanism of electromagnetic waves where a left polarized wave's polarization becomes right polarized and vice versa. Polarization reversal has already been observed in microwave frequencies with pure parallel propagation. This experiment is the first in which the results are explained on the basis of polarization reversal in the radio frequency (13.556 MHz) regime.

A.3.11. Magnetized Beam Plasma Surface Interaction Experiment

Plasma is generally viewed as a swarm of energetic electrons like sprightly kids dashing around playfully with massive positive and negative ions with limited mobility like leisurely members of a family. This family of charge particles is bound through intrinsic electric field that sets-up whenever opposing charges tend to separate. Like in an ideal family a harmony is set with in the plasma through establishing a quasi-neutral equilibrium between electrons and ions. The positive ions are mainly responsible for governing the so called "ambipolar flow" of charges towards the wall. However the rate of ions flowing towards the wall is rather influenced by agile electrons whose thermal energy much exceeds than positive ions. This may be thought of as the older generation trying to keep the pace with the new trends. The quasi-neutral equilibrium can be violated, at least locally when plasma comes in contact with a foreign object. This could be the walls of the vacuum chamber, discharge electrodes, electric probes or the radio-frequency antennas introduced inside the plasma for exciting electromagnetic waves. In fact it is difficult to imagine laboratory plasma that is completely free from the influence of external electrodes. One possible way to keep the plasma constrain is by applying infinitely long magnetic field. The magnetic field acts like a barricade for the charged particles those tending to cross the field lines. One important aspect concerning plasma wall interaction in fusion devices is the fate of materials that are exposed to immense plasma power of 50 MW/m^2. When such intense plasma comes in contact with a small part of plasma facing components namely limiters and diverters in a fusion device, it can cause erosion and ablation of material from the surfaces, hence reducing their life time drastically. Therefore research efforts are focused towards finding newer ways that can help in spreading the energy over large surface area. Such key concepts can be studied through basic experimentation in laboratory. For this purpose prototype experiments are planned on a Linear

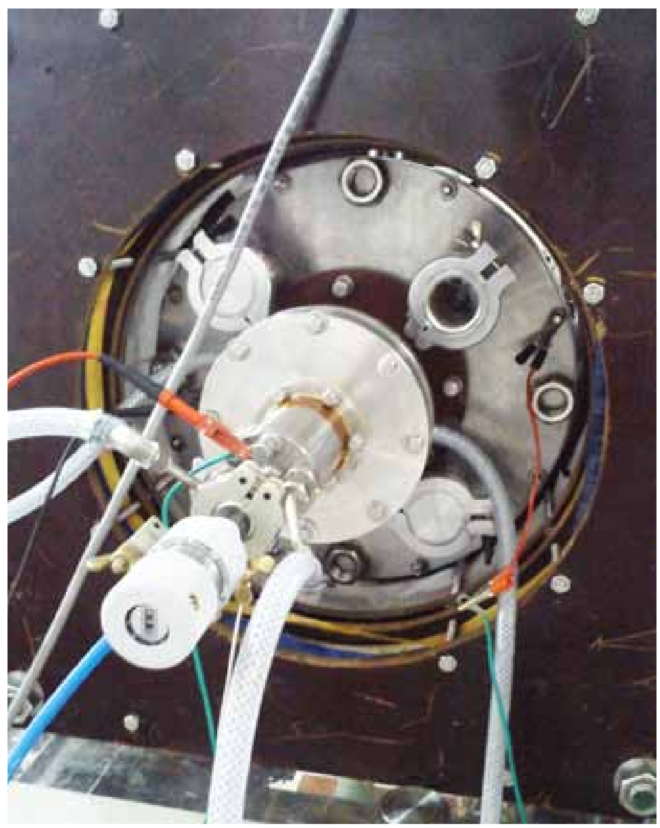

Figure A.3.11.1: Water-cooled cylindrical magnetron plasma source

Plasma Device that is currently being developed at the Institute. The Linear Plasma Device aims to address key physics and technological issues pertaining to plasma interaction with external electrodes exposed to intense magnetized plasma. The device shall help in addressing various fundamental aspects related with plasma-material interaction, plasma diagnostics and intense plasma sources. For the production of intense plasma a magnetron source is currently under investigation. The source can produce intense plasma of 5.0 cm diameter that is guided by strong axial magnetic field up to a distance of 50 cm from the source. In the next phase we are aiming to design water-cooled electromagnets for the Linear Device and systematically characterize the magnetron source by operating in both DC and Pulsed DC mode. In addition to this we have developed a microwave plasma diagnostics called resonance hairpin probe. This diagnostic is useful for measuring local electron density with very high accuracy. In the last decade this technique has attracted significant interest for diagnosing industrial plasmas such as the one demonstrated in plasma deposition system and phase resolved measurement of electron density in dual frequency confined capacitive coupled discharge. For all those applications, normal Langmuir probes is found to be unreliable because of many uncertain factors such as particle trajectories around the probe tips, probe's surface contamination, and stray circuit impedance that includes the properties of the reference electrode. The overall experimental program is multidisciplinary in nature and provides exciting opportunities of physics and engineering research through the engagement of M.Tech and PhD students in various areas of basic plasma physics, instrumentation and plasma diagnostics.

A.3.12 Plasma Torch Activities

High power torch development **:** A plasma torch is a device which harnesses the unique properties of the thermal plasma for many processing applications such as spraying, nano-powder generation, melting, smelting, aero-thermal testing of materials etc. Plasma torches have been developed with very high efficiency (> 80%) in the power range of 10 – 25 kW. High power source and heat exchanger have been procured and efforts to up-scale the powers to approximately 100 kW are underway. The plasma torch developmental activities are being complimented by computational efforts. A steady-state finite-volume computational model for the torch is already available with collaboration from BRFST project. The model has been used to validate successfully many results from experiments; improvements in the model are in progress to simulate complex geometries such as incorporation of stabilizing shroud gas and external magnetic field. First-cut enthalpy probe has been designed and fabricated; calibration and miniaturization is under progress. This probe will essentially be used to explore the temperature and flow pattern in the plasma plume profile; data will be fed to the numerical model which will enable further improvements in model as well as torch designs.

Studies on fundamental processes **:** Fluctuations of the plasma parameters inside a thermal plasma torch result in complex interactions among the electromagnetic, fluid dynamic and thermal fields present inside. Thus, an investigation of the origin of plasma fluctuations inside the plasma torch becomes imperative in order to understand the mechanism of growth or suppression of the plasma instabilities and explore the transition from stable to unstable modes. Experimental investigations on the role of external magnetic field and return current closure in the force balance mechanism of a plasma torch were carried out. The plasma torch used was of low power and had wall, gas and magnetic stabilization mechanisms incorporated into it. The return current closure was used as a tool to explore this phenomenon. It was found that in the presence of an external magnetic field, a new centrifugal force emerges that acts on the highly ionized plasma arc column as well as the non-thermal plasma sandwiched between the column and cold gas boundary layer. The total force attains a complex three-dimensional form and alters the overall force balance on different parts of the plasma and the net force acts in such a way that plasma reorganizes itself. To explore the fluctuations in the plasma arc column and root, magnetic probes were used. Plasma torch was designed to accommodate the probes inside the cooling water channels. While the probes cannot detect dc fields, they do detect transient fields due to the fluctuations. Detailed analysis and interpretation of the results is in progress.

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A.4. Theoretical, modeling and Computational Plasma Physics

Plasma physics requires a very intense computational capability for its modelling and simulation program.The institute has developed a versatile computational facility in many years. At present work is being done in the the following heads:

A.4.1. Basic Plasma Studies

Residual Bernstein-Greene-Kruskal-like waves after one-dimensional electron wave breaking in a cold plasma: 1-D particle in cell simulation of large amplitude plasma oscillations is carried out to explore the physics beyond wave breaking in a cold homogeneous unmagnetized plasma. It is shown that after wave breaking all energy of the plasma oscillation does not end up as random kinetic energy of particles but some fraction which is decided by Coffey's wave breaking limit in warm plasma, always remains with two oppositely propagating coherent BGK like modes with supporting trapped particle distributions. The randomized energy distribution of untrapped particles is found to be characteristically non-Maxwellian with a preponderance of energetic particles.

Spatio-temporal evolution and breaking of Double layers: A description using Lagrangian hydrodynamics: The nonlinear development and collapse (breaking) of double layers in the long scale length limit is well described by equations for the cold ion fluid with quasineutrality. It is shown that electron dynamics is responsible for giving an equation of state with negative ratio of specific heats to this fluid. Introducing a transformation for the density variable, the governing equation for the transformed quantity in terms of Lagrange variables turns out exactly to be a linear partial differential equation. This equation has been analyzed in various limits of interest. Nonlinear development of double layers with a sinusoidal initial disturbance and collapse of double layers with an initial perturbation in the form of a density void are analytically investigated.

Wave breaking phenomenon of lower-hybrid oscillations induced by a back-ground inhomogeneous magnetic field: We have studied the space-time evolution of lower hybrid oscillations in a cold quasi-neutral homogeneous plasma in the presence of a background inhomogeneous magnetic field. Within a linear analysis, a dispersion relation with inhomogeneous magnetic field shows "phase mixing" of such oscillations. By using Lagrangian variables, an exact solution is presented in parametric form. It is demonstrated that initially excited lower hybrid modes always break via phase mixing phenomenon in the presence of an inhomogeneous magnetic field. Breaking of such oscillations is revealed by the appearance of spikes in the plasma density profile.

Simulation of phase mixing of Upper Hybrid oscillations in the presence of an inhomogeneous magnetic field: Spatiotemporal evolution of large amplitude upper hybrid oscillations in the presence of an inhomogeneous magnetic field is studied numerically using the Dawson sheet model. It is observed that the inhomogeneity in magnetic field causes the upper hybrid frequency to acquire a spatial dependence, which results in phase mixing and subsequent breaking of the upper hybrid oscillations at arbitrarily low amplitudes. This result is in sharp contrast to the homogeneous magnetic field case where upper hybrid oscillations break, when the perturbation amplitude exceeds a certain critical amplitude and in a time scale which is a fraction of the period of oscillation. The phase mixing (wave breaking) time scale which is measured by the time of crossing of sheets in the Dawson sheet model is found to depend on inhomogeneity scale length, strength of the magnetic field perturbation and the density perturbation amplitude. This result is in agreement with recent nonlinear calculations reported in [Chandan Maity et. al., Phys. Rev. E 86, 016408 (2012)].

Study of sheath criterion in a magnetized multiple ion species plasma: Plasma sheath is a nonlinear electrostatic potential structure formed by a steady-state flow of plasma in to an absorbing boundary where plasma meets a surface. A study is done of the entry criterion for the plasma flow into this electrostatic boundary layer, or sheath, forming in a magnetized multiple ion species plasma. Finding valid entry velocity combinations in a magnetized set up requires a magnetized equivalent of the generalized Bohm criterion. A magnetized generalized entry criterion is obtained with the scale length distribution in a region of validity for the stable solutions. The analysis finds that the valid entry flow velocity combinations with distinct values of individual ion species can correspond to a unique system phase velocity. Magnetization effects govern the region of validity whose boundaries collapse to the unmagnetized sheath criterion in the limit of normal incidence, independent of the strength of the magnetic field. Considerably smaller entry velocities, in comparison to the unmagnetized system sound velocity, are recovered for the species in appropriate regime of magnetization in the cases of oblique incidences.

Analysis of EMHD wave propagation in radially nonuniform magnetic field: The Electron Magneto-Hydrodynamics (EMHD) model explains a large variety of electromagnetic waves that propagate in laboratory and astrophysical plasmas. The propagation of an (EMHD) waves is analyzed theoretically in a set up with radially varying ambient magnetic field. The wave magnetic field can be localized to finite radial extent by the magnetic field as the asymptotic solutions of the corresponding eigen value equation limit the wave propagation at larger radii. The critical radius for propagation of a helicon like bounded EMHD mode is found to be determined by the radial scale length of variation of the ambient magnetic field in combination with the parallel wave vector. The results potentially explain the bounded propagation of the EMHD waves observed in the experimental conditions as assumed in the present analysis.

1D Vlasov Plasma Simulations : An Eulerian-grid Vlasov-Poisson solver based on the Piecewise Parabolic Method (PPM) advection solver has been developed. This code was benchmarked to Arber and Vann's results using a linearized Vlasov Ampere complex eigen value solver developed at IPR during June – Aug 2012. In order to use the solver to study nonlinear Landau damping and formation of BGK-like structures, the solver was benchmarked to Manfredi's results. By the end of August, the Vlasov-Poisson solver was benchmarked and found suitable to compute nonlinear Landau damping. We then studied nonlinear Landau damping up to t~3000 (in inverse plasma frequency) for a specific set of distributions called q-distributions for the cases $q<1$ and $q>1$, where $q=1$ corresponds to a Maxwellian. We found that, for $q<1$, these BGK structures are limited by an increasing damping rate with decreasing q, and for $q>1$, the BGK structures were, under conditions of non-zero damping rate, were limited by an upper limit on k. we modified the Eulerian Vlasov solver code to include mobile ion background, as opposed to the stationary static constant ion density background which we have previously had. Further work was done to add and benchmark the ion component of the solver. Through an extensive literature survey, sample problems were isolated which were deemed appropriate for the benchmarking. Examples include, the phenomena of anomalous resistivity and magnetic reconnection in collisionless plasmas because of ion-acoustic turbulence, formation of jets in relativistic plasmas, and study of sheath formation in a plasma bounded by a conducting wall. There is a need to implement a higher-order advection solver, and simultaneously parallelize the solver.

A.4.2 Laser-Plasma Studies

Exact analysis of particle dynamics in combined field of finite duration laser pulse and static axial magnetic field: Dynamics of a charged particle is studied in the field of a relativistically intense linearly polarized finite duration laser pulse in the presence of a static axial magnetic field. For a Gaussian shaped pulse, exact analytical expressions are derived for the particle trajectory, momentum and energy as a function of phase of the laser pulse. From the solutions it is shown that, unlike the monochromatic plane wave case, resonant phase locking time between the particle and the laser pulse is finite. The net energy transferred to the particle does not increase monotonically but tends to saturate. It is further shown that with appropriate tuning of cyclotron frequency of the particle with a characteristic frequency in the pulse spectra can lead to the generation of accelerated particles with variable energies in MeV-TeV range.

Laser plasma interaction with few-cycle ultra-short light beam: Electron acceleration from a near critical density overdense plasma (steep density gradient) slab is studied using electromagnetic particle-in-cell simulation with normally incident few-cycle Gaussian light beam. It is observed that in the sub-relativistic regime energy gain by electrons is almost same for single-cycle and five-cycle pulses. For ultra-high intensities five cycle pulse produces more energetic electrons due to its longer penetration and subsequent supply of energy to a larger number of electrons under its envelope. The single-cycle pulse although penetrates deeper at a higher intensity it can only effect less number of electrons under its envelope. We have also found angular dependence of fractional absorption at different laser intensities, with a maximum fractional absorption at 60 degrees. The second harmonic signal at normal incidence of incident light strongly suggests JxB heating mechanism. Further investigation of this result is in progress.

Ionization, absorption and anisotropic Coulomb explosion of laser driven nano-cluster: Atomic clusters (typical size of a few nanometer) have caught attention in recent years to produce (i) energetic electrons, (ii) ions, (iii)X-rays after the irradiation with intense femtosecond laser light. Nuclear fusion was also shown possible with laser heated deuterium clusters. Laser cluster interaction studies are often limited to the collision-less case. However number of experiments have shown unexpectedly higher charge states of rare-gas cluster ions at sub-relativistic laser intensities with 800 nm near-infrared laser pulses. These unexpected higher charge states cannot be explained with simple "ionization ignition model" and the "over-the-barrier" ionization model included in the particle-in-cell simulation code. We have included collisional ionization and binary Coulomb collision based on Monte Carlo technique to address higher absorption and ionization for argon cluster. Although higher charge states of argon due to collisions are observed in simulation, the discrepancy with the experimental results still remains. Another experimental finding of laser-cluster study is the anisotropic Coulomb explosion. We have examined asymmetric expansion of argon clusters illuminated by 800 nm laser pulses of duration 23 fs, using PIC simulation. For such a short pulse duration, laser energy absorption by cluster electrons is dominated by the nonlinear resonance (NLR) absorption process. Concentrating on the ionic outcome in the NLR regime, we observe that higher charge states of argon ions are produced along the laser polarization than in the transverse directions leading to the anisotropy (asymmetry) in the ion energy distribution. We further show that collisional ionization also plays a role in the anisotropic explosion of a laser-driven cluster, but this anisotropy is originally created by the collisionless absorption processes– the NLR–by which an electron gains sufficient energy to ionize an ion at a later time.

A.4.3. Fusion Plasma Studies

Derivation of Newcomb equation in toroidal coordinates to study Tearing mode stability in a toroidally flowing plasma: The effect of a sheared toroidal equilibrium flow on the tearing mode stability index is studied. We have worked on an analytic calculation of the tearing mode stability index in a toroidal tokamak geometry with an equilibrium sheared toroidal flow for finite beta plasma. A flow modified external kink equation for a single helicity mode is derived in a toroidal geometry. Our calculations are a generalization of the earlier work by Hegna and Callen [Phys. Plasmas 1, 2308 (1994).] that was done in the absence of flow. The corrections to the stability index arising from flow contributions are estimated on the basis of a boundary layer calculation. Toroidal shear flow is seen to have a destabilizing influence on the tearing mode in a manner similar to pure axial flows in a cylindrical geometry. However the increase in the stability index as a function of increasing flow is seen to be smaller than the cylindrical case due to beneficial magnetic curvature effects. Shear flow associated stabilization, as observed in many recent experiments, might be arising from other physical effects such as toroidal mode couplings which have been neglected in the present model.

Turbulence in Scrap-Off Layer in Tokamaks : Turbulence in Scrape-off layer (SOL) of tokamak plasma has been studied using interchange modes with the help of electron continuity, quasineutrality, and ion energy equations. We have studied dynamics of seeded plasma blob and plasma turbulence to identify the role of ion temperature and its gradient. The ion temperature elongates the blob poloidally and reduces its radial velocity. Initial dipole nature of the plasma blob potential breaks and generates few more dipoles during its propagation in the SOL. Plasma turbulence simulation shows poloidally elongated density and ion temperature structures that are similar to the seeded blob simulation studies. Fluctuations of the density and ion temperature have been presented as function of scale lengths of the density and ion temperature. Reduction of the SOL width and increase of radial electric field have been measured in the presence of the ion temperature. Particle and energy transports have been also presented as the function of the density and ion temperature scale lengths. Intermittent structure or plasma blob is a magnetic field aligned plasma structure that is considerably denser than the surrounding background plasma and highly localized in the directions perpendicular to the equilibrium toroidal magnetic field. In experiments and simulations, these structures are generally formed near the boundary between open and closed field lines. These blobs become charge-polarized under the action of an external force and move poloidally and radially outwards through the edge and scrape-off-layer (SOL) regions. A number of authors have detected such structures using probe data and gas puff imaging techniques. This work reviews the relationship between the experimental and theoretical results on the blob formation, dynamics and transport that are obtained since last two decades. The blob theory and simulations have been compared and validated against the experimental results.

3-D Simulations of Plasma Transport in open field line Scrape-off Layer region of a toroidal plasma in Aditya: A magnetically confined plasma in a toroidal MHD equilibrium shows sharp changes in transport properties at the transition from the region of closed field lines to one where field lines are open and meet with a material boundary. The tokamak Aditya has a circular poloidal ring limiter at one toroidal location and therefore its contact with plasma produces a complex 3D flow pattern in the open field line, Scrape-off Layer plasma region. In order to properly understand the plasma transport in this region, we performed full 3D simulations of plasma transport in the Aditya SOL taking the toroidal asymmetry introduced by the ring limiter into account. The toroidal asymmetry of the plasma parameters and flows indicate the importance of limiter as a localized sink of plasma. The plasma and neutral particle density show a corresponding variation in the toroidal direction as well as in its radial penetration depth. The plasma configurations are characterized by sharp gradients in the edge and show the presence of extended zones of large parallel flow shear in the SOL and edge regions. The plasma flow patterns show poloidal modulations which correspond to effects of a rational surface interacting with the limiter.

A.4.4. Global Gyro-kinetic studies

Linear global gyrokinetic simulations using EMGLOGYSTO : EMGlogysto Code has been improved to take advantage of optimised libraries resulting in smaller runtimes. With this, the runtime is reduced by a factor of 2. A second level of parallelisation is implemented using OpenMP threads to take advantage of modern multi-core processers. With this, EMGlogysto is now scale-free, meaning it takes the same time no matter how many plasma species is considered. For the 1-potential 3-species EMGlogysto, the code runtime is speeded up by a factor of 3 and for 2 species, by a factor of 2. EMGlogysto code has been improved vis-a-vis numerical handling. The code now uses less RAM memory and hence ports smoothly across different HPC installations. The code is tested to work on Clusters in Garuda Grid, Utkarsh in DAE Grid etc (Clustserver, IPR, Pleiades2). Feasibility studies were done to port EM Glogysto code to CUDA Fortran (GPU-parallelization), but not yet successful.

Physics Problems addressed:A low n electromagnetic mode due to the kinetic electrons is identified. Usually at this long wavelength regime trapped electron mode and universal drift mode are considered responsible for electron transport; these are however stabilized by the magnetic perturbation/ electromagnetic effect. However, another mode that becomes destabilized in the presence of electromagnetic perturbation is found in the low 'n' / long wavelength regime. The mode is driven by temperature gradient of electrons in the presence of finite beta. With beta the mode grows more and more unstable. Same is the case with the electron temperature gradient. A proper recognition with the drift modes available in the literature at this long wavelength is yet to be done. We suspect it is a kind of micro-tearing mode. However, further analysis, such as study of parity need to be carried out in order to vindicate that fact. High-n branch of global AITG mode by including non-adiabatic electrons in the electrostatic component of the potential fluctuations indicates existence of new branches. Effect of Shafranov shift on ITGs (electrostatic and electromagnetic versions) is known to be weak when the mode is local or high-n mode. However, for a global ITG this effect expected to be different at different flux surfaces which cuts the mode structure. Hence a more dramatic effect may be expected. Moreover, when the pressure gradient magnitude is comparable to the local shear, the mode structure dramatically alters yielding a sizeable difference in the mixing length estimate. This work is also under progress.

Nonlinear Global Gyrokinetic Simulation Studies: A novel two weight scheme proposed by W W Lee with coupled governing equations for background dynamics and the turbulence was implemented in PPPL code GTC. However, the background weights were seen to increase beyond one over long time simulations thus increasing the noise level. A revised scheme is being studied where periodic redistribution of weights to a background phase space grid is being investigated

A.4.5. Non-Neutral Plasma Studies

To investigate issues in toroidal and cylindrical magnetized plasmas a 2D and 3D PIC code is being developed. The following work was done: a) Some time was spent on experimenting with different numerical schemes of charge distribution, Poisson solving, and particle pushing, in the 2D PIC code to see which combination of numerical schemes gave best conservation properties of energy , momentum, and number of particles. b) The code now has essentially two versions - one with full particle dynamics, and the other with Guiding-Centre approximated motion of electrons. c) After settling the numerical issues, several new diagnostics were added to the code. d) After studies on methods of generating various types of random numbers (pseudo, quasi) and shortcomings of each of these generators, particle-loading schemes based to pseudo and quasi random numbers were developed to get desired initial distributions in x-space and v-space using suitable random number generators. e) Studies were done on how to OPEN-MP parallelize a code. f) The code was modified to be able resume its work after sudden halt, to cope with sudden power cut-offs and reduce time and energy spent. g) The code was OPEN-MP parallelized over particles. During all the stages of the above mentioned period relevant papers and other resources on the physics and computational parts of the PhD problem was studied, useful theories were documented, and all useful material were categorically stored in soft/hard format, for future reference. In the near future, physics problems will be addressed.

A.4.6. Molecular Dynamics Simulation

2D Molecular Dynamics: In the molecular dynamics code MPMD2D, several new diagnostics were added in this period, for example, dynamic scattering function, longitudinal and transverse current correlation functions, velocity autocorrelation function etc. Presently several interesting physics problems are being looked at.

3D Molecular Dynamics: During this period, a 3D Molecular Dynamics (MD) simulation code, earlier reported is being converted to 2D. In this code, diagnostics techniques, such as pair correlation function, self-diffusion coefficient, velocity autocorrelation function, shear viscosity correlation function and correlation function for thermal conductivity have been re-implemented. A number of experimental approaches have been proposed for studying pair ion plasmas in the laboratory and several of these are now being actively pursued. Therefore, in the near future, we are mainly interested to study pair-ion plasmas -their linear and nonlinear properties. Taking this plan into account, during the period an additional new diagnostics technique has been implemented to provide information about the spectra of longitudinal and transverse current fluctuations in pair-ion plasma phase. The benchmarking of the new diagnostics techniques is still going on.

A.4.7. Modelling and Demo Studies

Modeling activities related to Aditya and SST-1 : The ADITYA tokamak is being upgraded to address advanced scenarios of tokamak plasma. In this up-gradation, one of the important issues to be studied is plasma-surface interaction. For this study, the circular plasma has to be converted to shaped divertor plasma using new divertor coil. A preliminary analysis of constructing divertor plasma equilibrium has been tried and the required current in this coil is about 150 kA for the sustaining plasma current of 200 kA. Figure A.4.7.1 shows the plasma with double-null configuration along with vacuum vessel. This analysis will be further extended. TORIC code has the capability to predict the ICRF wave absorption by ions and electrons to predict experimental observations. The TORIC code has been used to simulate the ion cyclotron resonance heating experiments of Aditya. In Aditya like tokamak, it is expected to have fast ion population. To quantify the fast ion population, one has to solve Fokker-Planck equation and this study can also estimate the parallel and

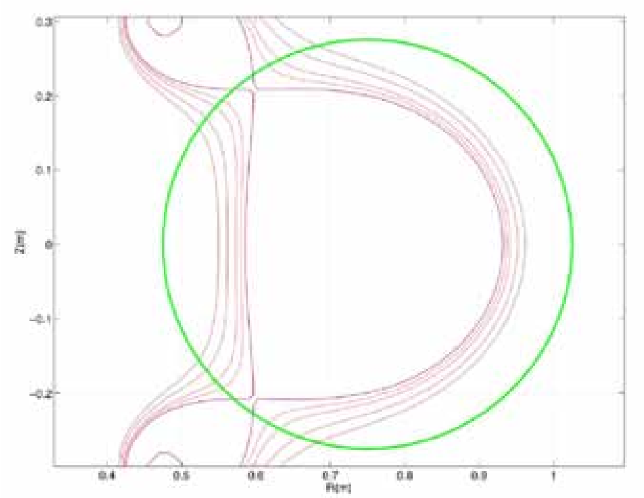

Figure A.4.7.1. ADITYA-Upgrade divertor equilibrium with circular vessel

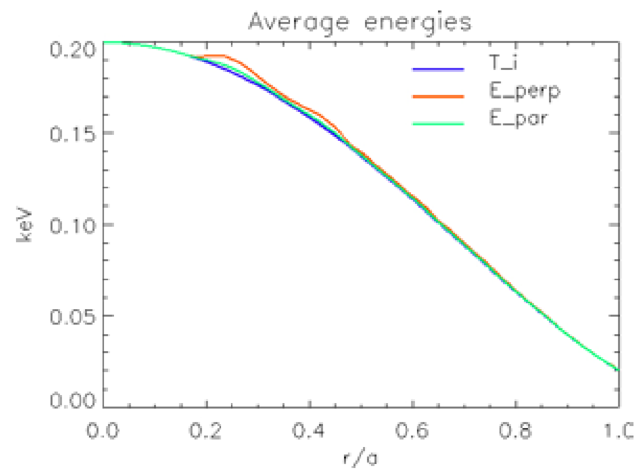

Figure A.4.7.3 Average energy of hydrogen ions due to total coupled power of 0.044MW

perpendicular contributions. For this, Steady State Fokker-Planck Quasi-linear (SSFPQL) module describes these phenomena has been coupled with TORIC. The module SSFPQL solves the linearised quasilinear equations for ions heated at the fundamental and second cyclotron harmonic in tokamak plasma. The results obtained so far are encouraging and further detailed analysis is in progress. Figure A.4.7.2 shows maximum effective perpendicular ion temperature of the tail as about 0.950keV whereas the maximum parallel effective

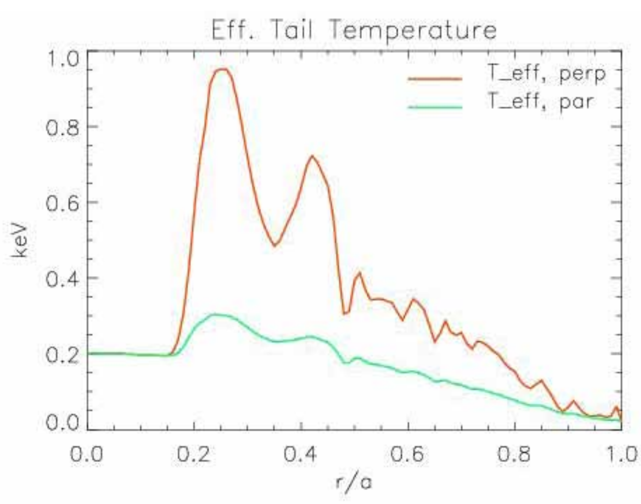

Figure A.4.7.2 Effective temperature for coupled power of 0.044 MW

ion temperature of the tail is 0.300keV due to absorption of 44 kW RF wave around cyclotron resonance layer. Average energy as shown in Figure A.4.7.3 is very small which indicates that the contribution of suprathermal hydrogen to the total energy is minimal. This also indicates that their number is very small. This is quite expected because it is well known fact that harmonic heating is a finite Larmor radius effect and hence will be effective at higher temperature of ions. We have studied the influence of plasma surface interactions on tokamak startup, using a zero-dimensional model. We have demonstrated that, the evolution of initial phase of the discharge is intimately linked to the condition of the plasma facing components and the resultant plasma surface interactions. We have applied our model to typical Aditya discharges, and we obtain good agreement with the initial plasma evolution profiles in Aditya tokamak.

DEMO design activity: The reactor physics design code has been used to design a medium sized fusion reactor. The fusion gain Q for this device is chosen to be 5. This device will serve as a test bed to qualify materials for future reactors. The physics code predicted a device with major radius of 4.7 m, minor radius of 1.6 m and carrying plasma current of about 12 MA. The fusion power produced in this device can be varied depending upon the availability of materials for in-vessel components to take higher dpa. Figure A.4.7.4. shows the radial build-up of various reactor components and Figure A.4.7.5. shows the top view of 1D neutronic model of

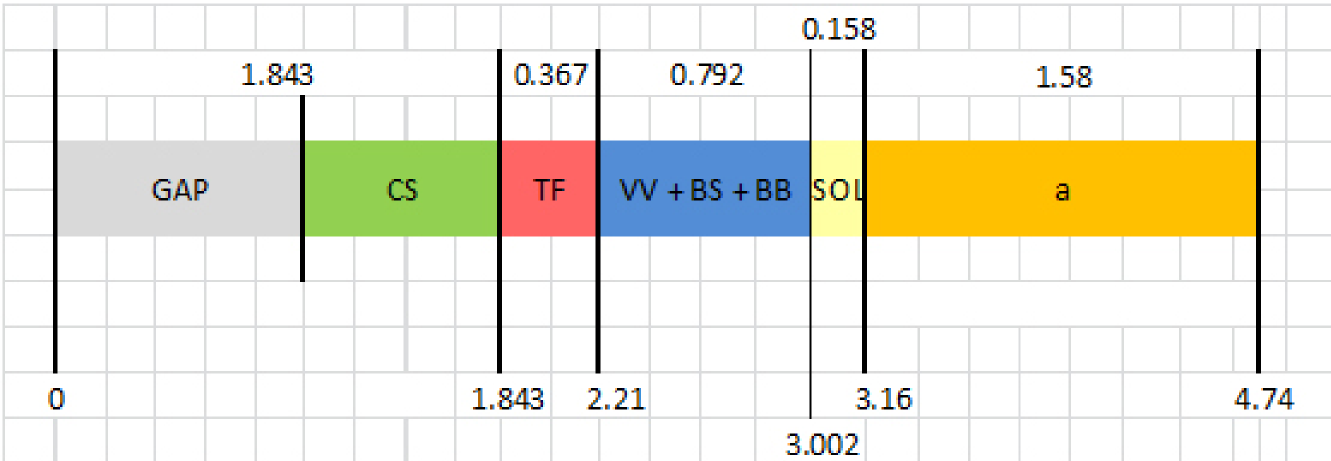

Figure A.4.7.4 Average energy of H+ ions due to total coupled power of 0.044MW, X-axis Machine Axis

this. The outboard side is filled with breeding and shielding blankets while the inboard side is filled with shielding blanket only. In this case, the fast neutron flux on the TF coil is estimated and found to be within the allowable limit. Figure A.4.7.6. and A.4.7.7 shows the neutron flux on the inboard and outboard side of fusion reactor with fusion power of 500 MW. The tritium breeding ratio is found to be around 0.87 and this can be increased further by optimization.

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B.1 Facilitation Center for Industrial Plasma Technologies (FCIPT) Activities

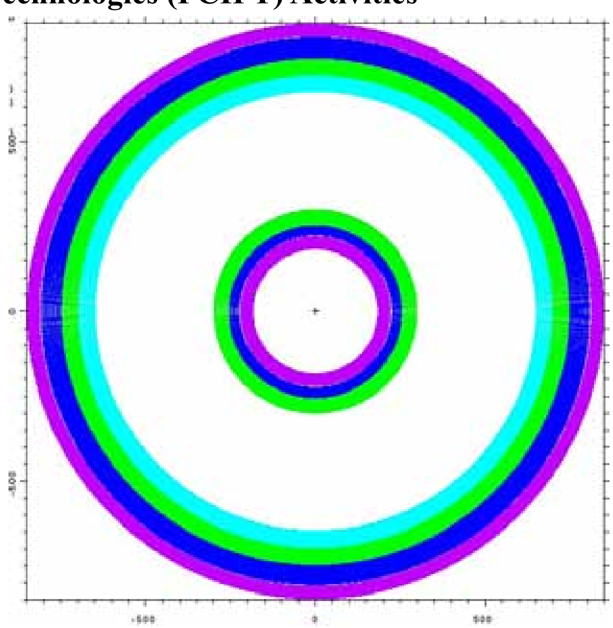

Figure A.4.7.5. The top view of neutronic mode

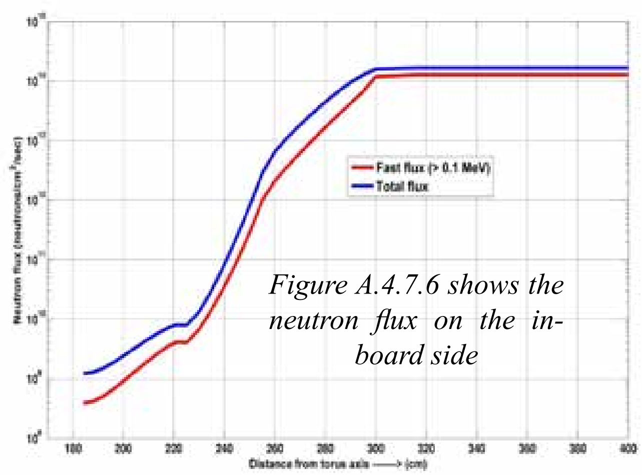

Figure A.4.7.6 shows the neutron flux on the inboard side

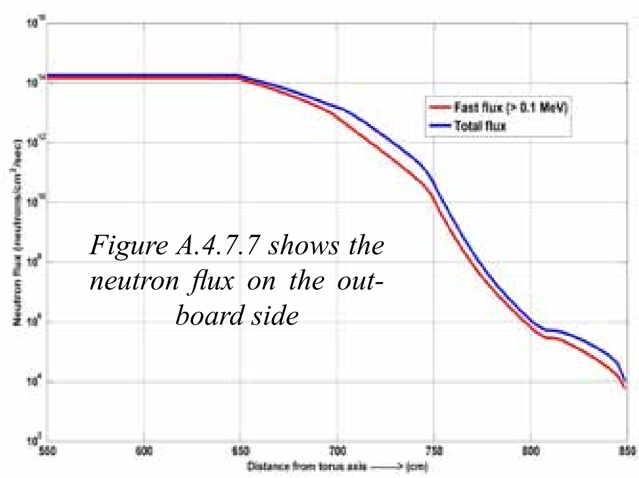

Figure A.4.7.7 shows the neutron flux on the outboard side

CHAPTER B

ACTIVITIES ON OTHER CAMPUSES.

The following are activites done on other campuses and other heads, even though the work done are all under the mandate of the Institute. There are three other campuses at present as following :

FCIPT (http://www.plasmaindia.com) is a division of IPR, and has a mandate to develop plasma based technologies on commercial basis. Further, it also acts as a link between the Institute for Plasma Research (IPR) and Indian industry. At FCIPT, the following activities were undertaken.

B.1.1 Plasma Surface Engineering

Plasma Nitrocarburizing process for improving the corrosion resistance of control valves: Control valves play a central role in the control and optimal performance of a myriad of flow processes in oil, gas and power industries. Wear and corrosion are the two most common problems that attack these control valves. Stainless Steel (SS) 316 is commonly used for manufacturing these valves because of its high strength and corrosion resistance. The wear resistance can be improved by subjecting them to processes like plasma nitriding. However the corrosion resistance was observed to decrease after plasma nitriding. Hence, plasma nitrocarburizing, a variant of plasma nitriding, was used to improve both wear and corrosion properties of this steel. In order to understand the corrosion behaviour of the control valves used in steam turbines which are exposed to marine environment, two electrolytes were selected. They are 3.5% NaCl solution and tapwater. The tap water has a TDS value of 600ppm, COD of 70mg O_2/ltr and conductivity of 0.75mohms. The polarization curves and electrochemical results indicate that the corrosion resistance is better for samples treated for 6 hours compared to samples treated with 24 hours. This improvement is due to the presence of expanded carbon-nitrogen austenite phase. After processing for longer duration, the expanded austenite tends to dissociate in to chromium nitrides and ferrite phase along with iron nitrides. As a result the corrosion rate increases compared to untreated sample. Salt spray tests were conducted as per ASTM B117 standard in 5% NaCl and tapwater for 96 hours. After 96 hours the samples were taken out and found that the AISI 316 austenitic samples treated for 6 hour did not corrode compared to samples treated for longer durations. The loss of corrosion resistance is due to the presence of chromium nitrides. Hence, we can conclude that plasma nitrocarburising process has indeed improved the corrosion resistance of AISI 316 austenitic stainless steels, due to carbon and nitrogen incorporation into the surface of the material.

FeAl coatings by Electrospark Deposition Technique: Protective coatings such as aluminides are required for resisting Pb-17Li attack in test blanket module (TBM) of fusion reactor. Fabrication (welding) of coated steels may lead to uncoated welded zones which may be susceptible to corrosion attack by flowing Pb-17Li eutectic at 550 ^{o}C. In this context, a preliminary evaluation of FeAl coatings deposited by electrospark deposition (ESD) technique on 9Cr steels has been conducted by FCIPT. The objective was to study the microstructure of such coatings formed after ESD process and their acceptability with reference to TBM applications. The preliminary studies indicated that the coatings so deposited by ESD technique revealed mud-crack pattern which are indicative of thermal cracking phenomena produced by ESD treatment. Further process optimization is required to eliminate such cracks. Interesting feature of this finding was the quasi-amorphous interface (indicated as HAZ in fig 1) of the coating which was observed to be deprived of grain boundaries. Such a soft quasi-amorphous interface as characterized by nanoindentation, tint-etching and SEM-EDS techniques seems promising from hydrogen barrier perspective. Since hydrogen permeation is a grain boundary diffusion phenomena, absence of grain boundaries could be of help in reducing the hydrogen permeation rates into steels. Further work is being investigated in this direction to explore a potential solution to blanket applications.

Deposition of ZnO thin films for TCO applications in Solar Cell: The objective of the project is to make a CZTS solar cell, of at least 1”X1” size, using non-toxic and abundantly available elements. In this project, ZnO is selected as the candidate material for the Transparent Conducting Oxide (TCO) layer of thin film compound solar cells. We have already initiated the work to deposit ZnO thin film on glass substrate by reactive DC magnetron sputtering using Oxygen as a reactive

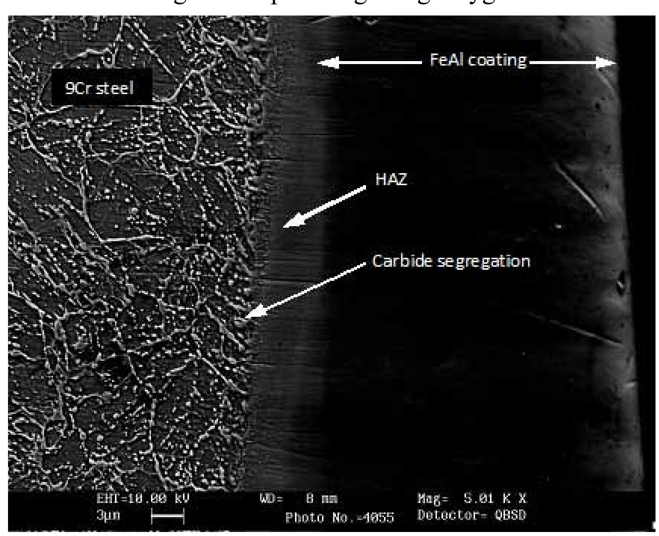

Figure B.1.1. Cross-section SEM micrograph of electrospark deposited FeAl on 9Cr steel.

gas. Films were deposited by varying Oxygen flow rates and magnetron power during the deposition process. After deposition, samples were annealed at 300^o C for 2 hours in vacuum environment. All the properties of the film were measured before and after annealing. All the samples were tested for the optical transparency, band gap and electrical resistivity before and after annealing. Band gap of film is observed 3.2 eV. XRD and SEM measurements of the samples show the variation in the crystal structure and surface morphology of the film with varying oxygen flow rate and annealing. 600 nm thick ZnO thin film with 1.5 X 10^{-3} ohm-cm resistivity and 80% transparency without any doping in the film was achieved. XRD results of the as deposited ZnO films at various oxygen concentrations are shown in figure below.

Plasma Modification System for Surface Treatment of Brass Valves: The objective of this project was to scale up eco-friendly plasma etching process for treatment of brass valves to improve rubber to brass bonding to an industrial scale (5000 valves per batch). FCIPT has successfully commissioned and demonstrated the plasma treatment on 4800 valves per batch at M/s Triton valves, Mysore. Subsequently, plasma treated brass valves were molded with rubber and tested for rubber to brass bonding. All valves have shown excellent bonding with rubber. The developed plasma system can treat 5000 valves per batch and approximately 50,000 valves per day. The plasma process (i) saves WATER (65000 lit/day) (ii) No Effluent Treatment required (iii) Reduction in consumable chemicals (iv) Elimination of chemical storage and usage problems. A photograph showing the valves getting treated in plasma environment is shown in the figure B.1.2.

Figure B.1.2 Photograph showing the brass valves getting treated in plasma

Material Characterization of Hall effect Thruster: A project for the characterization of materials used in the Hall Effect thruster, was sanctioned by LPSC, ISRO, Trivandrum in June 2012. The major objectives of the project are to measure the erosion rate of the anode liner materials, and to measure the magnetic and electrical properties of the materials used in thrusters. At present the project is in the procurement stage and the procurement request has been raised for majority of the necessary items including vacuum based experimental reactors, ion source etc.

Silicon nanostructure synthesis by plasma process: Work on synthesis and study of different nanostructures namely nanoparticles and nanowires were carried out for different materials in a thermal arc plasma chamber. It has been observed that, due to high thermal stress that exists in the high temperature plasma synthesis process, the nanostructures have a metastable crystalline phase or a mixed phase. The phase formation is greatly influenced by the plasma process conditions like arc current and ambient pressure. Both the morphology and crystallinity were studied as a function of synthesis parameters. Nanostructures of Silicon were synthesised at various arc currents and analysed by X-ray diffraction and Transmission Electron Microscopy. The results indicate that 1 – D structures, namely nanowires, of Silicon could be formed predominantly at an arc current of 75 A. The TEM image of silicon nanowires (formed at this arc current under atmospheric pressure in argon gas ambience), clearly indicates the dimension of the nanowires to be 10 – 20 nm in diameter and lengths in the order of few hundred nanometres. The nanowires are found to be terminated by spherical particles of similar diameters as nanowires. For other synthesis parameters like lower or higher arc currents, the formation of nanowires is limited with the presence of nanoparticles of larger size.

B.1.2 Plasma Pyrolysis

MoU with CSMCRI (CSIR lab), Bhavnagar: An MoU has been signed between Central Salt Marine Chemical Research Institute (CSMCRI) and Institute for Plasma Research (IPR) for the “Development of Plasma Pyrolysis System to dissociate Solvent and Solid Waste, and Recover Combustible Gases”. The MoU is signed in March 2013. FCIPT will develop a plasma pyrolysis system with a capacity of 15 kg/hr, for dissociation of the used solvents and solid waste and to generate combustible gases. The system will have a feeding mechanism for introducing both solid and liquid wastes. It will use IGBT based power source for efficient conversion.

Recovery of Phosphorus from Phosphoric Acid using a Plasma Pyrolysis system: This project was received from M/s Excel Industries Ltd., Mumbai. The objective of the project is to see the possibility of recovering Phosphorus from the Phosphoric acid through Plasma Pyrolysis. The pyrolysis system has been designed and developed at FCIPT and has been shifted to Roha, Maharashtra in November 2012. Feasibility studies to recover Phosphorus from Phosphoric Acid has been successfully completed. At present, attempts are being made to optimize the process to achieve maximum yield. After the process optimization is completed, the system will come back to FCIPT. Photographs of the developed system and of the recovered yellow Phosphorus are shown in the figures B.1.3.

Figure B.1.3(Top) Photograph of the installed system

Figure B.1.3 (Right) Photograph of the recovered Phosphorus

B.1.3 Systems Installed

Installation & Commissioning of Industrial scale Atmospheric Pressure Plasma Systems for Angora Wool Treatment: The developed Industrial scale systems for Angora Wool Treatment is approximately 7 m in length and 2 m in width, and can treat 1 m wide Angora web at a speed of 4.5 m/min or higher. This project has been sanctioned by DST and the industrial partner involved in developing the system is M/s InspirOn Engineering Pvt. Ltd., Ahmedabad. Two such systems have been installed & commissioned at (i) Himalayan Institute For Environment, Ecology & Development (HIFEED), Ranichauri, Uttarakhand in June 2012 and (ii) Kullu, Himachalpradesh in October 2012

Installation and Commissioning of Plasma Modification system for surface treatment of Brass Valves: Scaled-up version (industrial scale) of the eco-friendly plasma etching system for treatment of brass valves to improve rubber to brass bonding has been developed at FCIPT. The system has been installed at M/s Triton Valves, Mysore in November 2012. The developed plasma system can treat 5000 valves per batch and approximately 50,000 valves per day. A photograph of the installed system is shown in the below in the figure B.1.4.

Figure B.1.4 Photograph showing the installed plasma surface modification system

B.2. ITER-India

B.2.1 Background information on ITER

International Thermo-nuclear Experimental Reactor (ITER) (http://www.iter.org) is the world's largest experimental fusion facility, designed to demonstrate the scientific and technological feasibility of nuclear fusion power. ITER is being constructed at Cadarache, in the South of France. India is a full partner in the ITER Project and will contribute about 9% of the ITER construction cost mainly through In-kind contributions like other five of the six partners (China, India, Japan, the Republic of Korea, the Russian Federation and the USA), while Europe, being the host will contribute about 45%. ITER-India is the Indian Domestic Agency responsible for India's contributions to ITER.

B.2.2 Progress in the ITER Project

In the period of April 2012 to March 2013, overall there was good and steady progress made on the ITER construction. EUDA has informed during this period a possible delay of the availability of the buildings by up to 23 months, which unless mitigated, can potentially result in delay of the first plasma date beyond the baseline July 2021 limit agreed by all Parties at the ITER Council. There are 6 ITER procurements presently in the critical/supercritical schedule path and the IO and the DAs are working hard together through the unique ITER team (UIT) to evolve an effective strategy to arrest further schedule slippage and evolve mitigation measures for schedule recovery. Analysis of the overall schedule performance of the ITER project including IO and all DAs show achievement of a schedule performance index of about 80% with 389 of the overall 481 cumulative reference milestones as detailed in the detailed work schedule (DWS) having been achieved. The ITER headquarters building has been occupied since October 2012 and all staff has since shifted from the adjacent temporary offices at the CEA site to the headquarters building. The Council Room at the new headquarters was inaugurated by the ITER Council at its November 2012 meeting. Meanwhile work is progressing in the construction of other buildings at the ITER site, e.g., the Tokamak building and the assembly building. A building integration task force (BITF) has been constituted to expedite the interface issues in the buildings so as to allow EUDA to give building contractor necessary inputs for execution of the construction activities on schedule.

The ITER-India activities have also progressed a great deal with 5 new procurement arrangements (PAs) and a number of major industry contracts being signed during this period. There has been some delay in the In-wall shield and cryostat packages, mainly due to delays in completion of design by the IO. India has now signed the PAs for the X-ray crystal spectroscopy diagnostics (XRCS), the Cryodistribution system, electron cyclotron radio frequency sources and power supplies, totaling about 27kIUA (~47MEuro). With this ITER-India has signed all but 2 of the PAs, which amounts to more than 95% of its contribution to ITER.

ITER-India has also signed a number of major industry contracts for manufacture of the ITER deliverables. The most major of them was the signature of the contract for the Cryostat manufacture with Larsen and Toubro Ltd. (L&T) on 17 August 2012. The cryostat is a ultra high vacuum vessel of about 29m diameter and height, thus like a 10 storied building made of stainless steel (SS304L) and will be fabricated in 40 number of pieces in L&T's Hazira plant and shipped to ITER site. There these pieces will be sub-assembled (welded) into 4 sections, which will be lowered in the cryostat pit and welded into the final cryostat configuration. The cryostat will help keep the ITER magnets cooled at cryogenic temperature of -269^{o}C, thus it will be the biggest refrigerator to be built in the world and ITER-India is very proud to be involved in its manufacture and delivery. The ITER tokamak assembly will start with the lowering of the cryostat base and also end with the placement of the top lid and subsequent welding, thus India will be the only domestic agency apart from IO to be involved in the ITER assembly process. L&T will be involved in site work both in a temporary workshop as also in the tokamak pit and L&T has already subcontracted the fabrication of the temporary workshop to the French company Spie. A site support agreement has also been signed in this regard by ITER-India with IO.

Other major contacts signed by ITER-India involve that for the design, fabrication, testing, delivery, installation and commissioning of driver and final stage amplifiers for the Ion Cyclotron radio frequency sources along with vacuum tubes in June 2012. This technology is not available, especially for the high power tubes in India and to mitigate the challenges of the cutting edge R&D involved in the tube and amplifier chain development, ITER-India has signed the contract parallely with two global giants, namely the M/s Thales Electron Devices S.A., France and M/s Continental Electronics Corporation, USA. Depending on the success of the prototype R&D progress by these two companies, the final selection for the series production will be done.

Other major contracts, which were signed during this year was for the design and manufacture of the prototype cryoline with M/s Linde Kryotechnik, Switzerland and for design and fabrication of the SPIDER power supplies with ECIL, India

B.2.3 In-Wall Shielding (IWS) – ITER WBS 1.5

In Wall Shielding blocks (IWS) shall be placed between outer and inner shells of Vacuum Vessel (VV) to stop escaping the neutrons and to reduce the toroidal magnetic field ripple. These shield structures are made of SS 304B4, SS 304B7, SS 430 and SS 316L (N)-IG and Fasteners (Bolts, Nuts, Spacers, Washers etc.) are made from XM-19 and Alloy - 625. Manufacturing contract of IWS was already awarded to M/s. Avasarala Technologies Limited, Bangalore (ATL) in 2010.

IWS Materials Procurement : The contract for IWS materials was given to M/s. Carpenter Powder Product, USA (SS 304 B7,), M/s. Carpenter Technology Corporation (Alloy – 625) M/s. Industeel, France (SS 304 B4, SS 430 and SS 316L (N)-IG) and M/s. Valbruna, Italy (XM-19 as a subcontractor). Start of bulk production of the IWS materials has started with the acceptance and clearance of the sample production and process qualification documents.

Manufacturing Drawings of IWS Blocks

(a)ITER-India approved manufacturing Drawing template and title block of ATL for manufacturing drawing preparation. ENNOVIA reconciliation has been carried out with ITER IO and completed successfully.

(b)Manufacturing drawings of Support Rib for Poloidal Segment 1(PS 1) of Vessel Sector 6 (VS6) has been approved by ITER-India and IO.

(c)The design for Anti-rotation washer was modified from base line engineering design and approved through DR by IO. The various IWS design DRs of ATL have been reviewed and approved by ITER-India and ITER IO.

(d)After all design issues have been frozen for PS1, ATL started IWS manufacturing drawings of IWS blocks for the PS1 of VS6 applicable to all VS. The drawings for PS1 (row 1 to 2) are rejected by IO and under modification at ATL. The other rows drawings for PS1 are under checking at ITER-India.

(e)Manufacturing drawings preparation of IWS blocks for PS 2 of VS 6 (applicable to all VS) has been started by ATL.

Outgassing rate measurement of VV-IWS materials : Gas load due to outgassing of IWS plays an important role in leak detection of ITER vacuum vessel. Out gassing properties of IWS depend on machining, cleaning and handling procedures to be performed by ATL. As it is not possible to test out gassing of assembled IWS block, this test is performed on test coupons. ATL manufactured three coupons of SS304B7 following the same procedures to be applied for actual IWS components and outgassing rate measurement has been carried out on them. Typical out gassing rate observed for a coupon of SS304B7 is 2.3×10^{-8} Pa $m^3 s^{-1} m^{-2}$.

Mock-up 3 Manufacturing: Each IWS block consists of a set of fasteners to assemble the block, which are locked with an anti-rotation washer to prevent the loosening and rotation of the washer due to vibrations during the operation of the vessel. Mock ups is to validate the anti-rotation locking method used to lock the fasteners in the IWS block has been fabricated. The anti-rotation method consists of a non-circular washer, which is put in a similar slot cut in the IWS plate. To validate the anti-rotation mechanism, IWS block with a support rib was tested on a shake table, which simulated vibrations similar to the actual operating conditions. The effectiveness of the anti-rotation mechanism was checked by measuring the loss in the pre-loading of the bolts. Strain gauges were put on each of the fastener to measure the pre-loading. In all 10 strain gauges were used, 6 were put on bolts and 4 were put on cap screws. The setup was first subjected to resonance search test to check whether the natural frequency lies in the testing range or not. The categorization of IWS blocks was done using the 853 IWS blocks of the regular vessel sector. Each IWS block was observed with respect to each of the 10 parameters and categorized. In all, all 853 blocks were categorized under 55 categories.

Assembly Mock up : The IWS blocks will be attached to the vessel ribs using brackets and M30 bolt. Due to the double curvature of the vessel, the blocks during the assembly have to be manipulated to different angles along different axes. To facilitate this manipulation, additional threaded holes are provided in the IWS block. The block will be lifted using eyebolts and thereafter tilted to different angles using these additional holes. To validate the use of these holes, an IWS block and a dummy vessel model was fabricated. The setup is shown in Figure B.2.1.

Nesting Plan : Nesting plan is the arrangement of components on raw material to minimize its wastage. IWS manufacturer (ATL, Bangalore) is using nesting software called “Flownest” for nesting of IWS component (plates, ribs, and brackets). Water jet cutting of components will be performed as per this nesting plan to reduce the raw material wastage. Nesting Plan will be prepare for (a) SS316L (N)-IG for raw support rib & brackets (b) SS304B7, SS304B4 and SS430 for IWS plates.

B.2.4 Cryostat & VVPSS - ITER WBS 2.4

Cryostat is a reinforced, single walled stainless steel (SS304L) vacuum vessel structure with overall diameter and height ~29 m (Figure B.2.2). ITER machine will have superconducting

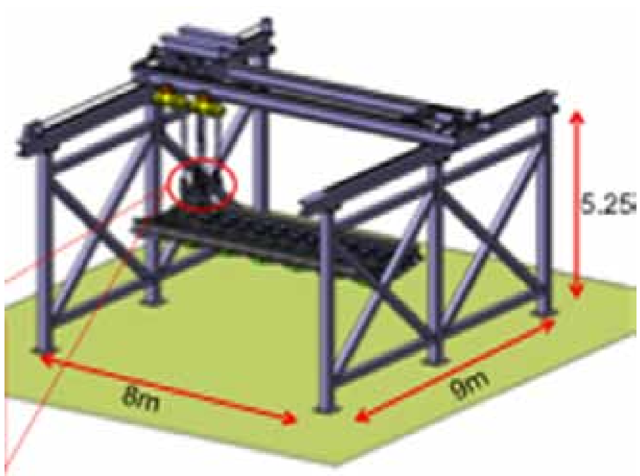

Figure B.2.1: Assembly test setup of IWS blocks and dummy vessel module

magnets which need to be thermally insulated from the environment. This is achieved by having a large vacuum vessel, within which is an 80 K thermal shield. The superconducting magnets operating at 4.5 K are surrounded by this 80 K shield. The Cryostat works as a secondary confinement and transfers all loads to the floor. It will be made up with more than 4000 Metric Tons of austenitic stainless steel.

Cryostat Manufacturing : Cryostat contract has been awarded to L&T on 17th August 2012. Following which the preliminary activities for the manufacturing has been started. The

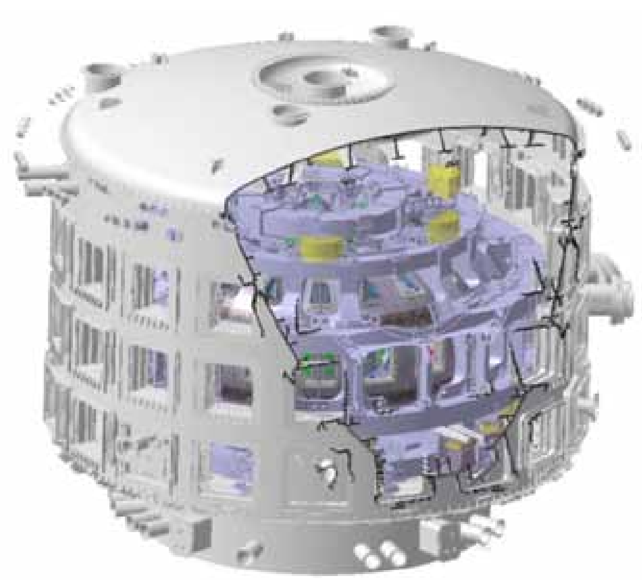

Figure B.2.2. 3D view of Cryostat with magnet and vacuum vessel

Manufacturing Readiness Review (MRR) for Cryostat Base section and Lower Cylinder have been completed. Further to this the design work for the cryostat instrumentation has been started.

Design of Temporary workshop: For the fabrication at site and sub-assembly of cryostat segment to form 4 main sections, a temporary workshop is needed for which building permit has been obtained from French Authorities. The temporary workshop is 50 m long, 120 m wide and is having height of 30 m with 200 Ton Goliath crane. Preliminary Design of Temporary Cryostat Workshop has been completed and review meeting held at IO on 13-14 December, 2012.

Vacuum Vessel Pressure Suppression System (VVPSS): During an in-vessel coolant leak VVPSS prevents overpressure by allowing the gas flow through the rupture disks. It is a long 30 mm thick cylinder of length 46m, diameter ~6 m made up of ferritic steel, containing enough water to condense the steam resulting from the most adverse in-vessel coolant leaks, thus limiting over-pressurization of the vacuum vessel within 0.15 MPa absolute.

VVPSS Design: The Vacuum Vessel Pressure Suppression system (Figure B.2.3) is a large SS tank which has to store the water (tritiated in nuclear phase) from the main vacuum vessel in the event of an accidental water ingress.

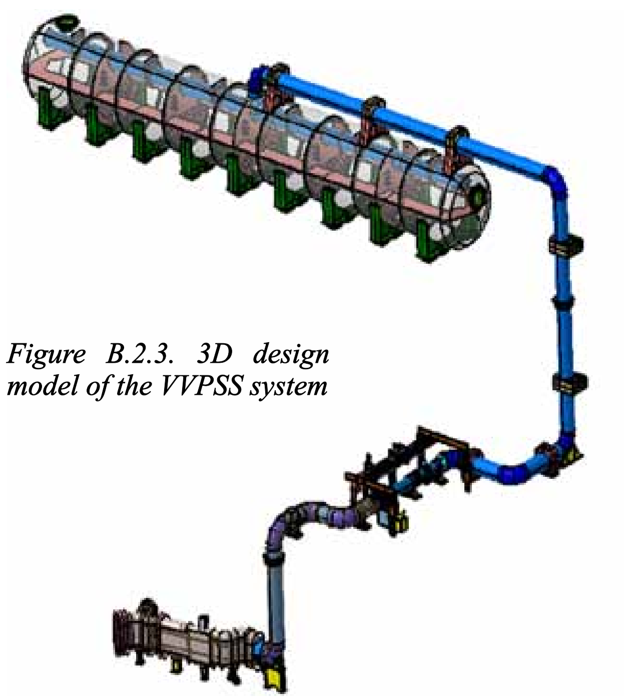

Figure B.2.3. 3D design model of the VVPSS system

B.2.5 Cooling Water system - WBS 2.6

Cooling water system is needed to maintain ITER components at their prescribed temperature and to take away heat from the various components/systems and reject this in to the atmosphere. The Cooling Water and Heat Rejection (CWHR) system will (i) provide cooling water at specified temperature (31^{o}C), flow rate, pressure and at specified quality to components and systems (CCWS), (ii) provide chilled water at specified temperature (6^{o}C) to HVAC systems and few components (CHWS); (iii) reject the total heat load (except that of CHWS-H1) of the ITER machine to the atmosphere & stores the excess heat during pulse operation and rejects the same during dwell period (HRS). The Preliminary Design Review (PDR) of ITER CCWS, CHWS and HRS was conducted in 2012 and the technical queries raised by the review panel were resolved and the Preliminary Design of CCWS, CHWS and HRS has been approved and accepted. The preliminary design of cooling tower basin has also been completed. The tender for "Detailed Design, Engineering, Procurement and Supply of ITER CCWS, CHWS and HRS" has been published, the tender document has been issued to the interested bidders, and Scope Appraisal Meeting and Pre-bid meeting were conducted with the interested bidders.

B.2.6 Cryo-distribution & Cryo-line – ITER WBS 3.4

The cryogenics is needed to transport cold power to different components to support and sustain the plasma fusion and to maintain specific systems on working temperature. The cryogenic system also minimizes the heat losses from the superconducting magnets and help to sustain the large current in them. IN-DA has two distinct PAs for the cryolines and cryodistribution systems with the following scope: (a) transport cold power from cryoplant to magnets, cryopumps and thermal shield (Cryoline package); (b) manage the distribution of cold power (steady state and dynamic) to magnets, cryopumps and thermal shield (Cryodistribution package). The ongoing procurement phases for cryoline and cryodistribution also have made significant progress. The project "infrastructure for prototype cryoline test" has completed the design reviews, fabrications and factory acceptance test during this year, which is marked as an important achievement of the project. Another very important milestone of the project, which is the qualification test of the "ITER cold circulator", the first of its kind in the global scenario has been finalized. The test auxiliary cold box (TACB), to be used for the ITER cold circulator test, has been designed and analyzed. Figure B.2.4 shows the model along with all internal details. This is a state of the art design to fulfill the test conditions as per ITER operational scenarios. As a part of the academic program, the ongoing study on the pulsed heat load mitigation using the cryogenic distribution system for fusion reactor in Tokamak scenario has been continued. A new study on evaluation of failure, effects and criticality aspects of cold circulators for fusion reactor has been studied in details.

B.2.7 Ion Cyclotron Heating & Current Drive Sources - WBS 5.1

The Ion Cyclotron Heating system will be one of the major auxiliary heating systems in ITER with 20MW of input ICRF heating power. Under this package IN-DA is committed to deliver 1 Prototype and 8 complete ICRF units each of

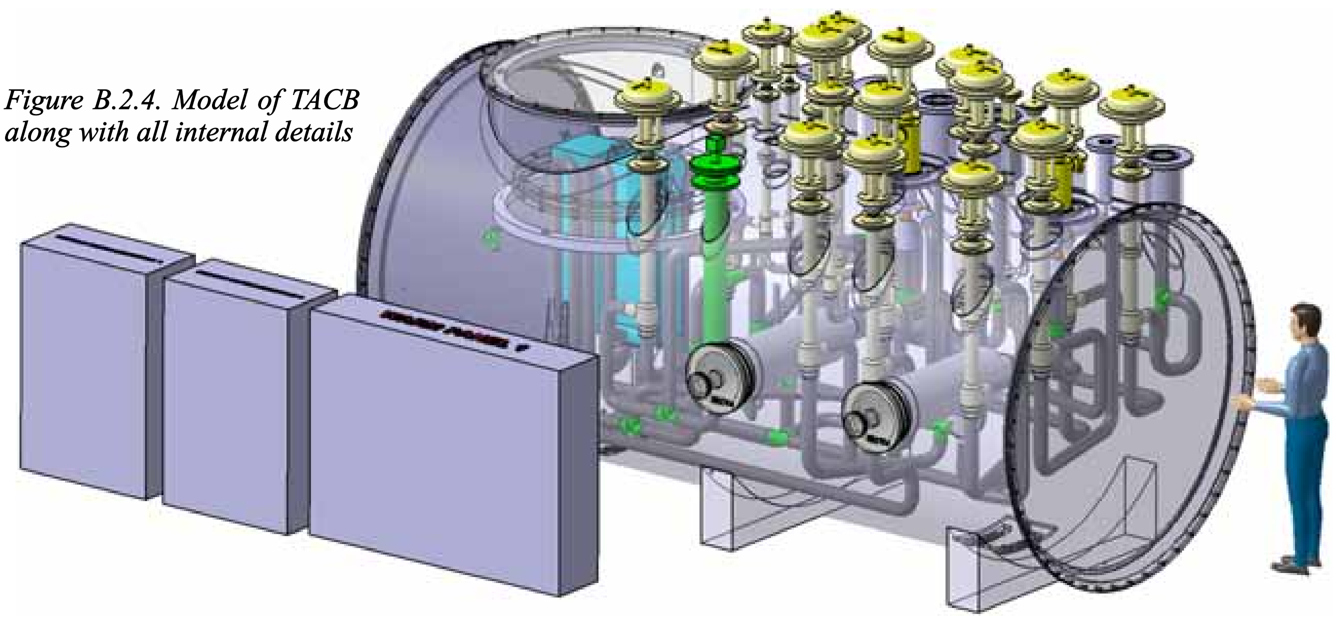

Figure B.2.4. Model of TACB along with all internal details

2.5 MW. Since the specifications for ITER source system is very stringent and 1st of its kind, an R&D program has been initiated to mitigate ITER programmatic risk. Under this program, two R&D chains are being developed using two different kinds of technologies to identify the best one for ITER application. During this reporting period ITER-India has signed two major contracts for development of driver & final stage amplifiers: one with Continental Electronics Corporation (CEC) USA for Tetrode based system and the other one with Thales Electron Devices (TED) France for Diacrode based system. Detailed engineering design including identification of materials for cavities related to driver and final stage amplifiers is completed. ITER-India has finalized Interface Control Document (ICD), Manufacturing & Inspection Plan (MIP), Risk Mitigation Plan (RMP), Quality & Safety Plan etc. along with the contractors. Manufacturing of vacuum tubes by both the contractors has been initiated. Since these cavities and tubes will be integrated in a full amplifier chain developed by ITER-India, activities initiated in other areas to support the R&D program. The pre-driver amplifier feeding to the main amplifier is being developed indigenously. A wide-band input network is implemented to avoid the tuning requirement while the output is a tuned network to cover 35-65MHz frequency range. Different configuration of the input circuit are being tried out and optimized for the best results. The amplifier has been tested up to 10.7kW at 40.2MHz for 5 seconds. The observed gain of the amplifier is ~18dB. The input circuit is further being improved to cover the whole frequency range and rigorous tests will be initiated soon. Design, simulation studies and procurement activities have been initiated towards a solid state wideband pre-driver amplifier.

Local Control Unit (LCU) for R&D source is under development along with local industrial partners. In this control unit, PLC based sequence control system and PXI based Real Time (RT) control, Interlocks, Acquisition & Display modules are employed. Logic for Interlock and RT control loop is implemented on FPGA module of PXI system & tested for their functionality. Integration module for PLC & PXI system is developed & implemented. After successful testing of prototype module, Signal Processing Boards are manufactured & tested to fulfill the bulk production requirement. Integrated test of LCU with dummy signals is presently in progress.
Procurement specifications developed for auxiliary power supplies for powering driver and final stage amplifiers and initiated tendering cycle.

A multi-megawatt level test facility is being developed for testing amplifiers as per ITER requirement (planned test up to 1.5MW/VSWR2.0/2000s/65MHz and 1.7MW/VSWR1.5/3600s/35MHz). All the necessary components/equipment/systems/sub-systems for testing amplifier chains based on Tetrode & Diacrode technologies finalized and procurement activities have been initiated. Contract finalized for 3MW/12 inch transmission line components, 3.0 MW dummy load etc. Cooling line installed from IPR cooling plant to the ITER-India lab through external contract. Work towards internal distribution of cooling headers is presently in progress. In-house development activities in the areas of power supply, high power dummy load, ring resonator etc. are initiated. Simulation for 9 inch soda water based dummy load, (operating range up to 100 MHz) have been completed using high frequency software MWS. Realization and conversion of RF design into mechanical design is completed and made ready for fabrication. Control and monitoring part for the dummy load is being developed using Siemens Hardware and Software. Concept of ring resonator for testing transmission line components at very high power proved through prototyping and fabrication process initiated. Interface issues related to floor loading and cooling requirement at ITER site resolved. Other specific interface issues related to high power operation will be addressed during R&D test phase.

B.2.8 Electron Cyclotron Heating (ECH) system - WBS 5.2

As a part of the in kind contributions to ITER international project, the Indian Domestic Agency (ITER-India) has to deliver part of the Electron Cyclotron radio frequency heating and current drive sources, whose main scope is to supply a set of two high power (170 GHz/1MW/3600s) Gyrotron sources including auxiliary systems. The execution approach includes procurement of high power tubes on functional specification basis and establishment of complete integrated performance. A Gyrotron test facility with prototype auxiliary systems is being developed to establish the integrated Gyrotron system performance.EC Gyrotron Source project has progressed further as procurements of various equipment and components are on-going to establish the ITER-India High Power Gyrotron Test Facility (IIGTF). From the procurement package point of view, an important formal start milestone has been achieved by signing the Contractual Procurement Arrangement with ITER international organization in October, 2012. Some of the main highlights of the activities carried out during this period are summarized below.

Activity related to Gyrotron Source System and Test Facility
Development of Prototypes/Pre prototype/Lab setups/Equipment for IIGTF is in progress.

Test Gyrotron & Waveguide Setup: A test Gyrotron with ITER relevant specifications (1MW/170 GHz) is planned for the IIGTF. An evacuated 63.5 mm corrugated waveguide test set with a dummy load will be used for establishing the Gyrotron Test setup. Requirements & configurations are being finalized and Pre tender preparations for the same are ongoing. A 75 kV industrial grade series ignitron based crowbar protection system (Figure B.2.5) has been developed for IIGTF. The three series ignitron crowbar successfully diverts the fault current in < 10 micro seconds and limits the fault energy deposition in the Gyrotron tube. A new improved design of Ignitron Trigger Module for reliable firing of crowbar unit has also been developed indigenously. The Local Control Unit (LCU) for the gyrotron system has progressed through pre prototype developments towards establishing a pre prototype Mini LCU . In parallel an engineering design task for the LCU in collaboration with the industry is in progress. Hardware for the pre prototype Mini LCU such as PLC, PXIe systems have been procured. Application development for the remote Gyrotron Operation in PLC and PXIe is in advance stage. Prototype signal conditioning unit with various design concepts are being developed through collaboration with industry. Hardwired fast interlock system with various design

Figure B.2.5. Ignitron based crowbar protection system

options are in development. Development of Data Acquisition System using PXIe is carried out. Integration requirements with ITER central control system (CODAC) have been evaluated through CODAC core system tools.

Diagnostics :An Infrared (IR) camera based Gyrotron output mode content analysis diagnostics has been planned for the IIGTF. For the purpose a task has been successfully completed in developing a numerical code for phase retrieval and mode content estimation using the amplitude data obtained through thermal images of the Gyrotron output beam taken at several cross sections. A low power mm Wave setup in the D-band frequency range has also been established at IIGTF with the main equipment such as a low power source, a HE11 mode converter and several waveguide components.

Mechanical Design & CAD activity : Gyrotron test setup requires heavy cooling distribution to dissipate the DC and RF heat loads. A Gyrotron Cooling manifold has been designed and is being updated to closely replicate the ITER proposed design. A standalone cooling test stand based on a Chiller is in procurement stage for the IIGTF. This will also be used for special circuits requiring chilled water. CAD models of Gyrotron support structure, oil tank and layout of cooling header in IIGTF have been prepared.

B.2.9 Diagnostic Neutral Beam (DNB) - WBS 5.3

A. ITER-DNB : The Diagnostic Neutral Beam (DNB) (3 S ON/20 S OFF with 5Hz modulation) in ITER is mandated to provide 100 kV, ~18-20A hydrogen beam to support the Charge Exchange Recombination Spectroscopy (CXRS) to measure helium ash in the ITER machine. Following subsections gives the present status and last year update on the different systems of the DNB.

DNB Vessel : This is a DD (Detail Design) package to IN-DA, under which detail design has been carried out to meet the various interface needs, RH compatibility, external / internal interfaces. It is a Safety Important Class (SIC) component and is being designed and validated with respected to RCC-MR code, which was presented at the Preliminary Design Review (PDR) by IO, which is now completed.

Magnetic Field Removal System : This consists of the Passive Magnetic Shield (PMS), shown in Figure B.2.6 and the Active Correction and Compensation (ACC) coils. Applicable design and construction code for PMS is RCC MR. ACC Coils along with PMS prevents Ion Beam from being affected by the Tokamak. Magnetic field due to the ACC coils (a set of 6 coils - 3 on top and 3 below the PMS) cancels the residual magnetic field of the Tokamak. Apart from preventing Ion Beam from getting deflected, ACC coils also demagnetises the PMS plates by generating damped magnetic field (in both the directions alternatively). The design is in progress and the challenge is to accommodate the design within a maximum limit of 800 A on the power supplies and the need to incorporate RH requirements for the bottom coil.

DNB Beam Source : The 8 driver based ion source will produce plasma by inductive coupling of 800 kW of RF power and 60A of H- ion beam, accelerated at 100 kV, over an area of 1766 mm x 866 mm. The performance of the source will largely depend on high precision engineering and how close manufacturing tolerances can be achieved. Presently the tendering process is ongoing and bids have been received from potential global suppliers and contract is expected to be placed by the end of May-13. The expected duration of manufacturing and testing is 30 months. As a part of procurement life cycle the source is first to be brought to the Indian test facility (INTF) and to be operated for specified period of time. After refurbishment, the same source is to be shipped to ITER DNB system. Also critical component is the DNB beam source movement mechanism (BSMM), whose design is presently ongoing and will mature after consolidation of remote handling provisions.

DNB High Voltage Bushing (HVB) : The DNB HVB is a complex system supplying hydraulic, gas and electrical supplies to the DNB beam source. It is a SIC component. To establish procedures for the qualification of the ceramic (as a safety component) and to study the behavior of different

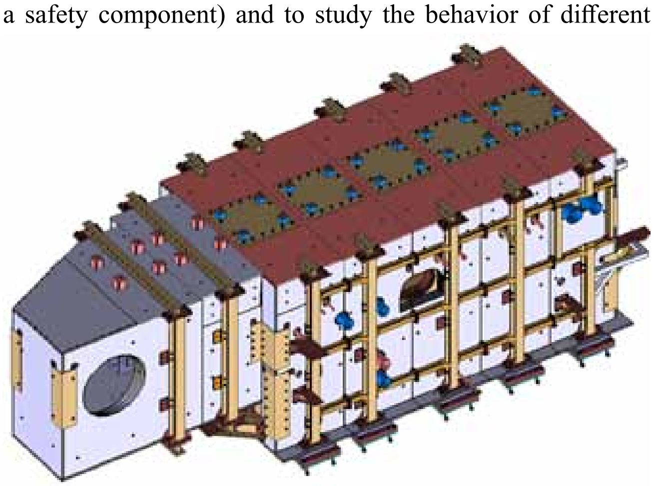

Figure B.2.6. Passive Magnetic Shield with support structure

material in high voltage and vacuum environment, prototype HVB (Figure B.2.7) experiment will be carried out on a scale about half scale structure of DNB HVB. Further, various technologies involved for the manufacturing of HVB e.g. large size Cearmic ring by Cold Isostatic process (CIP), FRP ring, Ceramic/FRP to metal bonding, fine surface finished electrostatic shields etc. Contract has been awared for Ceramic ring to Kyocera, Japan. Technical discussions are on going for FRP vendor. Contract will be realeased soon. 100 kV power supply is available for the testing. The HV testing is envisaged in the next year.

Alternative Proposal for DNB Calorimeter : The design of the movement mechanism for the calorimeter for DNB has evolved after analyzing several design proposals serving the basic functionality of the component and compatibility issues for the ITER Remote Handling (RH) scenarios, operational maintenance, ITER Vacuum Handbook (IVH) compliance for hydraulic integration, design of flexible elements for large displacements, neutron irradiation susceptibility and joint materials for Vacuum Quality Class 1 application.

Development of High voltage Feedthrough for DNB Residual Ion Dump (RID) : Detailed design of the DNB RID HV Feedthrough & Electrical feed line has been carried out. Structural & Thermal analysis has been carried out. The Remote Handling compatibility wrt ITER ITER Remote Handling Code of Practice – (IRHCOP) has been done. Electrical feed line has been designed keeping RH & component maintenance scenario into consideration.

B.INTF activities

To establish this facility and the technological development of ITER components, Indian Test Facility (INTF) has been proposed by India. INTF will generate 100 kV H beam with same specifications of ITER using 8 driver RF source. The beam will be further accelerated to 100 kV by a 3-grid accel-

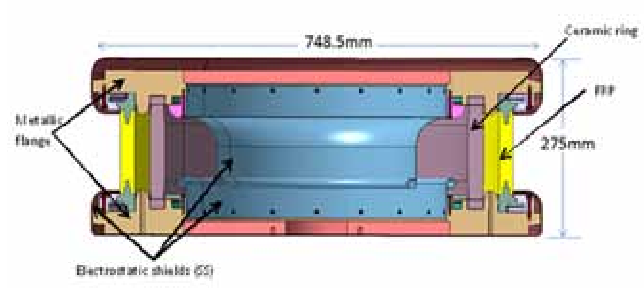

Figure B.2.7. Schematic of Prototype High Voltage Bushing for DNB erator system. Following sub-sections details the information and status of various components of INTF DNB Injector.

INTF Vessel : As a first milestone of the INTF, Vacuum vessel procurement contract has been placed with M/s Vacuum Techniques, Banglore and soon the manufacturing will commence at the factory. Expected delivery and subsequent commissioning of this vessel at ITER-India lab is in Sept. 2014. For the vacuum vessel, to be made up of SS304L major challenges involved in the manufacturing and fabrication are to achieved the required flatness and surface finish on the top lid sealing surface to meet the 10^{-5} mbar base pressure. Including the duct, vessel will allow to set-up a 20.65 m long test facility as a part of the R&D support to the ITER-NB system.

HV Feedthrough and interfaces with transmission lines : A special 100 kV feedthrough provides isolation between high voltage lines and grounded vessel. It is based on a porcelain cylinder based concept that is operational in conventional positive ion sources (PINI). Technical discussions with vendors are ongoing for its manufacturing assessment. Final design of the flexible components will be mutually agreed by DNB and PS group.

INTF Croyopumps :
For the DNB operation, the ion source and the neutralizer are supplied with gas feeds of 7.6 Pa-m^3/s and 7 Pa-m^3/s respectively. Beam transmission requires a pressure of < 0.3 Pa in the accelerator and even lower in the region beyond to limit the re-ionization losses to less than 5%. To meet this requirement, the beam transport path needs to be provided with a very high pumping speed of ~ 1.8 x 10^6 l/s. Such pumping can be effected through in-situ pumping. A comparative assessment the cryopumping options has been carried out and a choice has been exercised for cryo-sorption pumping at 12 – 15 K and 12 cryopumps of approx. size 3.2 m (H) x 0.6 m (W) x 0.3 m (D) are to be deployed for the pumping of the IN-TF beam line. The cryopump configuration allows pumping on both the surfaces. The cryopumps shall be serviced by a helium refrigerator for the 15 K supply (~ 340 W max.) and a LN2 feed system for the Chevron baffles (~17.5 kW max.). Technical specification document and drawings of the cryopump has been prepared. The tender for the procurement of 12 nos. of cryopumps has been raised and it is expected to finalise the award of contract by Q2, 2013.

Data Acquisition and Control System (DACS) for Indian Test Facility (INTF) : This is currently in design phase. Due to the specific nature of the facility the control system has an important responsibility to integrate several subsystems of the facility such as vacuum, cooling water, cryogenics, power supplies etc. Also since the duration of the beam is 3600 seconds, each experimental shot is expected to put stringent conditions on the DACS. Currently the preliminary conceptual design has been prepared, which has mainly three components (1) control and data acquisition, (2) interlock and (3) safety; similar as ITER CODAC. Functional requirements of the control system for INTF are finalized. The breakdown structure of INTF at plant and functional level is completed. This will enable the right developmental track for the DACS. To make use of maximum cooperation from international groups CODAC core is being explored as platform for control and acquisition. Currently tests related to acquisition are being carried out.

INTF Diagnostics : For safe operation of INTF and to identify the optimized operational parameter regime, a number of diagnostics are envisaged. Based on their objectives, INTF diagnostic is divided into three categories: (a) Protection diagnostics with active interlocks for safe operation, (b) Monitoring diagnostics to monitor the health of the system and (c) Characterization diagnostics for characterization of the plasma and the beam. In this year dedicated effort has been put to design some diagnostics in category (c). Those are Doppler shift spectroscopy (DSS) to characterize the beam by its energy and stripping fraction, Cavity Ring Down Spectroscopy (CRDS) to measure the negative ion density.

C. SPIDER Beam Dump

After successful completion of tendering and evaluation process, contract has been signed with M/s PVA Tepla , Germany on Dec. 2012 for Manufacturing , inspection ,testing and supply of Spider Beam Dump. Various manufacturing documents like Quality Plan(QP) , Manufacturing and Inspection Plan(MIP) , Weld Plan (WP) etc are reviewed and then approved by ITER-India and accepted(in case of QP, approved) by IO. Inspection of CuCrZr Raw material was performed by ITER India. Machining of Heat Transfer Elements and welding qualification of Copper alloys are in progress.

B.2.10 Power Supply Group

The group is responsible for design, development and supply of power supplies for the Diagnostic Neutral Beam (DNB), the Ion-Cyclotron (IC) System and the Start-up Electron Cyclotron (EC) System of ITER. A high voltage power supply shall be supplied for the SPIDER, the Neutral Beam Test

Facility at RFX, Padova, Italy. Preliminary design review (PDR-2) for high voltage deck-2 and transmission line-2 was held in September 2012, at ITER organization, Cadarache. The design of part of deck and transmission line inside Tokamak building was presented, the same is approved by review committee. The Accelerator grid power supply contract is launched to M/S ECIL. Design and interface issues aret resolved through interface management meetings with RFX, F4E and IO members for SPIDER Accelerator grid power supply. The design approaches final stage. Contract for manufacturing of power supply is launched to M/S ECIL. Credited task of (0.22KIUA) feed through development for RFX site was performed by the group.

Preliminary design for Power Supply of Ion Cyclotron system approached to its final stage, the design review was held at ITER organization. The design is approved by international review committee. ITER credit of 0.3kIUA received. Prototype power supply components for ICPS have been received and successfully tested at ITER India laboratory. Integrate test of the system shall be performed. For the Electron Cyclotron Power Supplies, the PDR was held in March 2013 and the design was approved. Manufacturing phase has started for these power supplies. As an R&D activity the development of PXI based power supply controller is in advance stage of fine-tuning. R&D for snubber and transmission line is going on for limiting and mitigating fault energy during accelerator grid breakdowns.

B.2.11 ITER-India Diagnostics – ITER WBS 5.5

In continuation to signing of first Procurement Arrangement (PA) of diagnostics package i.e. XRCS-edge system, 1st planned amendment to initial PA has been signed for the X-Ray Crystal Spectroscopy (XRCS) - Survey system for ITER, following successful completion of the Annex-B specifying the functional specifications and the technical scope of the package up to final acceptance at the site. The XRCS Survey is a seven channels Bragg spectrometer to measure impurity concentrations in plasmas in real time, for the safe ITER operations. The measurements will also help in the control of basic plasma performance. The technical document, Annex-B, was fully developed at ITER-India in collaboration with ITER Organization (IO). Category-1 chits and load specifications were prepared in discussion with Technical Responsible Officer (TRO) of IO. In May 2012, the concept design and performance study of the system was presented in 19th Topical Conference High- Temperature Plasma Diagnostics, Monterey, USA. A proposal for successfully developing prototype of XRCS systems at ITER-India laboratory was prepared after assessment of various possibilities to achieve required systems. Visits to X-ray lab were made to find common activity areas which can benefit our prototype or ITER deliverables development and test experiments. Furthermore, domestic and international market survey and technical communications with the vendors were carried for the procurement of the major building blocks of the spectrometer e.g. crystal, Multilayers mirrors, detectors, and X-ray sources etc.

For XRCS-Edge system, thermal analysis for the crystal has progressed with ANSYS code. The temperature rise of the crystal during plasma operation and machine backing phases has been assessed. It is found that crystal will require active temperature controller to keep its temperature stable at ±1.00C. The concept for the spectrometer chamber was detailed and proposal is made for a rectangular shaped chamber so that water cooling channels can be built-in to provide temperature stabilized environment for the X-ray analysing crystals. Hexapod based precision mounts have been explored and few are selected for the remote alignment of the crystal assembly. The 3D models for the spectrometer support in the interspace were generated and analysed for the possible deflection during a severe seismic activity. The maximum deflection was found about 4 mm, which is within the acceptable limit. Integration of the XRCS-Edge spectrometer with the upper port-plug #09 has also started.

Neutronics analysis with MCNP code has also progressed to resolve the CDR chits on the estimate of the contribution of shut down dose rate in the interspace from the aperture made in Diagnostics First Wall (DFW) for the X-rays. The XRCS-Edge contribution to shut down dose rate in the interspace is found within the safe limits. Optimization of the radiation shielding around the spectrometer has commenced. For these calculations, a licensed ATILLA code has been procured, setup on a high RAM workstation, and satisfactorily benchmarked with an ITER specified standard neutronics problem. The system design requirements for the Plant Instrument and Control system have been generated, documented and currently, conceptual design of the system is in progress.

In compliance with Quality Assurance requirements for both the signed PAs documents such as Quality Plan, Document deliverables, monthly progress reports and meeting minutes, and schedule creation and routine updates etc. were submitted to IO.

Further ECE team worked with Technical Responsible Officer (TRO) of IO diagnostics division for resolution of category one chits raised in the CDR and preparation of Annex –B for the ECE system. The Annex-B of the ECE system was reviewed by the committee, comments and suggestions were included in the Annex-B to finalize the documents for signature of the 2nd planned amendment to initial PA. Technical part of tender document of the Michelson interferometer for procurement was completed, reviewed by experts from India and abroad, also indent was raised. The design of smooth walled circular waveguide, miter bend, pump out unit and joints are completed. Offers for the waveguide components were received and evaluated. Millimeter wave component testing has started in the ITER-India diagnostics laboratory.

India is also responsible for supply of one Upper Port (UP-09) to house the diagnostics and to shield the diagnostics from neutron streaming. Towards the manufacturing of the Upper and Equatorial Port Plug Structures, single supplier approach to the manufacturing of Port Plug Structures was endorsed by IO. India is planning to sign the Memorandum of Understanding (MoU) with IO to get the benefits of common manufacturing of Diagnostic Generic Upper Port Plug (GUPP) Structure. Through our procurement process two Indian Industries have been identified and recommended to IO to participate to bid for common manufacturing of port plug structure. IN-DA Participated in Conceptual Design Review (CDR) of Interspace Support Structure (ISS) and Port Cell Support Structure (PCSS).

The CDR for the Beam Emission Spectroscopy (BES-edge) was conducted in October 2012, along with Charge Exchange Recombination Spectroscopy (CXRS-edge). Discussions are in progress towards the resolution of Category-1 chits raised during the CDR.

B.2.12 Activities of the Fusion Physics, Information Technology and IO-DA coordination group

A. Physics Modeling

The modeling activity for studies of mitigation of plasma disruption, VDEs and runaway currents in ITER using the TSC code is a continuous work. This year we focused on disruption and runaway mitigation studies using pellets. In ITER, during the thermal quench preceding the current disruption, the toroidal electric field can resistively grow to values about 50 times the critical electric field for runaway current generation, which can give rise to avalanche generation of runaway electrons with energies up to 15MeV and currents of unprecedented magnitude of more than 10MA, causing potential damage to the ITER first wall. In this paper we have carried out simulations for ITER plasma shutdown using neon doped deuterium pellets using the TSC code. The pellet model of TSC is also extended to approximately model injection of shattered pellets (SPI) into ITER plasmas. Using pellet initial radius of 5mm and initial pellet velocity of 500-1000m/s and repetition frequency of around 100-200 Hz launched from the outboard mid-plane, we have explored possibilities of safe plasma shutdown without large runaway current generation. The simulations show that these pellets can easily penetrate beyond the q=2 surface, giving rise to possibility of triggering MHD events, which can deconfine the runaway electron channel. In the conventional pellet cases the runaway current rises to levels of 7-10 MA in all our simulations. However, in the SPI like cases, it was demonstrated that a series of 10 pellets of ~10cm diameter, paced at 10-20msec intervals, with ~0.5%Ne impurity, injected from the outboard mid-plane at 500m/s speed can suppress the runaways keeping them below the ITER requirement of IRE<2MA. Figure B.2.8 shows the evolution of the plasma equilibrium and the plasma/runaway currents during the current quench phase following pellet pacing in ITER. In this case, the pellets can trigger MHD instabilities to destabilize the runaway beam, thus keeping the runaway current below 2MA.

B. Information Technology

The major focus of the IT group in ITER-India was to provide the standard IT services as usual maintaining a very high degree of efficiency and professionalism required for an international organization. No major new infrastructure was added. The contract placement for the networking and switching in ITER-India lab at IPR was placed with HCL which will be implemented soon. The other major activity of the IT group was for implementation of the SAP ERP software across IPR and its branches (ITER-India, FCIPT and CPP). We went live on SAP from April 2012 and all our finance, HR and procurement activities are now being executed in SAP. All the ITER-India payrolls are now processed in SAP. The implementer Arteria Technologies Ltd is still working with us as still some bug fixing activities are ongoing. We have also implemented a SAP portal on the IPR Intranet, which is available to all employee desktops, through which one can execute all ERP related activities. The servers are housed and maintained in ITER-India premises and are backed by a efficient storage and backup server, online 16kVA UPS and online generator power backup for ensuring 99.9% availability of the servers

C. IO-DA Coordination, Cost Containment and STAC activities

A total of 26 ITER Head Coordination Team (IHCT) meet-

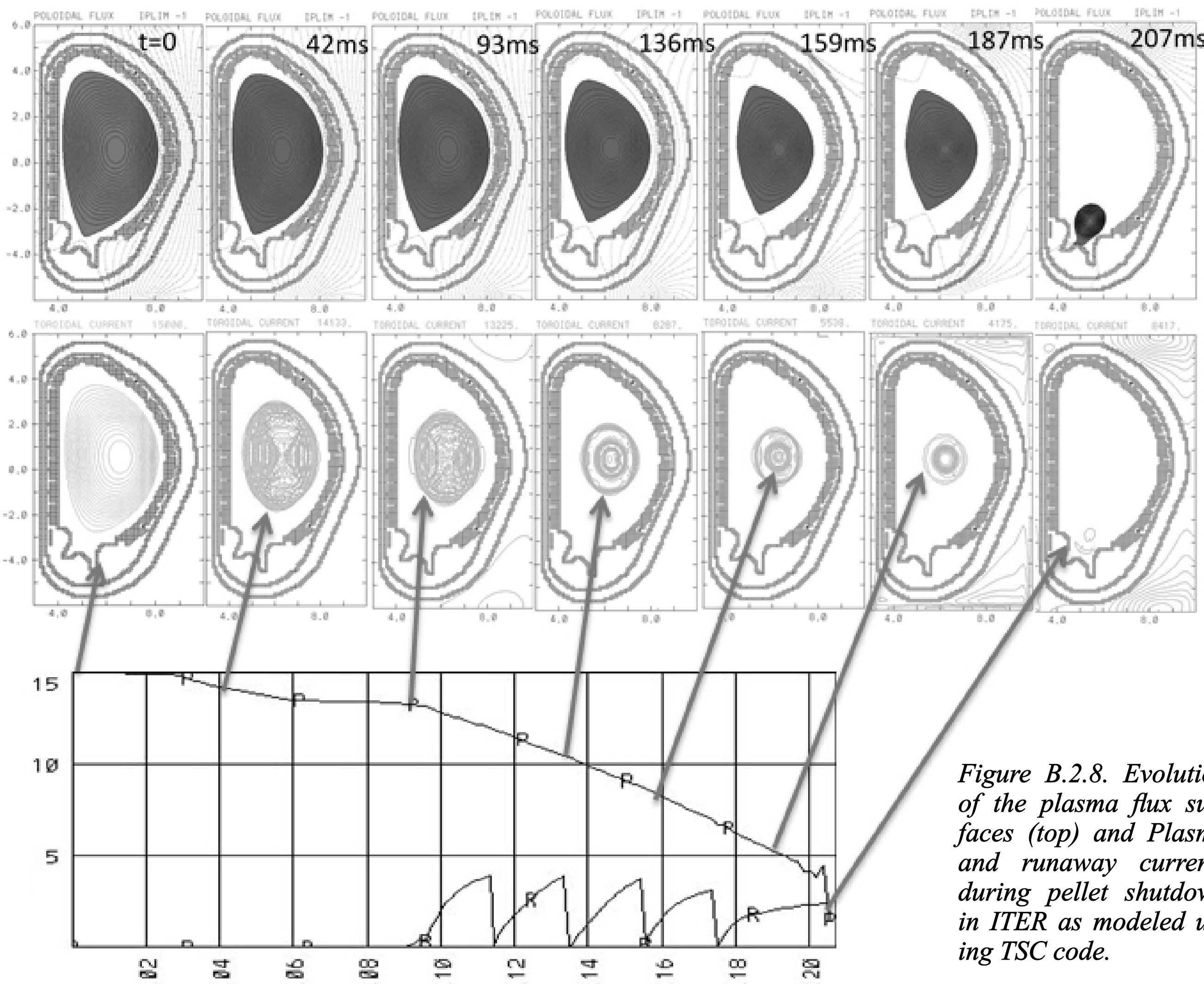

Figure B.2.8. Evolution of the plasma flux surfaces (top) and Plasma and runaway currents during pellet shutdown in ITER as modeled using TSC code.

ings were held in 2012-13. These meetings are mostly held bi-weekly through Videoconference. IHCM is the highest IO-DA decision-making body in ITER and takes most high-level management and technical decisions. Project Director, ITER-India and Indranil Bandyopadhyay (IBY), IO-DA Coordinator are members to the IHCM from India. IBY is also member of Project Performance Review (PPR) task group the cost control task force (CCTF) of ITER and participated in 12 PPR and 5 CCTF meetings during this time. IBY is an expert to the ITER Science and Technology Advisory Committee (STAC) of ITER and participated in the 12th and 13th STAC meetings in 2011. The STAC meetings are held twice every year and it reviews the progress of ITER project and advices the ITER Council on scientific and technological issues. IBY has participated in all 11 STAC meetings so far since its inception in 2007.

B.2.13 Activities of the Project Office

During last one year ITER-India made significant progress in the ITER project. ITER-India has now signed with all Procurement Arrangements (PAs) except Vacuum Vessel Suppression System (VVPSS) and planned amendments to Diagnostics package.

• Schedule related activities on various packages are continued to be regularly updated as per project progress using Primavera. Project Schedule Implementation Task Force (PSITF) activities were completed after finalizing the Strategic Management Plan (SMP) for effective monitoring & control of the project. All IN-DA Detailed Work Schedule (DWS) were reviewed and approved during last year.

• Documents related to Procurement Arrangement (PA) signature were reviewed and approved for Cryodistribution, Electron Cyclotron Resonant Heating (Gyrotron) Source and their Power Supply, planned amendment of Diagnostics package for X-Ray Crystal Spectroscopy and ECE system were signed.

• Participation and support in the Configuration Management and Change control activities for reviewing the Project Change Requests (PCRs) due to the design improvements, new procedures and documentation, impacts on scope, schedule and cost.

• Project Risk Management Plans and Risk Registers for Later Delivery Cryolines and EC HV Power Supply were formulated and submitted to ITER Organization (IO).

• Participation in SAP Implementation related activities.

• Package Progress Meeting (PPM) is organized for regular assessments of each package progress, schedule variances, recovery plans, interface issues etc., and common Issues are discussed in ITER-India Management Meeting (IIMM) for their best possible solutions and if required these are reported to higher management for necessary action.

• Various summary reports are prepared for summarizing the activities of the project and also the budget related reports are prepared for managing the expenditure.

• The Cranes has been installed for ITER-India Test Facility (INTF) in few package area.

• Involvement in Intellectual Property (IP) board for management of IP matters at ITER-India. Screening of abstracts / publications prior to submission for probable IP matter is being carried out through a novel checklist developed by ITER-India IP board. Participation in annual ITER IP Contact Persons Meeting at Cadarache, France to discuss and resolve matters with representatives from IO and ITER partner countries.

• Supporting activities for the Export Control Working Group (ECWG). Liaising with DAE for IP and Export Control Matters.

B.2.14 Quality Assurance Activities

• Arranged 10 days in house NDT level –II training as per the SNT-TC-1A of ASNT for 15 persons

• Arranged the presentation for PED and CE from TUV and BV agencies

• Arranged the presentation from IO for "Procurement quality requirements"

• Conducted QMS audit for various contractors like L&T LT-SHF Surat Hazira, Jindal steel Orissa, TCE Mumbai, ECIL Hyderabad

• Witness of NDT (Non Destructive Testing) for ICRF group for the Beryllium Copper Rod. X Ray film review and report review

• Participated in the material inspection for IWS material, Joint ICTP-IAEA Safety assessment Institute workshop at ICTP

• Review and preparation of various Quality Plan (TCE,ECI)

• Review of MIP for Bohler, CWS components

• Review of CWS EPC tender documents, IWS TPI tender documents, FTS tender document, PA document for ECE,XRSCS,

• Review of EMR (End of manufacturing report) for IWS materials

• Presentation given to Project managers on "French Quality Order understanding"

• Participated in various meeting with IO - SQAWG meeting , CMWG meeting, Supervision plan as per ASN French regulator requirement,

• Participated in various internal meetings – PPM, IIMM, IRC, CWS pre-qualification, IWS TPI qualification, Pri-Bid for cryoline.

• Meeting with TUV, Lloyds, BVIL for future inspection requirement and CE marking requirement

• Prepared Non-Conformity and Deviation control procedure as per French regulator requirement

B.3. Centre of Plasma Physics, Guwahati

B.3.1. Theory and Simulation

Effect of collision parameters in electronegative plasma with two species of positive ions: The understanding of wall plasma interaction for electronegative plasma is very essential and useful from the point of view of processing reactors. The energy that ions gain as they fall through the sheath regulates the physical and chemical processes at surfaces contacting the plasma. The ion neutral collisions in the sheath can significantly reduce the ion impact energy on the surface and needs a serious attention. However, in most of the cases the plasma processing reactor contains a gas mixture instead of using a single gas. In those cases the presence of two positive ions are inevitable. In this piece of work we try to investigate the dynamism of two positive ions in electronegative plasma under various collision conditions. There are basically two collision extremes; a) the constant cross section and b) the constant mobility. The two cases correspond to p = 0 and -1 respectively, where, p is the collision component for the power law variation of the collision cross section. The other important parameter is 'alpha', which signifies the collision strength.

Fluctuating dust charge in plasma- A discrete charging approach: Whenever dust appears in plasma, it gets charged up. Usually, the thermal velocity of the electrons is higher as compared to the ions. Due to this reason, the electrons approach the dust much faster than the ions and thereby making the dust particles negatively charged. Once, the dust become negatively charged, the ions start approaching the dust and thus reduce its negative charge. In this way the charge of the dust particles fluctuates. Till now accepted theory of the dust charging is given by the OML theory, which assumes a continuous flow of ions and electrons on to the dust. However, in reality the dust charging mechanism is a random process and discrete in nature. Considering this randomness, Cui and Goree came up with a discrete charging model of dust charging. Here, we show the reproduced result as well as the result showing the type of charge that appears on to the dust particle.

Numerical study of extraction region of negative ion sources: A Particle-In-Cell (PIC) based approach is being proposed to numerically study the extraction region of negative ion sources. The approach will be 3D-3V electrostatic PIC in nature, and will encompass realistic 3-D geometry to model the region around a single hole of a negative ion extraction system. Various collisional processes will be taken into account following the Monte Carlo Collisions (MCC) formalism. Previously, a prototype PIC module, along with realistic geometry has been developed and validated using a fleet of single particle and collective plasma behaviour tests. Now, we have studied the effect of filter magnetic field on the co-extracted electron current with a mass ratio of 100. It is seen that the co-extracted current decreases with increasing strength of the magnetic filter, becoming negligible beyond 8mT. The results show qualitative as well as quantitative resemblance with analytical results and also with numerical works of similar nature. The prototype is presently written in MATLAB. Conversion of the code to C + MPI system, as well as incorporation of MC collisions to the existing model will be taken up shortly.

Development of 2D transient model to study the characteristics of Hall Thruster: Hall thrusters constitute an important electric propulsion technology for certain applications requiring low thrust levels, e.g. satellite station keeping and orbit transfer. The thrust in Hall thrusters is generated by ions being accelerated through annular plasma by the electric field set up between an anode and a cathode. This electric field is strongly coupled to an externally applied radial magnetic field which typically localizes the electric field near the channel exit. The ions are generated through electron-impact ionization of Xenon neutrals. Due to their large inertia, the ions are not magnetized, and stream out of the device without experiencing very many collisions. The electrons, on the other hand, collide with the background neutrals as they migrate to the anode across the magnetic field. The cathode is located a few centimetres downstream of the channel exit and provides enough electrons to supply much of the discharge current, ionize the incoming neutrals, and neutralize the beam of exiting ions. However, Hall thrusters rely on much more complicated physics than ion thrusters to produce thrust. The details of the channel structure and magnetic field shape determine the performance, efficiency, and life. While the overall operational characteristics of Hall thrusters are understood, some key issues remain to be resolved. In particular, the relationship between the various types of fluctuations in these devices and the overall engine efficiency needs to be determined. Electron conductivity is critical in the operation of Hall thrusters since it impacts the ionization of neutrals and the potential drop which accelerates the resulting ions. Our objective is to develop 2D steady state and transient fluid model of stationary Hall thrusters and later on to develop a hybrid code for the same system. And then to study the various plasma processes viz. Ionization of neutral, particle collision, sheath formation, plasma oscillation and recombination etc. In our proposed work we are planning to develop a 2D steady state and transient fluid model of stationary Hall thrusters. In our proposed work a non-uniform orthogonal grid will be used and we shall use the experimental data of SPT100. Finally we shall try to develop a hybrid code. In the hybrid code we shall use the fluid simulation for the lighter species i.e. electrons and Particle in Cell (PIC) simulation will be done for the heavier species i.e. ions. Then we shall study the various plasma processes viz. Ionization of neutral, particle collision, sheath formation, plasma oscillation and recombination etc. Currently we are using the design specification of CAMILA Hall Thruster at Israel Institute of Technology, Haifa 32000, Israel. We are using open source PIC-MCC code XOOPIC for our simulation purpose. Some initial findings are given here. Here we have chosen two arbitrary time steps one at initially and another towards saturation. As neutral background gas we are presently using Argon later on we shall use Xenon.

Preliminary 1D analysis of initial radial build-up Indian fusion reactor: During the period of this report, we have performed several benchmarking simulation of 1D ITER neutronics models in preparation of 1D modelling and analysis of initial radial build-up of Indian fusion reactor model. The benchmarkings performed include (1) ITER computational shield benchmark: Testing of the FENDL-2.1/MC data library by A. Serikov and U. Fischer, July 2006; (2) Neutronics Assessment of Molten Salt Breeding Blanket Design Options by M.E. Sawan, S. Malang, C.P.C. Wong, and M.Z. Youssef, September 2004 [UWFDM-1234] and (3) Nuclear Analysis Report (NAR) by H. Iida, V. Khripunov, L. Petrizzi, G. Federici, July 2004. We have also developed a 1D neutronics model of the proposed Indian fusion reactor and performed preliminary neutronics analysis. The initial radial build-up, based on physics model, for a reactor of fusion power 500 MW, major and minor radius 4.74 m and 1.58m is as shown in Figure B.3.1 The initial materials chosen are lead-lithium cooled ceramic breeder (LLCB) for breeding blanket, water cooled SS for both shield blanket and vacuum vessel. The breeding blanket is placed on the OB side only. Our preliminary analysis shows a TBR of 0.99 for 50 cm breeding blanket on the OB side. Three different shielding materials have been studied and various neutronics responses were calculated. Table B.3.1 shows the fast neutron fluence at the inboard TFC for different shielding materials.

Shielding Material	Fast Neutron Fluence (>0.1 MeV)	Fast Neutron Fluence/FPY
SS+H2O	4.12E+009	1.30E+17
ZrH2	3.37E+009	1.06E+17
TiH2	3.00E+009	9.46E+16

Table B.3.1 Fast neutron Fluence

3D modelling using Attila: Using the 3D deterministic radiation transport tool Attila, we have replicated some of the neutronics analysis of In-DEMO performed in IPR using Monte Carlo simulation (C. Danani et al., Report No. IPR/RR-490/2010). The 3D solid geometry model of a 20 degree sector In-DEMO was prepared using solidworks. The parameters calculated include neutron spectrum at radial mid-point of the first wall, Tritium production rate in the LLCB blanket, etc.

B.3.2 Dusty Plasma Laboratory

Studies on argon mixing hydrogen plasma and its effect on dust charging: The results from the experiment reveals that the electron density rises at most by a factor ~2 and the electron temperature is reducing by a factor 0.5 upto 30% addition of Argon flow rate with hydrogen gas. Beyond 30% ad-

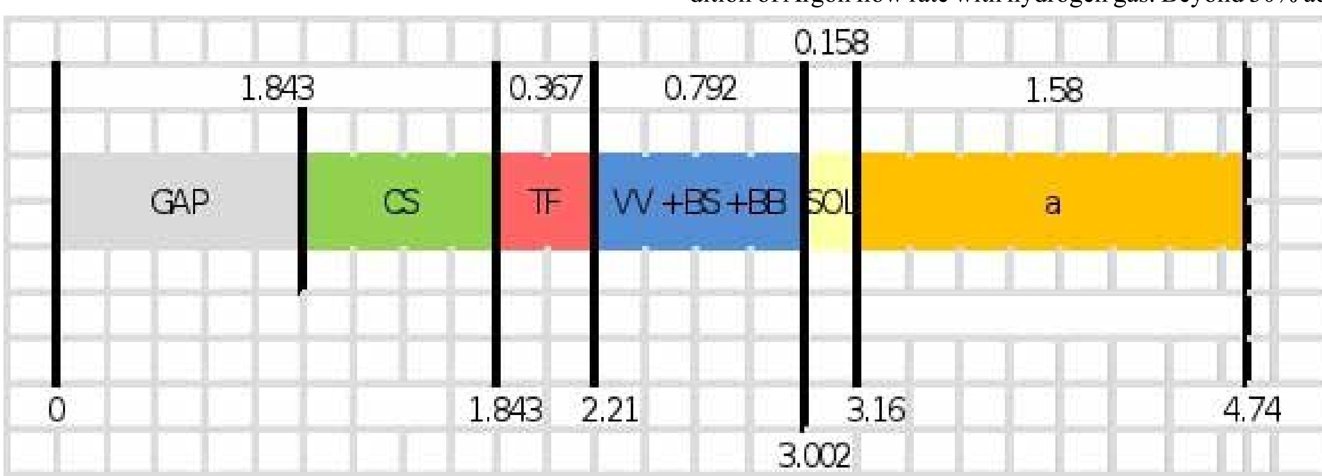

Figure B.3.1. The initial radial build-up for a reactor of fusion power 500 MW dition of argon with hydrogen flow rate, the electron density slightly goes on decreasing whereas the electron temperature gets saturated for 40 – 60% addition of argon flow rate. From the optical emission spectroscopy (OES) studies, it is found that due to the argon addition, the degree of dissociation of hydrogen plasma decreases. From the dust charging profile, it is observed that the dust current and dust charge decreases significantly up to 40% addition of argon flow rate in hydrogen plasma. But beyond 40% of argon flow rate, the reduction of dust current and dust charge is insignificant. The addition of argon into the hydrogen plasma can be used as a tool to control the dust charging in low-pressure hydrogen plasma.

Ion Acoustic Wave (IAW) Propagation in low-pressure hydrogen plasma in presence of dust: As working pressure increases (from 1.10^{-4} to 4.10^{-4} mbar), the electron density increases and electron temperature decreases. For the working pressure regimes of 4.10^{-4} to 2.10^{-3} mbar, plasma density as well as electron temperature becomes saturated. With increase in working pressure, it is observed that the phase velocity of IAW decreases. In presence of W dust, there is an increase in phase velocity of IAW due to the increase of electron temperature. The amplitude of the IAW decreases drastically at very low pressure becomes maximum at 4×10^{-4} mbar and decreases slowly at higher pressure also. At very high frequency, there is a decrease of amplitude of IAW observed.

Studies on IAW propagation in hydrogen plasma in presence of Cesium coated dust: This experiment is carried out as an additional technique for confirmation about the production of negative hydrogen ions (Other techniques are Langmuir probe, optical emission spectroscopy and dust charging). In presence of Cs coated tungsten dust, the response time (delta-t) is reduced compared to the uncoated tungsten dust. It implies that in presence of Cs coated W dust, the phase velocity of IAW increases. The increase in phase velocity in presence of Cs coated tungsten dust is a signature to the production of negative hydrogen ion. It validates that Cs coated W dust can be used for production of negative hydrogen ions.

Extraction of negative hydrogen ions produced by Cesium coated dust: The prime technical objective of the project is to develop the extraction mechanism of the negative hydrogen ions produced by the Cs-coated W-dust particles in the existing dusty plasma device. The preliminary designing of the experimental set up for H- ion extraction is completed which contains the designing of plasma chamber, Cs coating unit, Cs oven, designing and fabrication of Plasma Grid, Extraction Grid and the Acceleration Grid and their positioning.

B.3.3 Thermal Plasma Processed Materials Laboratory

Development and studies on a plasma assisted system for simulating Tokamak Divertor region : This system is developed with the long term aim of establishing a Tokamak Divertor simulator facility in this laboratory, not only in terms of the unprecedented heat flux projected for the modern ITER like Tokamak machines (10 MW/m^2), but reproducing actual fusion like hydrogen/helium plasmas, with typical electron temperature (1-5 eV), ion density (10^{20} m^{-3}) and ion flux (10^{24} m^{-2}s^{-1}). Along with exploration of the basic physics/chemistry issues of this interesting system, it will used to study plasma surface interaction (PSI) processes under extreme fusion conditions. We are also planning to utilize the system for synthesis of some high temperature nanomaterials (nano carbon, ceramics) and to further explore the effects of controlled residence time under the magnetic field and extremely low pressure likely to exist in the particle growth region. The cascaded plasma torch assisted high power flux heat source (MW/m^2 level) established in this laboratory, as a forerunner to the Tokamak Divertor simulator that we are developing under an on-going project, has produced some encouraging results in this period. Even without a magnetic field, the linear heat source had demonstrated production of a long, confined, laminar argon plasma jet extending even up to the other end of the chamber. This represents a simple yet ideal experimental configuration to conveniently arrange experiments on the interaction of the intense plasma jet with different material targets. Plasma surface interaction (PSI) experiments in an actual plasma fusion like situation demands production of the plasma jet with hydrogen alone; however the plasma beam in this case was seen to get diffused on addition of hydrogen to the primarily argon operated plasma jet. This may be rectified only upon application of an external axial magnetic field along the plasma jet. This is the most crucial element in terms of what the complete Tokamak Divertor simulator differs from the existing heat source, where water cooled copper coils wound around the chamber will produce up to 0.4 Tesla magnetic field, at maximum 250 kW input power. Preliminary PSI experiments with an argon plasma jet will be initiated soon in the linear heat source system without a magnetic field, till the complete simulator, the linear magnetized plasma device will be made ready in future. Optimization results from the heat source should be easily translated to this simulator system. Simple calorimeters were placed in the path of the beam to measure the heat flux delivered by the plasma jet on their exposed surface. Heat flux to the target increased with increasing input power to the torch, which in turn could be raised by increasing the total numbers of torch segments and adding hydrogen to the plasma jet. Under 53.6 kW input power (argon 25 liter per minute/lpm, hydrogen 10 lpm, total 9 torch segments) more than 10 MW/m^2 was measured to be delivered on a 20 mm diameter area. In agreement to the visual appearance, calorimetric measurements also confirmed that heat flux density gets more diffused with addition of hydrogen to the plasma. A very preliminary estimation of the plasma parameters at the same location as above were made with an Ocean Optics made simple spectrometer (USB4000) as follows: plasma temperature 0.4 eV and electron density 10^{21} m^{-3}. Assuming the plasma jet velocity to be at the threshold of supersonic, the upper limit of the ion flux density was further estimated as 10^{24} $m^{-2}s^{-1}$. Some other developments in terms of the complete Tokamak Divertor simulator include finalizing the design of the electromagnet, to be produced with thick copper conductors with through-hole for continuous water cooling. The complete scheme for arranging a differential pressure inside the chamber has been also done, which will ensure lower neutral density pressure near the target region. We have already placed order for five numbers high capacity root vacuum pumps (total 1600 m^3/h) to be backed by appropriate rotary vacuum pumps. A new, stand-alone vacuum chamber system with intense surface water cooling has been also designed, fabrication order for which will be placed shortly.

Studies on Thermal Plasma Assisted Synthesis of Nanostructured Materials: This laboratory is involved in developing thermal plasma assisted processes for synthesis of some novel nano-structured materials, and study the physics and chemistry issues involved for their ultimate optimization. Over the last few years, a specific thermal plasma assisted reactor configuration was developed, where a plasma beam seeded with the reactants expands supersonically into a low pressure sample collection chamber, out of which fine particles nucleate by the process of homogenous condensation. The use of a supersonic nozzle in this system allows reduction of pressure in the sample collection chamber without disrupting the plasma discharge. We had earlier reported that chamber pressure in this configuration can be utilized as a fine control knob influencing both average particle size and crystallinity. Average size and size dispersion decreases with decrease in pressure, but at the cost of crystallinity of the product material. Low pressure was demonstrated to induce mesoporosity in carbon nanoparticles, thus increasing their effective surface area, producing a material with optimized combination of both crystallinity and surface, which may be most ideal to be used in low temperature PEM fuel-cells. In this period we have also worked extensively for synthesis of carbon encapsulated magnetic (iron) nanoparticles which have vast area of application including that is nano-medicine (targeted drug delivery, hyperthermia treatment, MRI contrast agent). We had achieved fine control over the particle size with respect to the sample collection pressure, which in turn could be nicely correlated to their magnetic properties. High pressure synthesized particles had bigger sizes, which was measured to have also higher saturation magnetization values and a comparatively wider hysteresis curve. On the other hand, low pressure samples were smaller in size, smaller saturation magnetization but possessed a super-paramagnet like thinner M-H loop.

B.3.4 Pulsed Power Technology Laboratory

Alpha particle irradiation on materials: Alpha particles emanated from our plasma focus device were bombarded on electrode grade graphite as well as tungsten samples to investigate the morphological and structural changes occurring on them due to alpha particle irradiation. Morphological studies of graphite samples have been carried out using high resolution transmission electron microscope (HRTEM). The reference samples exhibit layered type of structure whereas the exposed samples exhibit rounded structure. Selected area electron diffraction (SAED) pattern of the exposed sample is indicative of development of new planes due to the thermal load deposited onto the samples. X-ray diffraction (XRD) pattern of exposed graphite indicates that many new planes have been developed. The surface of the exposed tungsten samples indicates micro-cracking, bubbles, holes etc. when viewed under the field emission scanning electron microscope (FESEM). XRD pattern of exposed tungsten samples indicate the appearance of new peaks that depends upon suggesting new phases.

Neutron source based on inertial electrostatic confinement fusion scheme: Portable and cheap neutron sources are in demand for various applications such as in oil and gold mining, cancer therapy, fusion material study, non-invasive interrogation of illicit drugs and explosive materials, identification of impurities coal etc. Our prime aim is to develop table top neutron sources (both the linear and spherical geometries) based on Inertial Electrostatic Confinement Fusion (IECF) scheme and use the sources for application in damage study of fusion materials. The designing of cylindrical IECF device has been completed and its drawing is shown in Figure B.3.2. The dimension of the cylindrical vacuum chamber is decided keeping in mind various technical constraints as well as our requirement of developing a portable linear neutron source of length around 20 cm.

Studies on pinched plasma of plasma focus: Plasma Focus is a pulsed plasma device which produces a high density, high temperature plasma for a duration of hundreds of nanoseconds. The plasma of this device, which emits copious amount

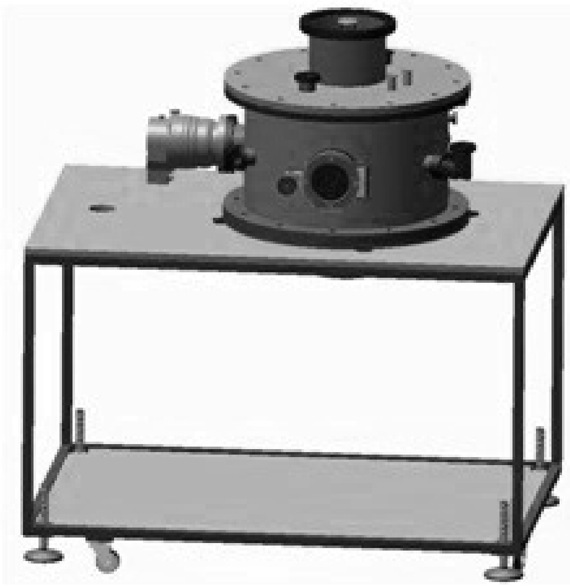

Figure B.3.2 Drawing of cylindrical inertial electrostatic confinement fusion (IECF) chamber

of X-rays and neutrons (in deuterium medium), has still been able to draw attention from researchers as a pulsed source for these emissions. Thus we have continued our work on the studies on X-ray emission from the PF device.

(i) Triple Pin-hole camera: To study the space resolved X-ray emission from pinched plasma region of plasma focus, we have developed a triple pinhole camera. In this camera we have used three pin-hole in a single enclosure to acquire three images simultaneously of a particular pinched plasma region through metallic filter like Aluminum . The soft X-ray emission from PF was studied for four different shaped anodes. We have employed the triple pin-hole camera to know the pinched structure of plasma column of PF device for different anodes tips. The hot spots (small localized intense X-ray emitting region in the form of spot) and other intense X-ray emitting regions can be resolved in this camera using three filter of same material with three different thicknesses. The instability and hotspot formation for the different shaped anodes (namely divergent, oval, cylindrical and converging depending on its shape) were studied. From the study we have concluded that the instability growth is higher in case of divergent and oval shaped anode comparing to cylindrical and converging anode tip.

(ii) Time resolved measurement of X-ray emission using Vacuum photodiode: A Vacuum Photo-Diode (VPD) is a two electrode system which works on the principle of photoelectric effect. In CPP-IPR, we have developed a very small cylindrical (VPD) and we used this VPD to measure the soft X-ray energy, electron temperature and total radiated power of different shape anode. For this measurement we have used a couple of identical VPD, fitted across the side port of PF device. The estimated electron temperatures using intensity ratio method are found to be around 0.64, 1.5, 0.60 and 0.55 keV for cylindrical, diverging, oval and converging anode tip respectively. For the plasma at a temperature of kTe (eV), the peak of its Bremsstrahlung occurs at the wavelength of lambda-0=6200/kTe Å. Hence for a plasma at kTe = 0.64, 1.5, 0.60 and 0.55 keV, its X-ray Bremsstrahlung is expected to peak at lambda-0 = 9.68, 4.13, 10.33 and 11.27 Å, which is in the soft X-ray region. So the measured soft X-ray photon energies are 1.28, 3.0, 1.2 and 1.1 keV.

(iii) Neutron Emission studies: We have also carried out the study of temporal evolution hard X-ray and of neutron emission from PF device using PMT combined with plastic scintillators. There is another detector, which is called as neutron bubble dosimeter, employed to determine the numbers of neutron emission in axial and radial direction of the PF device. When neutron passes through the emulsion of this detector, bubbles forms and converting those bubbles to the equivalent neutron dose, one can determine the number of neutrons emitted from the plasma. The intensity of neutron pulse (analyzed from in the PMT signal) and the number of neutron emission (counted from bubble dosimeter) is found to be greater in the axial direction as compared to the radial one.

Development of coaxial pulsed plasma accelerator: We are presently engaging to develop a coaxial pulsed plasma accelerator (gun) of GW/m^2 level power density. The objective of this work is to generate high power pulsed plasma stream to simulated the plasma matter damage studies similar to that occurring in the divertor regions of a tokamak. The gun will be energized by a pulse power system (PPS) of around 600kJ. It has been proposed to develop the pulse power system in steps and initially, we are targeting to develop a 100 kJ (or 80 kJ) PPS and upgraded it to 600kJ PPS in coming years.

Planning of PPS: As mentioned above, the earlier plan was to develop modules of either 80 kJ or 100 kJ PPS and finally to assemble it to 600 kJ PPS. Initially we may directly attempt to make 200 KJ PPS with 10 numbers capacitors (20 kJ for each capacitor). These PPS will be built on a lab which will be constructed in the coming months. So depending on the availability of space, we may opt for either 80 or 100 kJ PPS. In the project, we are proposing to achieve an output of 300 kA peak discharge current for 600 kJ bank. The

T/2 period will be few tens of microsecond to maximum few hundreds of microsecond (targeted FWHM = 500 μs). So, we have planned to get the output of 200 kJ PPS in a same pattern as that will be for 600 kJ bank, except the amplitude of peak discharge current will be a lower one. The peak discharge current of each 200 kJ will be reduced to 100 kA and when we will fire 3 modules of 200 kJ simultaneously (cumulatively making it the 600 kJ), it will give 300 kA peak discharge current in the same pattern of individual out of 100 kA from each module. The 200 kJ modules will be designed in a circular fashion with one ignitron at the centre of capacitors bank. There will be additional 20 kJ bank with single capacitors with dummy load or any other pulse discharge reactor to be readied whenever we get high voltage energy storage capacitors. This will facilitate to test the diagnostics like current probe, voltage probe, oscilloscope, antenna, photodiode etc. In this developing work, a lots of information has become necessary to identify and specify the right components and right items for build a PPS as well as plasma gun set up. Some of them have been allocated to be procured in the first year of the project.

Ignitron: One of the important parts of PPS system is the high power switch, which will connect the capacitor bank to its load to discharge the capacitor through the load. Since we are going to produce a relatively slower (T/2 = few tens of microsecond) pulse in the output of the PPS, we have identified that ignitron will be suitable for it. We have selected the ignitron NL8900 of M/S Richardson Electronics and three numbers of this ignitron will be required for 600 kJ PPS. Subsequently the ignitron driver and low voltage multi trigger generator as suitable to drive the NL8900 will be used to fire the capacitors. Currently, the procurement of items required for the building of PPS including the ignitron is at different stages of purchase process and some of the items will be procured in the coming years.

B.3.5 Double Plasma Device Laboratory

Study on surface processes in a negative ion source and measurement of negative ion parameters: Surface processes enhances the population of vibrationally excited hydrogen molecules resulting in improved yield of negative hydrogen ions by the process of dissociative attachment. Also, it is know that plasma uniformity near the magnetic filter should be kept as low as possible for good ion beam optics. Surface processes, through an enhanced production of negative ions, will also have an effect on the plasma uniformity near the magnetic filter. The project will investigate this important aspect of the influence of surface processes on plasma conditions near the magnetic filter.The time period under consideration have been spent in carrying our literature survey on the experiments to be performed. The most important part is fixing the parameters/specifications for the new laser photodetachment experimental setup that will be used to determine the negative ion number density. In order to generate the specifications for this important diagnostic apparatus, research papers have been collected and read. Apart from many other features which have been included in the complete list of specifications, the general specifications for the laser will be wavelength of 1064 nm including harmonics, aperture diameter of 4 mm and energy density of ~20 mJ/cm^2. Other essential accessories to be required along with the laser includes attenuator, energy sensor and energy meter. Attenuator will be used to attenuate the beam's energy density to the desired output level, energy sensor will be sensitive to the beam's energy and the energy meter will be used along with the energy sensor to measure the beam's energy. Furthermore, the following points have also been particularly considered.

1). On reducing the laser beam's diameter:- The laser's beam diameter will be variable from 4 mm to 1 mm. Using an iris/diaphragm to limit the beam diameter will affect the laser beam's output properties and profile due to diffraction. Therefore a pair of lenses will be used to reduce the beam diameter which will preserve the features of the beam.

2). On aligning the laser beam with the langmuir probe tip :- Two reflecting mirrors will be used to enable x,y and theta translation for aligning the laser beam (1 to 5 mm diameter) with the probe tip (< 1 mm diameter).

3). On using antivibration table :- Ambient vibrations are omnipresent and can result even from foot traffic. In our case there are many sources of noise and vibration nearby such as vacuum pumping systems, chillers, fans (used in case of power failure), laboratory activities requiring small fabrication and machining work (in the same or other laboratories) and construction activity outside. Motorized equipments and instruments generates noise between 10 Hz to 540 Hz, machinery generates between 10 Hz to 200 Hz and acoustic vibrations are usually above 20 Hz. Therefore, a pneaumatic antivibration setup will be used to eliminate noise/vibration in the laser photo detachment setup.

Ion ion plasma experiments in a Helicon source: Helicon sources are popular due to its high ionization capability.

However, the radio-frequency energy absorption mechanism in such sources is still debatable. Chen et.al. had shown the evidence of radio frequency (RF) energy absorption through Landau damping mechanism. Considering the electron mass in wave dispersion theory, Shamrai et al. had proposed that the efficiency of the absorption mechanism is due to Trivelpiece-Gould (electron cyclotron – TG Mode) modes, is a quasi-electrostatic, rapidly absorbed as they propagate inward from the radial boundary. Later, Chen et. al. also got the evidence of energy absorption through TG mode process in their experiment. The role of electrons in energy absorption mechanism in helicon sources can be further deeply studied, if the fraction of electrons can be varied without affecting the positive ion density. In this regard, electronegative gases (F, Cl, Br, I, O2 , SF6 etc.) can be used in the plasma, which can control the electron population density by their electron affinity property. Electronegative gases can even produce positive ion – negative ion (ion – ion) plasma with very small fraction of electrons. The project will try to study the role of electron in energy absorption in an “ion-ion” plasma in a Helicon source. The results from the project may pave a way for an efficient alternate scheme for developing a negative ion source for beam related requirements in future application, including NBI systems. The above period was used to fix the parameters/specifications for the new experimental chamber system to be set up. In order to do this, books and research papers on Helicon sources were collected, read and calculations done to find out the various parameters related to system design. Taking help from equations given in these publications and by solving them some of the design parameters were found out. The length of the antenna (half of wavelength) for four different gases and their average values have been determined. From survey of literature it has been found that Borosilicate glass is highly resistant to water, neutral and acid solutions, concentrated acids and acid mixtures, and to chlorine, iodine, bromine and organic substances. Even chemical reactions over longer time can be done at elevated temperatures up to 95°C without a problem. It gets affected only in the presence of heated phosphoric acid and (stronger) alkaline solutions. It has therefore been decided to use borosilicate glass in the part where the antennae would be wound to produce plasma. The length and inner diameter of the borosilicate glass chamber has been fixed at 70 cm and 10 cm respectively with a thickness of 5 mm and that of the stainless steel chamber has been fixed at 60 cm and diameter 30 cm. A helical antenna will be used to launch the RF wave.

B.3.6. Cross-Disciplinary Plasma Science Laboratory

Structural and Mechanical changes induced by of plasma nitriding in TiN thin films onto AISI M2 steel: The phase composition and texture in TiN thin film deposited onto AISI M2 high speed steel was analyzed by X ray diffractometer. In Figure B.3.3. shows the diffraction pattern of TiN layers deposited with N2 partial pressure of 5.10^{-2} Pa. at (a) Room Temperature(RT) (b) 500^0C and (c) After Plasma Nitriding treatement(TiN+PN). At room temperature three peaks of TiN corresponding to diffraction of the planes (111), (200) and (220) are observed. At room temperature , the diffractrogram shows a more pronounced (111) orientation with less (200) and (222) orientation. After plasma nitriding the intensity of all TiN peaks decreases indicating reduction of texture coefficient. On the other hand, the XRD pattern of TiN deposited at 500^0C shows a pronounced (200) orientation with less (111) and (220) orientation. Figure B.3.3 shows the XRD pattern of TiN deposited with N2 partial pressure of 8.10^{-2} Pa. with other treatments being same. Here, the only difference is the increased intensity of TiN(200) peak after plasma nitriding treatment of sample deposited at room temperature. The surface micro-hardness of the TiN films deposited onto AISI M2 substrate was measured using Vicker’s Micro hardness tester. The testing load was carefully selected in order to meet the requirement that the contact depth should be 1/10th of the film thickness. A load of 3gf was selected and for each sample five measurements are performed and avg. value is reported. The surface micro-hardness of TiN coated substrate increases after plasma nitriding. Several factors are known to effect the hardness, such as the packing factor, the residual stress, the stoichiometry, the preferred orientation and the grain size. In this study the changes in micro

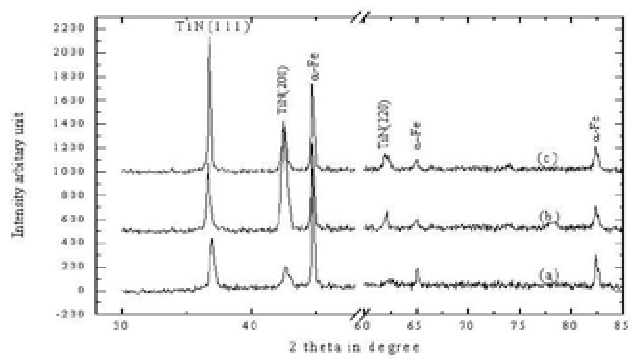

Figure B.3.3. XRD spectra of sample: a) deposited at RT and plasma nitrided at 500^0C b) deposited at 500^0C c) deposited at RT with N2 partial pressure 5.10^{-2} Pa.

hardness can be correlated with the fact that the crystallite size of TiN decreases after plasma nitriding. It seems like the hardness pattern follows well established Hall-Petch[19] relationship. Also, in the previous studies it is found that for highly preferred TiN(111) orientation the hardness increases with increasing TiN(111) texture coefficient. This fact is explained on the basis of the relationship between (111) preferred orientation and the resolved shear stress on the slip system of TiN. Since TiN has NaCl – type structure, if the film possesses highly (111) orientation it is very difficult to induce plastic deformation when the external load is perpendicular to (111) plane as the shear stress on slip system is zero. Since the texture coefficient of TiN(111) peak increases after plasma nitriding we have observed the increase of coating hardness in our case. As the depth of indentation is less than 1/10th of the minimum TiN coating thickness, the substrate effect on the hardness values is minimized. The cross sectional micro-hardness study of TiN + PN samples shows no formation of diffusion zone. It is contrary to the findings of previously published results. We have also took up the surface modification of polymers for use in biomedical application in CDPS laboratory in last year. Plasma treatment of polymeric materials has emerged as a promising research field for speedy commercialization of biomedical implants, as it is a safe and non-toxic process and can provide suitable surface modification for improving biocompatibility and cell growth within human body. In our lab a few toughened polymeric hydrogel substrates were treated in plasmagen gas with a suitably modified dc magnetron sputtering device to study the effects of surface treatment. The treated samples were studied with FTIR and SEM, and an increase in surface roughening was observed. In our future programme we will be treating these samples with RF magnetron sputtering to prevent the darkening of the polymer samples, which was observed with DC magnetron sputtering. A project was submitted to IPR for the purpose so that we can carry out our own in-house experiments with RF power. These treated samples will then be analysed for tests for biocompatibility and anitithrom bogenecity. The polymeric hydrogels used by us were previously toughened by a novel sol-gel cross linking process to increase their toughness and resilience. Surface treatment by plasma will be an effective tool for achieving enhanced surface properties for use as biomedical implants while retaining the desirable mechanical properties such as toughness and resilience.

B.4. Board of Research in Fusion Science and Technology (BRFST)

During the year 2012-13, in the reviews held in August 2012 and March 2013, the total committed budget for R&D projects was ~ Rs.458.61 Lakhs. 12 new projects were awarded during this period. Till March 2013, BRFST has awarded 100 R&D projects with a total commitment of ~ Rs.2,984 Lakhs of which 21 were awarded to industries with a total commitment of ~ Rs. 637 Lakhs. Seventy nine projects were awarded to academic institutions with a total commitment of ~ Rs. 2281 lakhs. Fifty conferences in various areas of fusion science & technology were supported by BRFST in this period with a total commitment of ~ Rs. 65 Lakhs. The total R&D funds during the period April 2012 and March 2013 was `.453.75 Lakhs.

As on March 2013, of the total 100 projects sanctioned, 62 are ongoing projects and 38 were completed.

The summary of the total R&D projects granted under NFP during the period August 2007 to March 2013 is given below and the distribution is given in the figures following that.

No. of projects to academic institutions	79
No. of projects to industrial collaborators	21
Total number of project staff	>130
Foreign travel support for project staff	01
Number of project staff registered for PhD	32
Publications in peer reviewed journals	>60
No. of PhD's completed	03
Conference publications/presentations	>90
No. of M.Techs / M.Phils / MSc	11
Patents / technology transfer	04/02
No. of NFP Internships	60
No. of conferences supported	50

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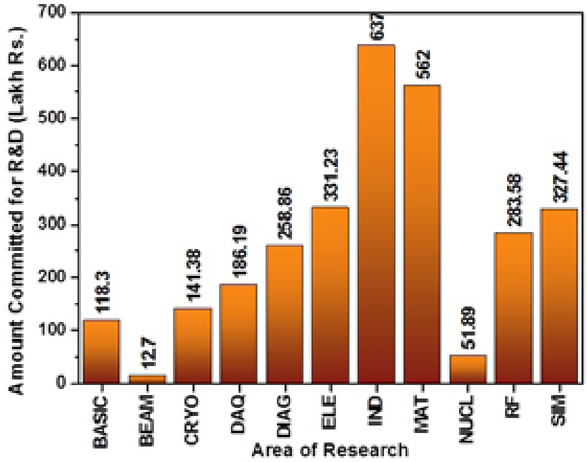
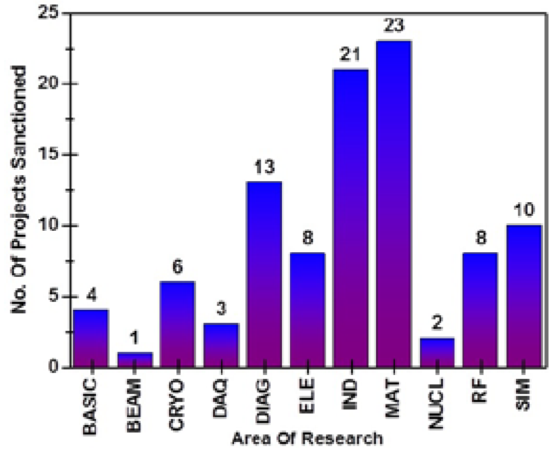
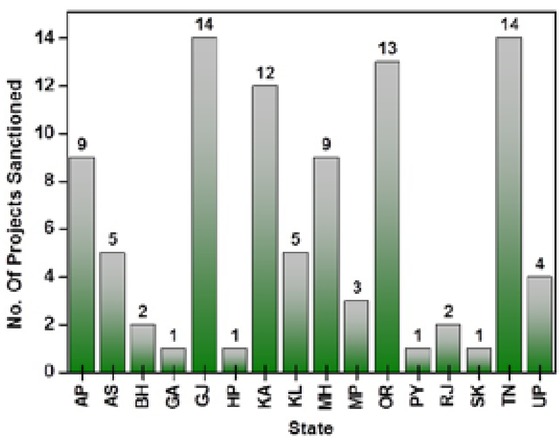
Total commitment of funds to sanctioned R&D projects



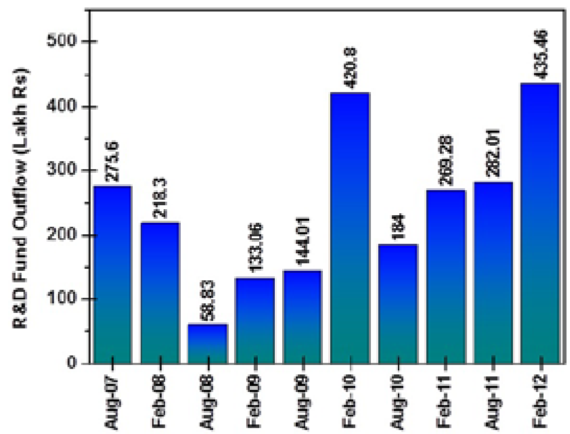
Areas of R&D supported by BRFST



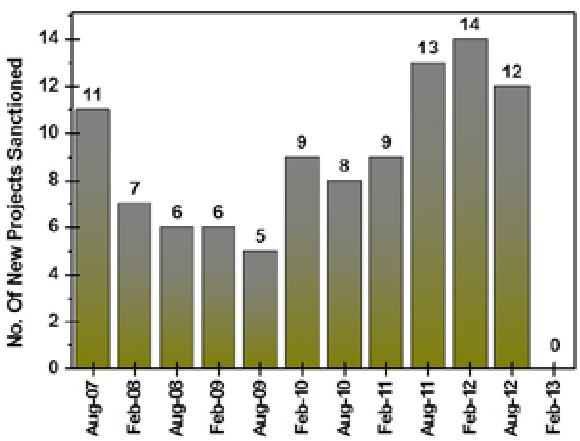
State-wise distribution of sanctioned R&D projects



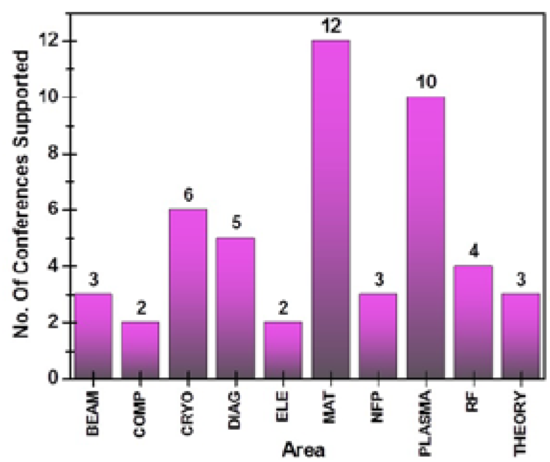
Outflow of sanctioned funds for R&D projects



Number of new projects after each review meeting



Areas of R&D in which conferences were supported



CHAPTER C. Academic Programme

CHAPTER D. Technical Services

CHAPTER E. Publications and Presentations

C. ACADEMIC PROGRAMMES

C.1 Doctorate Programme

In the Ph.D. programme conducted by the institute thirty six (36) research scholars have been enrolled at present. Out of them, thirteen (13) are working in theoretical and simulation projects while eleven (11) are engaged in experimental projects. Twelve (12) new students have joined this programme during the year and are going through the course work. After successful completion of this course work, they will be enrolled for their Ph.D. works. Presently seventeen (17) Post Doctoral Fellows are engaged in their research work.

Ph.D. Thesis Submitted (during April 2012 - March 2013)

Study of Fluctuations and Intrinsic Flows in a Simple Toroidal Plasma
T. Shekar Goud
Homi Bhabha National Institute, 2012

Study of Nonlinear Oscillations and Waves in Plasma
Prabal Singh Verma
Homi Bhabha National Institute, 2012

Study of Fast Time Scale Phenomena in Plasmas
Sita Sundar
Homi Bhabha National Institute, 2012

C.2 Summer School Programme

Sixty-three (63) students participated in this programme, which aimed at providing an opportunity to (26) students from M.Sc. Physics and (37) students from Engineering discipline which include Mechanical, Electronics and instrumentation, Electrical, Chemical and Metallurgy, to interact actively with scientists of the institute and learn about Plasma Physics and related areas through a project and series of lectures.

Besides the above-mentioned training programme, project works are routinely offered in Computer, Electronics, Electrical and Mechanical Engineering for regular students as a part of their academic requirements.

D. TECHNICAL SERVICES

D.1. Engineering Services

D.1.1. Air conditioning (AC) and Water cooling (WC)

Air-Conditioning related work : Installation, Testing & Commissioning of package type AC system in aditya tokamak control room and air-washer system in workshop is done and design, tender & SOQ preparations work for the upcoming HVAC systems in Additional Offices Building, IPR new Extension Lab and HVDC Lab are completed. These HVAC systems will be installed and commissioned in next financial year. ITER Laboratory HVAC system is on the verge of completion.

Process Cooling System related work : Design, Installation, Testing and Commissioning of process cooling system for basic lab and ITER-ICH lab is done and design, preparation of SOQ & tender documents for upcoming Cooling Tower Water system for Dummy Load in HVDC Lab is already completed and will be commissioned in next financial year.

SST-1 Cool Down Campaigns : Maintained cooling water temperatures, pressures and conductivity within desired limits during SST-1 cool down campaigns for cryogenic, LHCD, ECRH, SST NBI & Negative NBI.

Miscellaneous work : The following are the works done routinely : supervision of day-to-day activities and complaints attended by contractors for domestic AC units, water coolers and screw chilling plant, fulfilling of new requirements of split ACs, water coolers by CDC approval, indenting procedure and then supervising the installation & commissioning activities. Routine maintenance of SST-1 WCS plant equipments like pumps, motors, electrical panels, field instruments etc.

D.1.2. Computer Services

The following are the highlights of the services provided by computer center :

• New Email system with Webmail facility and 10 Tb total storage was commissioned in the last year. This system enables IPR users to check their email from any location via internet browser.
• Online application for Summer School as well as PhD admissions were successfully launched in the last year.
• The IPR as well as the E-Office websites were given a new layout and look to match the colors of the IPR logo. The E-office was also moved to the internet so that approving officers could approve applications even when not present at IPR.
• New video conferencing systems having better video quality as well as multiple participation options were procured and installed at IPR. This would facilitate VC between multiple participants.
• Extensive IT support was provided for International Events that were organized by IPR viz., International Conference On Complex Processes In Plasmas And Nonlinear Dynamical Systems (ICCPPNDS-2012), ITER-International School, IUVSTA Workshop on Ultra High Vacuum Techniques for Large Volume Devices (IUVSTA-LVD), National Symposium on Cryogenics (NSC-24) & IAEA meetings.
• Streamlining of Internet distribution through single proxy server for the whole IPR campus.
• Server Room streamlined with two parallel 20kVA UPS and DG power backup. This would provide uninterrupted power to the major servers and IT services at IPR. Also, all major network distribution points were linked to the UPS system.
• Website created for Computer Center (for IT services information). This intranet page provides details of all the services offered by the Center.
• New high resolution digital projectors (NEC) installed at Seminar Hall, Committee Rooms and offices of the Director and Administration Officer.
• Regular safety audits were conducted and planning for setting up of a state-of-the-art data/server center were also initiated.
• A pilot project for real time broadcast/recording of talks/lectures at IPR over internet/intranet through IP camera was initiated.
• Networking at the new IPR campus at Gandhinagar as well as the new additional offices building have been initiated.
• A demo HPC cluster created using existing hardware so that the students and other users can get some experience using an HPC cluster before the 5.2TF cluster at IPR is established later this year.
• All OFC / inter-building links were terminated on new fiber switch. This will facilitate better monitoring and management of the existing optical networks at IPR.
• Management, maintenance and updates of commonly used administration software (Payroll, SAP, Canteen, Medical, e-office, etc.) we carried out.
• Management and maintenance of all network at IPR, FCIPT and at New Campus.
• License management CATIA, ANSYS, MATLAB etc.
• The computer center for the first time accepted graduate as well as post graduate students for term projects. Two major projects, viz., Email System Analyzer and up-gradation of E-office using Joomla environment were successfully completed.

D.1.3 Workshop Services

Workshop provides the basic mechanical manufacturing and fabrication services as per the requirements given by the users. The workshop has facilities for cutting, welding, milling, turning etc. Workshop has carried out more than 1000 jobs (small and big) for various groups of the institute. Apart from this workshop also provides small materials that are kept in its stock for the users for their requirements. Some of the works being done at the workshop involves materials such as Graphite, Ceramic, Lead and Glass-fiber. It is quite difficult to find outside parties who can do these types of jobs and the workshop needs to prepare itself in handling such jobs. Keeping in view the condition of the existing machinery, some of which is quite old (more than 20 years), it is being proposed to upgrade a lathe machine and a milling machine in the current year.

D.1.4 Drafting Services

Drafting section caters to the different groups of the institute by generating the necessary drawings. These drawings include conceptual, engineering and fabrication types as well as as-built types. The section is equipped with trained manpower, necessary hardware and software to make the drawings in various platforms that include Auto-CAD, MDT and

CATIA, etc. The Drafting section helps in generating engineering drawings for the users for fabrication works to be carried out within the workshop as well as outside. In the last year (2012-13) some of the draftsmen were deputed abroad for working on JET ELM coils and ITER related works. The section also has worked on generating the drawings for RCC coil, Magnet diagnostics of SST-1, Model of the NBI vessel, detailed drawings with model for the small and large ELM coils, CX-NPA system, 80 kW and 20 kW RF cavity system, Thomson scattering diagnostic system for SST-1, conversion of LIGO drawings, etc.

D.2. Library Services

Institute for Plasma Research (IPR) Library is one of the advanced libraries in Plasma Sciences in terms of its collection and services. Library always act as a facilitator in the research carried out in the laboratory by making available latest resources in various related subject areas.

As a part of fulfilling this objective, IPR library subscribes to major databases such as SCOPUS, SCIENCE DIRECT, IOP Archives, Archives of Journal of Plasma Physics, AIP, APS Journals and PROLA. During this year library has undertaken digitization process of scanning all SST reports available in library and made full text access of these reports available through library webpage.

About 661 books, 41 internal research reports, 39 technical reports, 57 new research reports, 7 standards, 298 reprints and 65 software's were added in to the library collection and subscribed to 105 periodicals. Total 6 E-books and 3 theses were added to the collection.

83.95% of the requests made by IPRites were satisfied through Inter Library Loan (ILL) service. IPR Library provided documents to other institutes against ILL queries and 100% of the total need were satisfied. Total 65290 photocopies supplied to users. The library homepage acts like a window, through which it is possible to access the digital content subscribed by IPR as well as open access content. It also provides access to the institutional repository consisting of journal articles published by the IPR authors from year 1986 to present using DSpace an open source repository software. More than 1193 articles by IPR authors are now part of the repository. IPR theses from year 1982 onwards (66) are now available full text for IPR users. These collections can be accessed from library homepage (http://www.ipr.res.in/~library/LIBRARY.html), also added alert service through website for users. Continued to provide current content services, very widely to plasma physicists at national level. A total 45 news items were displayed as an Alert Service in the field of Plasma Physics and Fusion Technology. During reporting period total of Rs. 1,72,52,483.00 budget was utilized.

IPR Library helped in RTI activities and Official Language Implementation Committee (OLIC) programmes.

All library staff actively participated in professional meetings and institutional activities. Also trained three library trainees and divisional library staff especially CPP-IPR by providing all technical support.

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E. Publications and Presentations

E.1 Journal Articles

Effect of Hydrogen Ion Beam Irradiation onto the FIR Reflectivity of Pulsed Laser Deposited Mirror like Tungsten Films
A.T.T. MOSTAKO, ALIKA KHARE, C.V.S. RAO, PRAKASH M. RAOLE, SUDHIRSINH VALA, SHRICHAND JAKHAR, T.K. BASU, MITUL ABHANGI, RAJINIKANT J. MAKWANA
Journal of Nuclear Materials, 423, 53-60, 2012

Effect of Electron Accretion by Quantum Tunneling on Charging of Dust Particles in Complex Plasmas
SHIKHA MISRA, S. K. MISHRA, and M. S. SODHA
Physics of Plasmas, 19, 043702, 2012

Nature of Energetic Ion Transport by Ion Temperature Gradient Driven Turbulence and Size Scaling
J. CHOWDHURY, W. WANG, S. ETHIER, J MANICKAM, and R. GANESH
Physics of Plasmas, 19, 042503, 2012

Measurement and Processing of Fast Pulsed Discharge Current in Plasma Focus Machines
S. LEE, S. H. SAW, R. S. RAWAT, P. LEE, R. VERMA, A. TALEBITAHER, S. M. HASSAN, A. E. ABDOU, MOHAMED ISMAIL, AMGAD MOHAMED, H. TORREBLANCA, SH. AL HAWAT, M. AKEL, P.L. CHONG, F. ROY, A. SINGH, D. WONG, K. DEVI
Journal of Fusion Energy, 31, 198-204, 2012

Some Characteristics of a Double Plasma Device Operated as a Triode
M.K. MISHRA, A. PHUKAN
Canadian Journal of Physics, 90, 345-349, 2012

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Y. KHRISTI, A.N. SHARMA, K. DOSHI, U. PRASAD, P. VARMORA, S. KEDIA, D. PATEL, S. PRADHAN
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Physics of Plasmas, 19, 043104, 2012

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Geomorphology, 151-152, 89-98, 2012

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J. VANAJA, K. LAHA, SHIJU SAM, M. NANDAGOPAL, S. PANNEER SELVI, M.D. MATHEW, T. JAYAKUMAR, E. RAJENDRA KUMAR
Journal of Nuclear Materials, 424, 116-122, 2012

Free-flowing, Transparent γ-alumina Nanoparticles Synthesized by a Supersonic Thermal Plasma Expansion Process
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Scrape-Off Layer Tokamak Plasma Turbulence
N. BISAI, R. SINGH and P. K. KAW
Physics of Plasmas, 19, 052509, 2012

Sliding Wear Behavior of Plasma Nitrided Austenitic Stainless Steel Type AISI 316LN in the Temperature Range From 25 to 400 °C at 10^{-4} Bar
A. DEVARAJU, A. ELAYA PERUMAL, J. ALPHONSA, SATISH V. KAILAS, S. VENUGOPAL
Wear, 288, 17-26, 30 2012

Perturbative Analysis of Sheared Flow Kelvin-Helmholtz Instability in a Weakly Relativistic Magnetized Electron Fluid
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M. RANJAN
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KSHITISH K. BARADA, P. K. CHATTOPADHYAY, J. GHOSH, SUNIL KUMAR, and Y. C. SAXENA
Review of Scientific Instruments, 83, 063501, June 2012

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MADHU PATEL and SUBRATA PRADHAN
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S. PRADHAN
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New Journal of Physics, 14, 063008, 2012

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E. PLATACIS, A. ZIKS, A. POZNJAK, F. MUKTEPAVELA, A. SHISKO, S. SARADA, P. CHAKRABORTY, K. SANJAY, M. VRUSHANK, R. FOTEDAR, E. K. RAJENDRA, A. K. SURI
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Progress of Indian Test Blanket Module Program for ITER
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Numerical Modeling of Plasma Plume Evolution against Ambient Background Gas in Laser Blow Off Experiments
BHAVESH G. PATEL, AMITA DAS, PREDHIMAN KAW, RAJESH SINGH and AJAI KUMAR
Physics of Plasmas, 19, 073105, 2012

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Journal of Applied Polymer Science, 125, 1068–1076, 2012

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Nuclear Engineering of Diagnostic Port Plugs on ITER
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PARITOSH CHAUDHURI, E. RAJENDRA KUMAR, A. SIRCAR, S. RANJITHKUMAR, V. CHAUDHARI, C. DANANI, B. YADAV, R. BHATTACHARYAY, V. MEHTA, R. PATEL, K.N. VYAS, R.K. SINGH, M. SARKAR, R. SRIVASTAVA, S. MOHAN, K. BHANJA, A.K. SURI
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Microstructure and Dry Sliding Wear Resistance Evaluation of Plasma Nitrided Austenitic Stainless Steel Type AISI 316LN against Different Sliders
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M. K. MISHRA and A. PHUKAN
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Direct Observation of Turbulent Magnetic Fields in Hot, Dense Laser Produced Plasmas
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Indian Fusion Test Reactor
R. SRINIVASAN and FTR TEAM
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BISWANATH SARKAR, RITENDRA NATH BHATTACHARYA, HITENSINH VAGHELA, NITIN DINESHKUMAR SHAH, KETAN CHOUKEKAR, and SATISH BADGUJAR
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NITIN DINESHKUMAR SHAH, RITENDRA NATH BHATTACHARYA, BISWANATH SARKAR, SATISH BADGUJAR, HITENSINH VAGHELA, and PRATIK PATEL
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Operational Experience with the Supercritical Helium during the TF Coils Tests Campaign of SST-1
ROHITKUMAR NATVARLAL PANCHAL, RAKESH PATEL, JIGNESH TANK, GAURANG MAHESURIA, DASHRATH SONARA, VIPUL TANNA, JAYANT PATEL,G. L. N. SRIKANTH, MANOJ SINGH, KETAN PATEL, DIKENS CHRISTIAN, ATUL GARG, NITN BAIRAGI, MANOJ KUMAR GUPTA, HIREN NIMAVAT,PANKIL SHAH, RAJIV SHARMA, and SUBRATA PRADHAN
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ANIRUDDH MALI, MALAY BIKAS CHOWDHURI, RANJANA MANCHANDA, NILAM RAMAIYA, NIRAL CHANCHAPARA and JOYDEEP GHOSH
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Conceptual Design of Data Acquisition and Control System for Two Rf Driver Based Negative Ion Source for Fusion R&D
JIGENSH SONI, R. K. YADAV, A. PATEL, A. GAHLAUT, H. MISTRY, K. G. PARMAR, V. MAHESH, D. PARMAR, B. PRAJAPATI, M. J. SINGH, M. BANDYOPADHYAY, G. BANSAL, K. PANDYA and A. CHAKRABORTY
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E.1.3 Book Chapters

The Case for Fusion
P.K. KAW and I. BANDYOPADHYAY
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MUKESH RANJAN, THOMAS W. H. OATES and S. FACSKO
Advances in Nanofabrication: From Lithography to Ion-Beam Sputtering, Pan Stanford Publishing, 2012

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S. K. NEMA, HEMEN DAVE and LALITA LEDWANI
Computational and Experimental Chemistry: Developments and Applications, Apple Academic Press, 2013

E.2 Internal Research and Technical Reports

E.2.1 Research Reports

Dense strongly coupled plasma in double laser ablation of lithium: experiment and simulation
AJAI KUMAR, V. SIVAKUMARAN, ASHWIN JOY and R. GANESH
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Breaking of nonlinear oscillations in a cold plasma
PRABAL SINGH VERMA, SUDIP SENGUPTA, PREDHIMAN KAW
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Surface activation of polyethylene using low pressure and atmospheric pressure air plasma and ageing studies
PURVI KIKANI, BHAKTI DESAI, SACHIN PRAJAPATI, P. ARUN, NARENDRA CHAUHAN and S. K. NEMA
IPR/RR-550/2012 MAY, 2012

Kelvin-helmholtz instability in a strongly coupled dusty plasma medium
SANAT KUMAR TIWARI, AMITA DAS, DILIP ANGOM, BHAVESH G. PATEL and PREDHIMAN KAW
IPR/RR-551/2012 MAY, 2012

Asymmetric explosion of clusters in an intense laser field
M. KUNDU
IPR/RR-552/2012 MAY, 2012

Development of time sequencing and synchronizing electronics for double pulse laser ablation experiment
VISHNU CHAUDHARI, KIRAN PATEL, AMIT SRIVASTAVA, V. SIVAKUMARAN, R.K. SINGH and AJAI KUMAR
IPR/RR-553/2012 MAY, 2012

Gettering effect of lithium in tokamak environment
B.K. DAS, S.B. BHATT, AJAI KUMAR, M. GUPTA, N. CHAUHAN, K.M. PATEL, K.A. JADEJA and ADITYA TEAM
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Adiabatic formulation for charged particle dynamics in an inhomogeneous electro-magnetic field
VIKRAM SAGAR, SUDIP SENGUPTA AND PREDHIMAN KAW
IPR/RR-555/2012 MAY, 2012

High heat flux performance of brazed tungsten macro-brush test mock-up for divertors
YASHASHRI PATIL, S S KHIRWADKAR, D KRISHNAN, A PATEL, S TRIPATHI, K P SINGH, S M BELSARE
IPR/RR-556/2012 MAY, 2012

Valid flow combinations for stable sheath in a magnetized multiple ion species plasma
DEVENDRA SHARMA and PREDHIMAN K. KAW
IPR/RR-557/2012 MAY, 2012

Power balance analysis of diii-d plasma discharges using glf23 turbulent model
ASIM KUMAR CHATTOPADHYAY, HOLGER ST. JOHN and LANG LAO
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Emhd waves bounded by magnetic bubble
V. P. ANITHA, D. SHARMA, S. P. BANERJEE and S. K. MATTOO
IPR/RR-559/2012 JUNE, 2012

Determination of magnitude and phase of reflection coefficient for icrh transmission line on aditya using least square technique
RAJ SINGH, DHAVAL PATEL, VISHWA DADHANIYA
IPR/RR-560/2012 JULY, 2012

Modeling effect of edge current density < j > on bz to determine the effectiveness of reciprocating magnetic probe to measure edge < j >
QILONG REN, ASIM KUMAR CHATTOPADHYAY, LANG LAO
IPR/RR-561/2012 JULY, 2012

Characterization of laboratory scale high-tc ‘d-shaped’ magnet
ZIAUDDIN KHAN, ANANYA KUNDU and SUBRATA PRADHAN
IPR/RR-562/2012 AUGUST, 2012

Investigations on etg turbulence in finite beta plasma of lvpd
S. K. SINGH, L. M. AWASTHI, S. K. MATTOO, P. K. SRIVASTAVA, R. SINGH and P. K. KAW
IPR/RR-563/2012 AUGUST, 2012

Design and development of 3db patch compensated tandem hybrid coupler
RANA PRATAP YADAV, SUNIL KUMAR and S.V.KULKARANI
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Investigation of oxygen impurity transport using o v visible spectral line in aditya tokamak
M. B. CHOWDHURI, J. GHOSH, S. BANERJEE, RITU DEY, R. MANCHANDA, VINAY KUMAR, P. VASU, K. M. PATEL, P. K. ATREY, Y. SHANKARA JOISA, C. V. S. RAO, R. L. TANNA, D. RAJU, P. K. CHATTOPADHYAY, R. JHA, C. N. GUPTA, S. B. BHATT, Y. C. SAXENA and ADITYA TEAM
IPR/RR-565/2012 AUGUST, 2012

Exact analysis of particle dynamics in combined field of finite duration laser pulse and static axial magnetic field
VIKRAM SAGAR, SUDIP SENGUPTA and PREDHIMAN KAW
IPR/RR-566/2012 SEPTEMBER, 2012

Estimation and experimental verification of mueller matrix for plane ss304 mirror
ASHA ADHIYA, RAJWINDER KAUR and PABITRA KUMAR MISHRA
IPR/RR-567/2012 SEPTEMBER, 2012

Temperature distribution in fibre-glass composite impregnated with epoxy-cyanate ester blend
PRIYANKA BRAHMBHATT, MONI BANAUDHA & SUBRATA PRADHAN
IPR/RR-568/2012 SEPTEMBER, 2012

Experimental study on mhd flow through square to circular duct transition zone
A. PATEL, R. BHATTACHARYAY, E. RAJENDRA KUMAR, P. K. SWAIN, P. SATYAMURTHY, S. IVANOV, A. SHISHKO
IPR/RR-569/2012 SEPTEMBER, 2012

Investigation of suitable locations for neutronic responses measurements in llcb tbm
A. K. SHAW, H. L. SWAMI, S. TIWARI, C. DANANI, V. CHAUDHARI, E. RAJENDRAKUMAR
IPR/RR-570/2012 SEPTEMBER, 2012

Nonlinear landau damping and formation of bgk modes for plasmas with q-nonextensive velocity distributions
M. RAGHUNATHAN and R. GANESH
IPR/RR-571/2012 OCTOBER, 2012

An overview of spacecraft charging research in india: spacecraft plasm interaction experiments - spix-ii
SURYAKANT B. GUPTA, KEENA KALARIA, NARESH VAGHELA, SUBROTO MUKHERJEE, SURESH E. PUTHANVEETTIL, M. SANKARAN and RANGANATH S. EKKUNDI
IPR/RR-572/2012 NOVEMBER, 2012

Observation of low magnetic field density peaks in helicon plasma
KSHITISH K.BARADA, P.K. CHATTOPADHYAY, J. GHOSH, SUNIL KUMAR and Y.C. SAXENA
IPR/RR-573/2012 NOVEMBER 2012

Plasma response to transient high voltage pulses
S. KAR and S. MUKHERJEE
IPR/RR-574/2012 NOVEMBER 2012

Experimental observation of left polarized wave absorption near electron cyclotron resonance frequency in helicon antenna produced plasma
KSHITISH K.BARADA, P.K. CHATTOPADHYAY, J. GHOSH, SUNIL KUMAR and Y.C. SAXENA
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Opacity and atomic analysis of double pulse laser ablated plasma
V. SIVAKUMARAN, AJAI KUMAR and H.C. JOSHI
IPR/RR-576/2012 NOVEMBER 2012

MHD flow meter calibration using numerical tools
S. SAHU, R. P. BHATTACHARYAY, A. PATEL, E. RAJENDRAKUMAR, E.PLATACIS, I.BRUCENIS
IPR/RR-577/2012 NOVEMBER 2012

Improved electrical properties of epitaxial multiferroic bifeo3 films by oxygen rf plasma treatment
DEEPTI KOTHARI, SANJAY UPADHYAY, C. JARIWALA, P. M. RAOLE and V.RAGHAVENDRA REDDY
IPR/RR-578/2012 NOVEMBER 2012

Plasma heating by electric field compression
K. AVINASH and P.K. KAW
IPR/RR-579/2012 NOVEMBER 2012

Different synthesis routes of lanbo4 and its effect on electrical properties
DEEPTI KOTHARI and P. M. RAOLE
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Role of ion temperature on scrape-off layer plasma turbulence
N. BISAI and P. K. KAW
IPR/RR-581/2013 JANUARY 2013

Application of x-ray diffraction in characterization of plasma processed materials
P. A. RAYJADA and P. M. RAOLE
IPR/RR-582/2013 FEBRUARY 2013

Single image super-resolution via non sub-sample contourlet transform based learning and a gabor prior
AMISHA J. SHAH, RUJUL MAKWANA, SURYAKANT B. GUPTA
IPR/RR-583/2013 FEBRUARY 2013

Development of image processing based arc location identifier
RASHMI S. JOSHI and SURYAKANT B. GUPTA
IPR/RR-584/2013 FEBRUARY 2013

Modification of plasma flows with gas puff in the scrape-off layer of aditya tokamak
DEEPAK SANGWAN, RATNESHWAR JHA, JANA BROTANKOVA, and M.V.GOPALKRISHNA
IPR/RR-585/2013 FEBRUARY 2013

Performance of large electron energy filter in large volume plasma device
S. K. SINGH, P. K. SRIVASTAVA, L. M. AWASTHI, S. K. MATTOO, R. SINGH and P. K. KAW
IPR/RR-586/2013 FEBRUARY 2013

Microwave synthesis of tungsten copper functionally graded material for plasma facing components
CHARULATA DUBE,YASHASHRI PATIL, SHAILESH KANPARA, S.S. KHIRWADKAR, SUBHASH C.KASHYAP
IPR/RR-587/2013 FEBRUARY 2013

Validity of the generalized bohm criterion in a multiple ion species plasma
DEVENDRA SHARMA and P.K. KAW
IPR/RR-588/2013 MARCH 2013

E.2.2 Technical Reports

Design of an Improved Filter Coupled Bolometer Camera for ADITYA tokamak
PRABHAT KUMAR, KUMUDNI TAHILIANI, M.V. GOPALAKRISHNA, SAMEER KUMAR, VAIBHAV RANJAN, RATNESHWAR JHA and THE ADITYA TEAM
IPR/TR-206/2012 (APRIL, 2012)

Design Modification and Testing of the Analog Input-Output Isolation Cards and its Interfacing with RF-ICRH System
MANOJ SINGH, H. M. YADAV, RAMESH JOSHI, BHAVESH, KIRIT PARMAR, Y. S. S. SRINIVAS, S. V. KULKARNI and ICRH GROUP
IPR/TR-207/2012 (APRIL, 2012)

Development Programme Overview for Regulated High Voltage Power Supplies (RHVPS) at IPR
PARESH J. PATEL, C. B. SUMOD, D. P. THAKKAR, L. N. GUPTA, V. B. PATEL, L. K. BANSAL, K. QURESHI, V. VADHER, N. P. SINGH and U. K. BARUAH
IPR/TR-208/2012 (APRIL, 2012)

Kinetics of Nb3Sn, Cu6Sn5 and Cu3Sn Layer Growth
YOGENDRA SINGH and SUBRATA PRADHAN
IPR/TR-209/2012 (APRIL, 2012)

A Technique on Vacuum Coupling of Photo Multiplier Tube with Monochromator for Improved Monitoring of VUV Emission from Aditya Tokamak
R. MANCHANDA, M. B. CHOWDHURI, J. GHOSH, K. M. PATEL, N. RAMAIYA, S. BANERJEE, NIRAL CHANCHAPARA, ANIRUDDH MALI, VIPAL RATHOD,

C. J. HANSALIA, VINAY KUMAR and P. VASU
IPR/TR-210/2012 (APRIL, 2012)

Thermo-mechanical Analysis of Plasma Facing Components for SST-1
PARITOSH CHAUDHURI, P. SANTRA, D. CHENNA REDDY
IPR/TR-211/2012 (MAY, 2012)

Four Channel Sequence Detection and Display Electronics Card for the Analysis of Fault Sequence in the Rf-ICRH System
MANOJ SINGH, H.M. JADAV, RAMESH JOSHI, S.V. KULKARNI and RF-ICRH GROUP
IPR/TR-212/2012 (MAY, 2012)

Bolometer Diagnostics for SST-1 Divertor: A Hardware Modification Perspective
PRABHAT KUMAR, KUMUDNI TAHILIANI, P. YUVA KIRAN and RATNESHWAR JHA
IPR/TR-213/2012 (MAY, 2012)

Design and Development of FPGA based Multi Channel Interlock System
HARSHIDA PATEL, RAJAN BABU, B.K. SHUKLA, K. SATHYANARAYANA, D. PRAGNESH, JATIN PATEL and ECRH GROUP
IPR/TR-214/2012 (MAY, 2012)

Estimation of Thermal Anchoring Length for Various Instrumentation Wires used in SST -1 Coils Test Campaign
DIPAK PATEL, A. N. SHARMA, UPENDRA PRASAD, YOHAN KHRISTI, PANKAJ VARMORA, KALPESH DOSHI and S. PRADHAN
IPR/TR-215/2012 (MAY, 2012)

Experimental Simulation of Grid Breakdowns & High Voltage Conditioning of NBI Power Supply System
L.N.GUPTA, PARESH.J.PATEL, N.P. SINGH, VISHNU PATEL, DIPAL THAKKAR, SUMOD C.B, L.K.BANSAL, KARISHMA QURESHI, VIJAY VADHER and U.K BARUAH
IPR/TR-216/2012 (JUNE, 2012)

Development of an Eco-Friendly Technology for the Surface Activation of Carbon Granule - by using Dielectric Barrier Discharge Process
SURYAKANT GUPTA, NARESH VAGHELA, KEENA KALARIA, RAMKRISHNA RANE, ADAM SANGHARIYAT, VIREN ACHARYA and SUBROTO MUKHERJEE
IPR/TR-217/2012 (JUNE, 2012)

Revisiting Plasma Hysteresis with an Electronically Compensated Langmuir Probe
P. K. SRIVASTAVA, S. K. SINGH, L. M. AWASTHI and S. K. MATTOO
IPR/TR-218/2012 (JULY, 2012)

Analytical Model for Active Cooling of ICRF Transmission Lines in SST-1
PRABHAT KUMAR and RAJ SINGH
IPR/TR-219/2012 (JULY, 2012)

Monitoring and Control Software for Cooling System of 82.6 GHz Gyrotron using NI LabView 8.5
JATINKUMAR PATEL, PRAGNESH DHORAJIYA, SUNIL BELSARE, HARSHITA PATEL, K SATHYANARAYANA, B K SHUKLA
IPR/TR-220/2012 (JULY, 2012)

Bipolar Pulsed Plasma Oxidation of Aluminized 9Cr-1Mo Steels
NIRAV I. JAMNAPARA, DILIP U. AVTANI, N. L. CHAUHAN, S. B. GUPTA, KEENA KALARIA, NARESH VAGHELA, S. MUKHERJEE, A. S. KHANNA
IPR/TR-221/2012 (JULY, 2012)

Analytical Results on Suitability of SST-1 Auxiliary Support Structure for Installation of Diagnostics
PRABHAT KUMAR SHARMA and THE SST-1 TEAM
IPR/TR-222/2012 (JULY, 2012)

Evaluation of True Hardness of Tungsten by Micro Vickers Hardness Test
CHARU LATA DUBE, S.S. KHIRWADKAR
IPR/TR-223/2012 (JULY, 2012)

Information Literacy: An Overview of Information Literacy Programmes at IPR
PRAGNYA J. PATHAK and S. SHRAVAN KUMAR
IPR/TR-224/2012 (JULY, 2012)

Design of Flow Distribution Network and it's Manifold Systems for Plasma Facing Components of SST-1 Tokamak
PARITOSH CHAUDHURI, P. SANTRA, N. RAVI PRAKASH, S. KHIRWADKAR, D. CHENNA REDDY, Y.C. SAXENA
IPR/TR-225/2012 (JULY, 2012)

Signal Monitoring, Data Acquisition, Interlocks and Control Electronics for 91.2 MHz, 1.5 MW (ICRH) System for SST-1
H. M. JADAV, RAMESH JOSHI, MANOJ SINGH, B. R. KADIA, K. M. PARMAR, S.V. KULKARNI and ICRH-RF GROUP
IPR/TR-226/2012 (AUGUST, 2012)

Development of Versatile Analog and Digital Isolation Cards for High Voltage DC Power Supplies and Protection Systems
BHAVESH R KADIA, YSS SRINIVAS, S.V. KULKARNI & ICRH GROUP
IPR/TR-227/2012 (AUGUST, 2012)

Design and Comparison of Two Different Orientations of People Bed in Indian HCCB Blanket Concept
PARITOSH CHAUDHURI
IPR/TR-228/2012 (AUGUST, 2012)

Thermal Properties of Tungsten and Tungsten Alloys for Divertor Applications
YASHASHRI PATIL, S.S.KHIRWADKAR, S. KANPARA
IPR/TR-229/2012 (SEPTEMBER, 2012)

Silicon Drift Detector Calibration for Soft X-Ray Measurements
SHISHIR PUROHIT, JAYESH V. RAVAL, Y. SHANKARA JOISA, CHINTAN SHAH
IPR/TR-230/2012 (SEPTEMBER, 2012)

Ignitron Switch based Crowbar Protection System for 1.5 MW CWRF Amplifier
BHAVESH R KADIA, YSS SRINIVAS, ATUL VARIA, S.V. KULKARNI and ICRH GROUP
IPR/TR-231/2012 (SEPTEMBER, 2012)

Data Acquisition, Control and Interlocks for 82.6GHZ(ECRH) System
HARSHIDA PATEL, J PATEL, B K SHUKLA and ECRH GROUP
IPR/TR-232/2012 (OCTOBER 2012)

Effect of Plasma Nitriding and Nitrocarburising Process on the Corrosion Resistance properties of Grade 2205 Duplex Stainless Steel
J. ALPHONSA, J. GHANSHYAM, M. SATYAPAL, PRATIPAL RAYJADA, NARENDRA CHAUHAN, SUBROTO MUKHERJEE and V.S. RAJA
IPR/TR-233/2012 (OCTOBER 2012)

Study of Suppressing Induced Voltages in PF System during Ohmic Operation
V. JAIN, A. VARDHRAJULU, C. N. GUPTA, R. SRINIVASAN, R. DANIEL, V. AGARWAL
IPR/TR-234/2012 (OCTOBER 2012)

Overload and Short Circuit Protection System for Multi-Secondary Transformers Utilised in a “Regulated High Voltage Power Supplies”
PARESH J. PATEL, C.B. SUMOD, D.P. THAKKAR, L.N. GUPTA, V.B. PATEL, L.K. BANSAL. K. QURESHI, V. VADHER, N.P. SINGH and U.K. BARUAH
IPR/TR-235/2012 (NOVEMBER 2012)

Differential Protection Scheme for Power Transformer with Micro Processor Based Numerical Relay: Introduction, Installation, Wiring, Configuration and Testing
AKHILESH KUMAR SINGH, A.VARDHARAJULU, C.K.GUPTA, CHIRAG B BHAVSAR
IPR/TR-236/2012 (DECEMBER 2012)

Studies on Divertor Cooling Finger of Helium Mock-Up through CFD Approach
S. RIMZA, K. SATPATHY, S.S. KHIRWADKAR, V. MENON, D. KRISHNAN
IPR/TR-237/2012 (DECEMBER 2012)

Glow Discharge Pulsed Plasma Aluminizing of 9Cr Steels
N. I. JAMNAPARA, V. S. NAYAK, D. U. AVTANI, N. L. CHAUHAN, D. PANDA, S. B. GUPTA, K. KALARIA, N. VAGHELA, S. MUKHERJEE and A. S. KHANNA
IPR/TR-238/2013 (JANUARY 2013)

Fabrication of Bridge Type Joints for PF#3T Winding Pact of SST-1
UPENDRA PRASAD, A.N. SHARMA, D.PATEL, K.DOSHI, Y. KHRISTI, P.VARMORA, S.J. JADEJA and S. PRADHAN
IPR/TR-239/2013 (JANUARY 2013)

Design, Fabrication and Inspection of Gun Drilling Machine Developed under “Magnet Technology Development Programme”
MAHESH GHATE, SUBRATA PRADHAN, ARUN SINGH, R.J. MALLIK, T.L. GOVINDANKUTTY, M.M. HUSSAIN, S.B. JAWALE
IPR/TR-240/2013 (JANUARY 2013)

Vacuum Gauge Calibration System based on Spinning Rotor Gauge
PRATIBHA SEMWAL and ZIAUDDIN KHAN
IPR/TR-241/2013 (JANUARY 2013)

Data Acquisition System for SST-1 Vacuum Vessel Baking
MANTHENA HIMABINDU and ZIAUDDIN KHAN
IPR/TR-242/2013 (FEBRUARY 2013)

A Review on Satellite Solar Array Arcing Phenomenon
RASHMI S. JOSHI and SURYAKANT B. GUPTA
IPR/TR-243/2013 (FEBRUARY 2013)

Design and Development of a Laboratory Scale Experimental System for Plasma Diagnostics (E×B Drift Velocity Measurement)
A. SATYAPRASAD, R. S. RANE, and S. MUKHERJEE
IPR/TR-244/2013 (FEBRUARY 2013)

E.3 Conference Presentations

13th International Vacuum Electronics Conference and 9thInternational Vacuum Electron Sources Conference (IVEC-IVSEC 2012), Monterey, California, USA, 24-26 April 2012

Conceptual Design for Multi-Spectral Component Characterization of a VIRCATOR
Renu Bahl, Anitha V P, Rajesh Kumar, Sanjay Kulkarni, Y C Saxena and Chenna Reddy

19th Topical Conference High-Temperature Plasma Diagnostics (HTPD-2012), Monterey, CA, 6-10 May 2012

Bragg X-ray survey spectrometer for ITER
S.K. Varshney, R. Barnsley, M.G.O. Mullane and S. Jakhar

Measurements with Imaging Diagnostics on Aditya Tokamak
Manoj Kumar, S.V. Kulkarni, Santosh Pandya, J. Govindrajan and Ajai Kumar

17th Joint Workshop on Electron Cyclotron Emission and Electron Cyclotron Resonance Heating, Deurne, Netherlands, 7-10 May 2012

Conceptual design of ITER ECE receiver systems and their performance parameters
Hitesh Kumar B. Pandya, V.S. Udintsev, G. Vayakis and Max Austin

Effects of Non-thermal Electrons from ECCD on ECE Temperature Measurements for ITER
P V Subhash, Hitesh Kumar B. Pandya, Ravinder Kumar, and P. Vasu

Extending the physics studied by ECE on ITER
V.S. Udintsev, G. Vayakis, D. Bora, M.-F. Direz, A. Encheva, T. Giacomin, M.A. Henderson, K.M. Patel, M. Portales, A. Prakash, J.A. Snipes, C.I. Walker, M.J. Walsh, C. Watts, M.E. Austin, H. Pandya, G. Hanson, E. Popova, P. Sanchez, D. Shelukhin, G.D. Conway, J.W. Oosterbeek

International Conference on Communication Systems and Network Technologies, (CSNT 2012), Rajkot, Gujarat, 11-13 May 2012

Wave Propagation Characteristics of Dielectric Tube Waveguide Filled with Plasma
R.R. Hirani, U.V. Mehta, S.K. Pathak

Propagation Characteristics of Guided Modes in a Solid Dielectric Pyramidal Horn
S.S. Menon, J.K. Bhalani, S.K. Pathak

24th International Cryogenic Engineering Conference-International Cryogenic Materials Conference (ICEC 24 - ICMC 2012), Fukuoka, Japan, 14-18 May 2012

Extenuation Mechanism of Energy Pulses in Cryogenic Distribution System of the Fusion Devices
R. Bhattacharya, B. Sarkar, H. Vaghela, S. Badgujar, N. D. Shah, Y. C Saxena

12th Spacecraft Charging Technology Conference (12th SCTC), Kitakyushu, Japan, 14-18 May 2012

An Overview of Spacecraft charging research in India: Spacecraft Plasma Interaction Experiments
Suryakant B. Gupta, Keena Kalaria, Naresh Vaghela, Subroto Mukherjee, Suresh E. Puthanveettil, M. Sankaran, and Ranganath S. Ekkundi

39th European Physical Society Conference on Plasma Physics & 16th International Congress on Plasma Physics, Stockholm, Sweden, 2-6 July 2012

Scaling of Electron Temperature Gradien
t with EEF for ETG Turbulence Study
S. K. Singh, L. M. Awasthi, P. K. Srivastava, S. K. Mattoo, R. Singh and P. K. Kaw

39th IEEE International Conference on Plasma Science (ICOPS-2012), Edinburgh, UK, 8-12 July 2012

Atmospheric pressure plasma jet on floating electrode in air using half bridge resonant converter
V. Jain, A. Visani, R. Srinivasan, S. Mukherjee, V. Aagrwal

7th National Conference on Nonlinear Systems and Dynamics (NCNSD-2012), Indian Institute of Science Education and Research, Pune, 12-15 July, 2012

Role of fluctuations and flows in sustaining mean profiles in a simple toroidal plasma
T. S. Goud, R. Ganesh, Y. C. Saxena, D. Raju, K. Sathyanarayana, K. K. Mohandas, and C. Chavda

16th National Congress on Corrosion Control, National Corrosion Council of India, Kolkata, 23-25 August, 2012

Plasma Nitrocarburizing process - a solution to improve wear and corrosion resistance of materials used for making control valves
Alphonsa Joseph, Ghanshyam Jhala, P. A. Rayjada, R M Anklesaria, K. M. Anklesaria, and Kelly Buchia, Praveen Patel and S. Mukherjee

3rd International Symposium on Negative Ions, Beams and Sources (NIBS 2012), Jyvaskyla, Finland, 3-7 September 2012

Conceptual Design of Data Acquisition and Control System for Two Rf Driver Based Negative Ion Source for Fusion R&D
Jigensh Soni, R. K. Yadav, A. Patel, A. Gahlaut, H. Mistry, K. G. Parmar, V. Mahesh, D. Parmar, B. Prajapati, M. J. Singh, M. Bandyopadhyay, G. Bansal, K. Pandya and A. Chakraborty

Proposal of Actively Heated, Long Stem Based Cs Delivery System for Diagnostic Neutral Beam Source in ITER
G. Bansal, S. Mishra, K. Pandya, M. Bandyopadhyay, J. Soni, A. Gahlaut, K. G. Parmar, S. Shah, A. Phukan, G. Roopesh, I. Ahmed, A. K. Chakraborty, M. J. Singh, B. Schunke, R. Hemsworth, L. Svensson, J. Chareyre and J. Graceffa

13th International Conference on Plasma Surface Engineering, Garmisch-Partenkirchen, Germany, 10-14 September 2012

Effect of Plasma Nitriding and Nitrocarburising Process on the Corrosion Resistance of Grade 2205 Duplex Stainless Steel
Subroto Mukherjee, Alphonsa Joseph, Ghanshyam Jhala, Satyapal M, A. S. Khanna, Pratipal Rayjada, Narendra Chauhan, Raja V. S.

27th Symposium on Fusion Technology (SOFT 2012), Liege, Belgium, 24-28 September 2012

Mechanical Properties and Microstructural Investigation of TIG Welded 40mm and 60mm Thick SS 316L Samples for Fusion Reactor Vacuum Vessel Applications
Ramesh Kumar Buddu, Narendra Chauhan, P.M. Raole

Liquid Metal MHD activities for LLCB TBM Development
Rajendraprasad Bhattacharyay, Anita Patel, Pravat K Swain, Polepalle Satyamurthy, Sushil Kumar, Sergei Ivanov, Andrew Shisko, Erik Platacis, Anatoli Ziks, and Rajendrakumar Ellappan

New High Heat Flux Test Facility at IPR for Testing Plasma Facing Components
S.S.Khirwadkar, M.S.Khan, Rajamannar Swamy, Sunil Belsare, Alpesh Patel, Sudhir Tripathi, Deepu Krishnan

Simulation of Wire-burn Test for -70 kVdc Solid State Crowbar
Srinivas Y.S.S. and S.V. Kulkarni

Negative Ion Beam Extraction in ROBIN
Gourab Bansal, Agrajit Gahlaut, Jignesh Soni, Kaushal Pandya, Kanu G. Parmar, Ravi Pandey, Mahesh Vuppugalla, Bhavesh Prajapati, Amee Patel, Hiren Mistery, Arun Chakraborty, Mainak Bandyopadhyay, Mahendrajit J. Singh, Arindam Phukan, Ratnakar K. Yadav, Deepak Parmar

Cooling the Tokamak - Evolution of the Secondary and Tertiary Heat Transfer Systems Design
Liliana Teodoros, Giovanni Dell'Orco, Steve Ployhar, Babulal Gopalapillai, Ajith kumar, Dinesh Gupta, Mahesh Jadhav, Nirav Patel, Hiren Patel, Lalit Sharma, Gohil Gumansinh and Jinendra Dangi

Vacuum System of SST-1 Tokamak
Ziauddin Khan, Firozkhan Pathan, Siju George, Pratibha Semwal, Kalpesh Dhanani, Yuvakiran Paravastu, Prashant Thankey, Gattu Ramesh, Manthena Himabindu and Subrata Pradhan

International Corrosion Conference and Expo (CORCON 2012), Goa, India, 26-29 September 2012

Comparison of Plasma Nitriding and Nitrocarburising process on 17-4 PH precipitation hardening stainless steels for

improving corrosion resistance properties
J. Alphonsa, J. Ghanshyam Jhala, , Pratipal Rayjada, Narendra Chauhan, V.S. Raja, Subroto Mukherjee

11th International Conference on High Nitrogen Steels and Interstitial Alloys (HNS-2012), Chennai, 27-29 September 2012

A Study on Laser Shock Peening of 316 Stainless Steel Weldments
Y. Rajkumar, S. Vikas, N. Ankush Nayak, Neeta Magaji, B. Ramesh Kumar, K.R. Udupa, G. Umesh, K. Udaya Bhat

Baltic School on Applications of Neutron and Synchrotron Radiation in Solid State Physics and Materials Science (BSANS–2012), Riga, Latvia, 1-4 October 2012

A comprehensive study and analysis of aluminium nitride nanostructures by inelastic neutron scattering, XANES, FTIR and Luminescence spectroscopies
C. Balasubramanian, S. Bellucci, M. Cestelli Guidi, A. Ivanov, A. Popov, H. Schober, V. Sarchyu, Yu. Zhukovskii

International Centre for Theoretical Physics ICTP-IAEA Joint College on Plasma Physics, ICTP, Trieste, Italy, 1-12 October 2012

Coherent to turbulence transition, enhanced flow and confinement in a simple toroidal plasma
T. S. Goud, R. Ganesh, Y. C. Saxena, D. Raju, K. Sathyanarayana, K. K. Mohandas, and C. Chavda

24th IAEA-Fusion Engineering Conference (IAEA FEC 2012), San Diego, USA, 8-13 October 2012

SST-1 Tokamak Integration and Commissioning
S. Pradhan, Z. Khan, V. L. Tanna, A. N. Sharma, P. Biswas, A. Varadarajulu, H. Masand, K. J. Doshi, U. Prashad, H. S. Patel, P. Santra, T. J. Parekh, P. Yuvakiran, F. S. Pathan, H. J. Dave, P. K. Chauhan, J. K. Tank, P. N. Panchal, R. N. Panchal, R. J. Patel, S. George, P. Semwal, P. Gupta, Y. S. Khristi, C. K. Gupta, D. K. Sharma, G. I. Mahesuria,D. P. Sonara, K. R. Dhanani, A. Kumar, S. P. Jayswal, M. Sharma, N. C. Gupta, J. C. Patel, P. L. Thankey, M. K. Bhandarkar, P. Varmora, D. J. Patel, G. L. N. Srikanth, D. S. Christian, A. Garg, N. Bairagi, M. Himabindu, G. R. Babu, A. G. Panchal, M. M. Vora, A. K. Singh, I. A. Mansuri, K. M. Patel, R. Sharma, H. D. Nimavat, P. R. Shah, J. R. Dhongde, K. B. Patel, H. H. Chudasma, T. Y. Raval, A. L. Sharma, A. K. Singh, A.Ojha, K. R. Vasava, V. R. Prajapati, N. N. Kadamdhad, S. K. Patnaik, B. R. Praghi, D. Raju, M. Banaudha and A. R. Makwana

SST-1 Magnet system progress towards device assembly
S. Pradhan, A. N. Sharma, U. Prasad, K. Doshi, Y. Khristi, P. Varmora, D. Patel, S. J.Jadeja, P. Gupta

Activation Analyses of Lead Lithium Cooled Ceramic Breeder Test Blanket Module in ITER
Chandan Danani, H. L. Swami, A. K. Shaw, Vilas Chaudhari, E. Rajendra Kumar

Preliminary Safety Analysis of the Indian Lead Lithium Cooled Ceramic Breeder Test Blanket Module System in ITER
Vilas Chaudhari, Ram Kumar Singh, Paritosh Chaudhuri, Brijesh Yadav, Chandan Danani, E. Rajendra Kumar

Theory of Rapid Formation of Pedestal and Pedestal width due to Anomalous Particle Pinch in the Edge of H-mode Discharges
P.K. Kaw, Raghvendra Singh, Rameswar Singh, H. Nordman, X. Garbet, C. Bourdelle, David Campbell, Alberto Loarte, Dhiraj Bora

Steady State Particle-In-Cell Simulations of Microturbulence in Tokamaks
Rajaraman Ganesh, Wei-Li Lee, Stephane Ethier, Janardhan Manickam

Status of the Negative Ion Based Diagnostic Neutral Beam for ITER
Beatrix Schunke, Dhiraj Bora, Deirdre Boilson, Julien Chareyre, Hans Decamps, Francois Geli, Ronald Hemsworth, Joseph Graceffa, Marc Urbani, Deepak Lathi, Arun Kumar Chakraborty, Ujjwal Baruah, Irfan Ahmed, Mainak Bandyopadhyay, Gangadharan Roopesh Nair, Chandramouli Rotti, Sejal Shah, Mahendrajit Singh, Narinder Pal Singh, Alexander Krylov, Alexander Panasenkov

Modelling of ITER Plasma Shutdown with Runaway Mitigation using TSC
Indranil Bandyopadhyay, Masayoshi Sugihara, Stephen C. Jardin, Amit Kumar Singh

Preliminary Corrosion Studies on Structrural Materials in Lead-Lithium for Indian LLCB TBM
A. Sarada Sree, Tanaji Kamble, Hemang Agravat, Poulami Chakraborty, R.K. Fotedar, E. Rajendrakumar, A.K. Suri
Exploring the Engineering Performance Limits of DNB
Chandramouli Rotti, Arun Kumar Chakraborty, Mainak Bandyopadhyay, Mahendrajit Singh, Roopesh Gangadharan, Irfan Ahmed, Sejal Shah, Chareyre Julien, Beatrix Schunke,

Deirdre Boilson, Joseph Graceffa, Ronald Hemsworth, Lennart Svensson

Tungsten Divertor Target Technology and Test Facilities Development
S.S. Khirwadkar, K. Balasubramanian

Resonant and Non-resonant type Pre-ionization and Current Ramp-up Experiments on Tokamak Aditya in the Ion Cyclotron Frequency Range
S.V. Kulkarni, Kishore Mishra, Y.S.S. Srinivas, H.M. Jadav, Kirit Parmar, B.R. Kadia, Atul Varia, R. Joshi, Manoj Parihar, M.K. Gupta, Nilam Ramaiya, J. Ghosh, P.K. Atrey, R. Jha, Y.S. Joisa, Rakesh Tanna, S.B. Bhatt, C.N. Gupta, P.K. Kaw, ICRH Group and Aditya Team

Tearing mode stability in a toroidally flowing plasma
A. Sen, D. Chandra and P. Kaw

ITER Diagnostics - Technology and Integration Challenges
D. Johnson, P. Andrew, R. Barnsley, L. Bertalot, D. Bora, J.M. Drevon, T. Fang, R. Feder, Y. Kusama, H. G. Lee, B. Levesy, D. Loesser, S. Pitcher, R. Reichle, V. Udintsev, P. Vasu, G. Vayakis, C. Walker, M. Walsh, C. Watts, A. Zvonkov

10th International Oil & Gas Conference and Exhibition (Petrotech 2012), New Delhi, 14-17 October 2012

Plasma Gasification of Petroleum Waste into Syn Gas
S. K. Nema, A. Sanghariyat, P. V. Murugan, C. Patil, S.Mukherjee, S. Das and J. Sharma

1st IAEA DEMO Programme Workshop, University of California, Los Angeles, California, USA, 15-18 October 2012

DEMO Divertor Readiness Gaps and Needed R&D
S.S.Khirwadkar, Vinay Menon, Sandeep Rimza, K. Satpathy, Deepu Krishnan

65th Annual Gaseous Electronics Conference, Austin, Texas, USA, 22 - 26 October 2012

Role of external magnetic field and current closure in the force balance mechanism of a magnetically stabilized plasma torch
G. Ravi and Vidhi Goyal

International Welding Symposium (IWS 2K12), Mumbai, 30th October-1st November 2012

TIG Welding to Join Dissimilar Materials: Copper to SS304
Suresh Akella, B. Ramesh Kumar

Workshop on Atmospheric Plasma Processing (WAPP -2012), Department of Physics, Bharathiar University, 31 October-3 November 2012

Waste Treatment by Thermal Plasma & Energy Recovery Possibilities
S. K. Nema

COMSOL Conference India 2012, Bangalore, 2-3 November 2012

Calibration of MHD Flowmeter using COMSOL Software
S. Sahu, R.P. Bhattacharyay, E. Rajendrakumar, E. Platacis, I. Brucenis

Thermal Hydraulic Study for Heavy Liquid Metal Flows using COMSOL Multi-physics
K. T. Sandeep, S. Sahu, V. Chaudhari, R. Bhattacharyay, E. Rajendra Kumar

Thermo-mechanical Analysis of Divertor test mock-up using Comsol Multiphysics
Yashashri Patil, D. Krishnan, S.S. Khirwadkar

Theoretical Calculation and Analysis Modelling for the Effective Thermal Conductivity of Lithium Metatitanate Pebble Bed
M. Panchal, A. Shrivastava, P. Chaudhuri, E. Rajendrakumar

International Conference on Advanced Materials Processing - Challenges and Opportunities, (AMPCO 2012), IIT Roorkee, 2-4 November 2012

Mechanical and Microstructural Characterization of 8mm Thick Samples of SS 316L by CO2 Laser Welding
B. Ramesh Kumar, N. Chauhan and P.M. Raole

International Conference on Complex Processes in Plasmas and Nonlinear Dynamical Systems (ICCPPNDS-2012) was held at Institute for Plasma Research in Gandhinagar, India, 6-9 November 2012

Investigations of nonlinear Structures in Large Volume Plasma Device
S. K. Singh, L. M. Awasthi, S. K. Mattoo, R. Jha, P. K. Srivastava, R. Singh and P. K. Kaw

Plasma Turbulence in the Complex Scenario of near EEF region
A. K. Sanyasi, L. M. Awasthi, S. K. Mattoo, S. K. Singh, P. K. Srivastava, R. Singh and P. K. Kaw

Coulomb Crystals of Charged Water Droplets and Carbon Dust on the Surface of Oil using Corona Discharges
S.V. Kulkarni and Abhijit Sen

Design and Development of 3dB High Power Hybrid Coupler for the Ultra-wideband Frequency Range (30-110 MHz)
Rana Pratap Yadav, Sunil Kumar and S.V. Kulkarni

The role of Non-Gaussian fluctuations in the induced poloidal flows in a simple toroidal plasma
T. S. Goud, R. Ganesh, Y. C. Saxena, and D. Raju

Complex Dynamics of 2D Patterns in Cold Magnetized RF Plasma
Devendra Sharma

Elastic Turbulence: In Context of Dusty Plasma
Sanat Kumar Tiwari, Vikram Singh Dharodi, Amita Das, Bhavesh G. Patel and Predhiman Kaw

Influence of Polarization Force on the March Cones in a Strongly Coupled Dusty Plasma
R. Dey, P. Bandyopadhyay, K. Jiang and G. Morfill

Excitation of IAW with Two Species of Positive lons and Dust Grains
B. Kakati, M. Bandyopadhyay, S.S. Kausik, B.K. Saikia and Y. C. Saxena

Study on Charged Collimated Dust Beam in Low-pressure Plasma
S.S. Kausik, B. Kakati and B.K. Saikia

Biased Electrode Experiment in Aditya Tokamak
Pravesh Dhyani, Joydeep Ghosh, P.K. Chattopadhyay, K. Sathyanarayana, K.A. Jadeja, R.L. Tanna, S.B. Bhatt, D.S. Varia, M.B. Kalal, Pintu Kumar, V.K. Panchal, Jayesh Raval Shankar Joisa, Nilam Ramaiya, M.B. Chowdhuri, Aniruddh Mali, Umesh Dhobi, P.K. Atrey, Kumudni Tahiliani, C.N. Gupta, Y.C. Saxena and ADITYA Team

Simulation of Blob Transport Phenomena from Bulk Plasma Structure like Scrape off Layer (SOL) of TOKAMAK Like Machine Using the Compact Plasma System (CPS) at Ravenshaw University
G. Sahoo, R. Paikaray, D.C. Patra, N. Sasini, J. Ghosh, M.B. Chowduri, R. Ganesh and A. Sanyasi

Measure of Structure of a Slowly Rotating Tearing Mode in Dlll-D Tolamak
Y. Shankara Joisa, Rob La Haye and Eric Hollmannn

Hydrodynamic Stability of Conservative Regularized Couette Flow
R.P. Prajapati, R. Ganesh, A. Sen and C. Thyagaraja

Experimental Measurement of Electron Energy Distribution Function of Solitary Electron Holes
Satyananda Kar, Mangilal and S. Mukherjee

Wave Breaking Phenomenon of Lower-Hybrid Oscillations Induced by a Background Inhomogeneous Magnetic Field
Chandan Maity, Nikhil Chakrabart and Sudip Sengupta

Breaking of Nonlinear Oscillations and Waves in a Cold Plasma
Prabal Singh Verma, Sudip Sengupta, Pradhiman Kaw

Pondermotive Ion Acceleration in a Viscoelastic Dense Plasma
Ujjwal Sinha

Anisotropic Coulomb Explosion of Argon Clusters in Intense Laser Fields
Mrityunjay Kundu

Detailed Characterization of Relativistic Electromagnetic Solitons in Cold Plasmas
Sita Sundar and Amita Das

Electrical Breakdown Study of Liquid Dielectrics under Pulsed Conditions
G. Veda Prakash, R. Kumar, C. Reddy, J. Patel and A. Shyam

On the Behaviour of Pulsed Plasma Blob Produced By Gas injected Washer Plasma Gun
S. Samantaray, R. Paikaray, G. Sahoo, D.C. Patra, J Ghosh, R. Ganesh, M.B. Chowdhuri and A.K. Sanyasi

Dynamics of Laser Induced Barium Plasma in Strong Magnetic Field
Ajai Kumar, R. Srinivasan and R.K. Singh

23rd Meeting of the ITPA Topical Group on Diagnostics, ITER-India, IPR, Gandhinagar, India, 27-30 November 2012

Effect of Non-Thermal Electrons on ITER ECE Temperature Measurement: A Computational Study
P.V. Subhash, Nikita Chhetri, Trupti Sharma, Hitesh Kumar B. Pandya, and P .Vasu

Neutronics activities at ITER-India
P.V. Subhash, S. Jakhar, C.V. Suresh, U. Sati, Ramesh Vettur, C.V.S. Rao , T.K. Basu and P. Vasu

Status of XRCS-Edge and –Survey spectrometers for ITER
Sanjeev Varshney, Robin Barnsley, Gunter Bertschinger, Martin O' Mullane, Shrichand Jakhar and XRCS-team

Neutronics analysis of ITER x-ray crystal spectrometer (survey) in Eq. port #11
Shrichand Jakhar, Robin Barnsley, Sanjeev Varshney, Luchiano Bertalot

IN-DA diagnostics engineering and port integration
Shrishail Padasalagi, Siddharth Kumar, Sanjeev Varshney, Parameswaran Vasu, Vinay Kumar

Overview of ITER ECE system
Hitesh Pandya, Suman Danani, Ravinder Kumar, Siddharth Kumar, Shrishail Padasalagi, Vinay Kumar

International Conference on Mechatronics and Control Engineering, ICMCE 2012, Guangzhou, 29-30 November 2012

A Compact Plasma System for Experimental Study
G. Sahoo, R. Paikaray, S. Samantaray, D.C. Patra, N. Sasini, J. Ghosh, M.B. Chowdhuri and A.K. Sanyasi

6th ITER International School (IIS-2012), IPR, Gandhinagar, 2-6 December 2012

Thermal Analysis of Ion Cyclotron Resonance Heating Antenna for SST-1
Pratibha Gupta, S.V. Kulkarni, D. Bora, A. Mukherjee and ICRH group

Experimental Observation of Coherent Structures in Finite Beta Plasma
S. K. Singh, L. M. Awasthi, S. K. Mattoo, R. Jha, P. K. Srivastava, R. Singh and P. K. Kaw

Solid State Physics: Proceedings of the 57th DAE Solid State Physics Symposium, Indian Institute of Technology, Bombay, Mumbai, India, 3-7 December 2012

Molecular Dynamics Simulation of He Diffusion in FeCr Alloy
A. Abhishek, M. Warrier, and E. Rajendra Kumar

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Instrumentation Architecture for ITER Diagnostic Neutral Beam Power Supply System
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Microcontroller Based DAQ System for IR Thermography by Hot and Cold Water Flow
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Client Server Architecture Based Embedded Data Acquisition System on PC104
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PC Based Real Time Data Exchange on 10GbE Optical Network Using RTOS
R.P. Gupta, H.D. Dave

A Large Channel Count Multi Client Data Acquisition System for Superconducting Magnet System of SST-1
K.J. Doshi, J.A. Dhongde, Y.S. Khristi, H.A. Masand, B.A. Parghi, D.A. Patel, S. Pradhan, U.A. Prasad, A.N. Sharma, P.A. Varmora

High Voltage Controller System for Spectroscopy Diagnostics of SST-1
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Effect of temperature on the corrosion resistance properties

of A-286 precipitation hardening stainless steel after Plasma Nitriding process
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A Review on Satellite Solar Array Arcing Phenomenon
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An Analytical Understanding of Plasma Surface Interaction in N2-H2 Discharges
K.S. Suraj, Prince Alex and S. Mukherjee

Study of Hall Thruster Performance due to Magnetic Mirror Effects
Deepti Sharma and R.Srinivasan

Generation of Fluctuations and Intrinsic Flows in a Simple Toroidal Plasma
T. Shekar Goud, R. Ganesh, Y.C. Saxena and D. Raju

Studying Bohm Criterion in Two Ion Species Plasma
K. Vara Prasad, Joydeep Ghosh, Devendra Sharma, P.K. Chattopadhyay and P. Mehta

Imaging of X-Ray Emitting Zone of Plasma Focus Device by Simple Triple Pinhole Camera
N.Talukdar, N.K. Neog and T.K. Borthakur

Non-linear Study in a Cold Cathode Glow Discharge
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Correlation of Neutron with Deuteron and X-ray Emission from 2.2kJ Plasma Focus Device
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An Integrated Four-gun Plasma Source for Symple
V.P. Anitha, Priyavandna J. Rathod, Renu Bahl and Jayesh Rawal

Wave Breaking Phenomenon of Lower-hybrid Oscillations Induced by Background Inhomogeneous Magnetic Field
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Magnetized Quiescent Plasma Device for Wave Studies
Sayak Bose, P.K. Chattopadhyay, J. Ghosh, Y.C. Saxena and S. Sengupta

Current Free Double Layer Study in a Low Pressure Helicon Discharge
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The Low Magnetic Field Density Peak in a Helicon Discharge
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Analysis of EMHD Wave Propagation in Radially Nonuniform Magnetic Configuration
D. Sharma, Anita V.P. and S.K. Mattoo

Characterization Studies of Lithium Vapor Generated in the Heat Pipe Oven for the Plasma Wakefield Accelerator Experiment
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Experimental Measurement of Electron Energy Distribution Function of Solitary Electron Holes
Satyananda Kar, Mangilal and S.Mukherjee

Comparison of Langmuir Probe Characteristic of Argon and Oxygen Plasma in Presence of External Magnetic Field
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Novel Method for Scavenging of Energetic Electrons by Pulse Modulation of Discharge Supply
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ETG Turbulence in Finite Beta Plasma of LVPD
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Phase Mixing of Upper Hybrid Oscillations in the Presence of an Inhomogeneous Magnetic Field
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MD Simulational Study of Driven Yukawa System
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Plasma Diagnostics of Reverse Polarity Planar Magnetron
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First Implementation of 2-D Scrape-off Layer Plasma-neutral Transport Simulation Code SOLPS5.1 to a Double-null Diverted Plasma-Magnetic Equilibrium
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Electromagnetic Particle-in-cell Simulation in Three-dimensions of the Kelvin-Helmholtz Instability in a Plasma
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A Synthetic Diagnostic to Modeled Expected 2-D Radiation Power Loss for the Infrared Imaging Video Bolometer of ADITYA TOKAMAK
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Numerical Simulation of Non-transferred Arc Plasma Torch Built at IPR
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Fluid Simulation of Electrostatic Sheath with Negatively Charged Dust
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Simulation of High Power Microwave Source-A Vircator for SYMPLE
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Analysis of 3-dimensional Characteristics of Simulated Scrape-off Layer Plasma Transport in TOKAMAK ADITYA
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Molybdenum Limiter for ADITYA Tokamak
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Wire Burn Test of Multi Mega Watt Regulated High Voltage Power supply for NBI, LHCD and ECRH
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A Comparative Study of Ion Trajectories between a Two and Three Electrode System of a Positive Ion Source
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Effect of 30keV Deuterium Ion Beam onto Pulsed Laser Deposited Rh/W/Cu Multilayer
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Y.S.S. Srinivas, Hemal Kansagara, K.M. Parmar, B.R. Kadia, S.V. Kulkarni and I.C.R.H. Division

Development of Hydrogen Isotopes Recovery System using Gas Adsorption Method for Tritium Extraction System of LLCB-TBM
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ARC Detection and RF Inter-Lock for High Power Operation of CW Klystron Test Bed
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Testing of Water Dummy Load for CW High Power RF
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Bhargav Pandya, A.K. Sahu, V. Prahlad and U.K. Baruah

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Manoj Singh, H.M. Jadav, Ramesh Joshi, S.V. Kulkarni and RF-ICRH Group

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On the Spectroscopic Diagnostics of Atmospheric Gas Plasma Blob Produced from Washer Stacked Plasma Gun
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Nikita Chhetri, Trupti Sharma, Hitesh Kumar, B. Pandya, P.Vasu and P.V. Subhash

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Conceptual Design for Upgraded Version of Control and Data Acquisition System for NBI Power Supply
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Rakesh Patel, Gaurang Mehsuriya, Vipul Tanna and S. Pradhan

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Integrated Distribution Network for SST-1 Liquid Nitrogen Service
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Langmuir Probe Diagnostics Electronics for Symple (System for Microwave Plasma Experiments)
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Study of Helium Glow Discharge Cleaning in ADITYA TOKAMAK
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Conceptul Design of ITER-India Gyrotron Test Facility (IIGTF)
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Implementation of Sequence Control System for ITER-India Gyrotron Test Facility (IIGTF)
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The Effect of Nitrogen (N2) Partial Pressure and Substrate Biasing on the Growth of TiN Thin Film on Pre Nitride AISI M2 High Speed Steel
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Radiation Power Loss Measurement in Tokamaks
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Modified Atomic Spectral Lines Due to Opacity Useful for Branching Ratio Technique in Plasma Spectroscopy
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Daniel Raju, Sameer Kumar and Ratneshwar Jha

Ultra High Vacuum Testing and the Initial Calibration Results of Time of Flight Neutral Particle Energy Analyzer
Snehlata Gupta, Santosh P. Pandya, Priyanka Mishra, Hitesh Mandalia, Kumar Ajay and J. Govindarajan

Conceptual Design of Charge Exchange Recombination Spectroscopic Diagnostics on the SST-1 Tokamak
M.B. Chowdhuri, K.H. Burrell, B.A. Grierson, R. Manchanda, Sanjeev K. Sharma,V. Prahald and J.Ghosh

Effect of 30 keV Deuterium Ion Beam onto Pulsed Laser Deposited Rh/W/ Cu Multilayer
A.T.T. Mostako, Alika Khare, C.V.S. Rao, Sudhirisinh Vala, R.J. Makwana and T.K. Basu

Design of a Rectractable Bolometer System for Divertor-Bolometry Application in SST-1 Tokamak
Prabhat Kumar, Kumudni Tahiliani and Ratneshwar Jha

Development, Calibration and Performance Testing of the Infrared Imaging Video Bolometer for the SST-1 Tokamak
Zubin Shaikh, Santosh P. Pandya, Shamsuddin Shaikh, Shwetang N. Pandya and J. Govindrajan

Parametric Study of Total Radiation Power Loss from the ADITYA TOKAMAK using Infrared Imaging Video Bolometer
Shamsuddin Shaikh, Santosh P. Pandya, Zubin Shaikh, Shwetang N. Pandya, J. Govindrajan and ADITYA TEAM

Signal Conditioning System for Neutral Beam Power Profile Analysis of NBI (SST-1)
L.K. Bansal, P.J. Patel, K. Qureshi, V.B. Patel, L.N. Gupta, D.P. Thakkar, C.B.Sumod, V.V. Vadher and U. K. Baruah

Comparison of Langmuir Probe Characteristic of Argon and Oxygen plasma in Presence of External Magnetic Field
Roopendra singh Rajawat and Shantanu Kumar Karkari

Spectroscopy Data Management System based on Linux Server
Aniruddh Mali, M.B. Chowdhuri, R. Manchanda, N. Ramaiya, N. Chanchapara and J. Ghosh

Spectroscopic Studies of ADITYA TOKAMAK Discharges during Electrode Biasing Experiments
Nilam Ramaiya, Pravesh Dhyani, Niral Chanchapara, Aniruddh Mali, Ranjana Manchanda, M.B. Choudhari, J. Ghosh, R. Tanna, P.K. Chattopadhyay, S.B. Bhatt and ADITYA TEAM

A New Phenomenological Method for Obtaining Plasma Density using Spectral Line-Ratio Technique
Sharvil Patel and J. Ghosh

Zero Bias Emission Current Characteristics of Graphite Material due to Laser Heating used for Laser Heated Emissive Probe
P.Mehta, A. Sarma, J. Ghosh, A. Mali, R. Manchanda, Vara Prasad K. and N. Ramaiya

Plasma Diagnostics of Reverse Polarity Planar Magnetron
S. Chauhan, M. Ranjan and S. Mukherjee

Estimation of ADITYA Soft X-ray Spectrum
Shishir Purohit, Malay Bikas Chowdhuri, J. Raval and Y. Shankara Joisa

Modeling of Phase Changes of Hypo Eutectoid Steels
Suresh Akella and B. Ramesh Kumar

VUV Assisted Advanced System for Testing and Calibration in Vacuum-The VAASTAV Facility
Prabhat Kumar, Kumudni Tahiliani, Ratneshwar Jha and M.V. Gopalakrishna

A Novel 9-D Model for determining Relativistic Momentum, Force and Energy of a Particle Moving on a 4-Sphere
A.K. Agarwal

Large Volume Double Ring Penning Plasma Discharge Source and its PIC Simulation
Gheesa Lal Vyas, Ram Prakash, Jalaj Jain, Jitendra Prajapati, Udit Narayan Pal, Malay Bikas Chowdhuri , Ranjana Manchada and Vishnu Shrivastava

Electrical Breakdown Study of Liquid Dielectrics under Pulsed Conditions
G. Veda Prakash, R. Kumar, C. Reddy, J. Patel and A. Shyam

Synthesis of Nanocrystalline Li2TiO3 by High Energy Ball Milling
Umasankar Dash, S.K.S. Parashar, Kajal Parashar and Paritosh Chaudhuri

Design and Development of Integer Fringe Counter Circuit for Real-Time Plasma Density Measurement in ADITYA TOKAMAK
E.V. Praveenlal, Praveena Kumari, P.K. Atrey, Rachana Rajpal, Hitesh Mandaliya, Varsha, Umesh Dhobi and S.K. Pathak

Development of PLC and SCADA Application for SST-1 80 K Control Systems
G. Mahesuria, R. Patel, R. Panchal, P. Panchal, D. Sonara, V.L. Tanna and S. Pradhan

Welding Activities for Superconducting Magnets Systems of SST-1
S.J. Jadeja, U. Prasad, A.N. Sharma, D. Patel, P. Gupta, Magnet Division and S. Pradhan

Preliminary Fusion Reactor Performance Analysis for the Radial Build-up of Reactor Components
Chandan Danani, B.J. Saikia, Vinay Menon, J. Agrawal, A.N. Sharma, Upendra Prasad, M. Stephan, Naveen Rastogi, R. Pragash, E. Rajendra Kumar, S. Pradhan , S. Khirwadkar, R. Gangradey, R. Srinivasan , S.P. Deshpande and P.K. Kaw

Fault Detection and Repairing for the Insulation Breakdown of TF Coil No. 2 and Trouble Shooting for Inductance and Resistance of TF Coils in ADITYA TOKAMAK
M.B. Kalal, D.S. Varia, R.L. Tanna , Pintu Kumar, Deepak Sangwan, J. Ghosh, P.K. Chattopadhyay, R. Jha and the ADITYA Team

Studies for the Optimization of Brazed PFC using Coupon Based Samples
K.P. Singh, S.S. Khirwadkar, M.S. Khan, Sunil Belsare, Alpesh Patel, Shailesh Kanpara, Prakash Mokariya, Nikunj Patel, Amee Patel, Kush Shah

A new paradigm of toroidal zonal flow - ITG turbulence - Poloidal zonal flow system
Rameswar Singh, R Singh and P Kaw

Structural and surface morphological changes on tungsten due to ion irradiation
M. Bhuyan, S. R. Mohanty, C. V. S. Rao, P.A. Rayjada and P. M. Raole

2nd Joint IAEA-ITER Technical Meeting on Analysis of ITER Materials and Technologies, Institute for Plasma Research, Gandhinagar, 11-13 December 2012

Development of Flux assisted GMAW process for fusion reactor fabrication
V.J. Bhadeka, S. Shrinivas, B. Ramesh Kumar

Investigation of Microstructure and Mechanical properties of 60mm thick SS316L welded plates by multipass TIG welding and Electron Beam welding for fusion reactor applications
Ramesh Kumar Buddu, N. Chauhan, P.M. Raole

α-Al2O3 growth by plasma assisted tempering of aluminized 9Cr1Mo steels
Nirav I. Jamnapara, Dilip U. Avtani, N. L. Chauhan, E. Rajendra Kumar, Subroto Mukherjee, Anand S. Khanna

Lab scale development of lead-lithium eutectic alloy by MHD stirring technique
Abhishek Mehta

Effect of heat treatment on micro structure and formation of intermetallic layers on hot dip Aluminized coating on RAFMS
A. Sarada Sree, Suraj Kumar Gupta and E.Rajendra Kumar

Curved small Tungsten (W) macro-brush test mock-up fabrication using vacuum brazing for divertor target element
K.P Singh, S.S Khirwadkar, Atul Prajapati, M.S Khan, Sunil Belsare, Alpesh Patel, Kedar Bhope, Prakash Mokariya, Nikunj Patel

Development of Er2O3 coating by reactive magnetron sputtering for Demo relevant Blanket Modules
P A Rayjada, N P Vaghela, N L Chauhan, Amit Sircar, E Rajendrakumar, L M Manocha and P M Raole

Qualification of tungsten coatings for in-situ coating and repair of first wall and target components of fusion reactors
A.K. Sanyasi, V.Philipps, H.G.Esser, M. Zlobinski, J.W.Coenen, S.Brezinsek

Effect of Fabrication Processes on Jacket Material for Fusion Relevant Superconducting Magnet
Mahesh Ghate, Abhinav Kumar, Pratik Charkhawala, Narendrasinh Chauhan, Subrata Pradhan

Molecular Dynamics Simulation of He Cluster Formation in FeCr Alloy
A. Abhishek, M. Warrier and E. Rajendra Kumar

19th National Symposium on Radiation Physics (NSRP-19), Mamallapuram, 12-14 December 2012

Fast Neutron Detection by BF3 long counter
Shailja Tiwari, Shrichand Jakhar, Rajnikant Makwana, Mitul Abhangi, C.V.S. Rao, T.K. Basu and Vilas Chaudhary

29th DAE Safety & Occupational Health Professional Meet, Rawatbhata Rajasthan Site (RRSITE), 17-19 December 2012

A case study on hazard identification & management for "multi mega watt regulated high voltage power supply (80kV, 130A)" systems at IPR
D.V. Modi, CVS Rao, Paresh Patel, L.N. Gupta, C.B. Sumod, Dipal Thakkar, Ujjwal Baruah

International Conference on Solar Energy Photovoltaic (ICSEP-2012), KIIT University, Bhubneswar, 19-21 December 2012

ZnO Thin film deposition for TCO application in solar cell
S. Agrawal, R. Rane, S. Mukherjee

IEEE International Conference on Emerging Technology Trends in Electronics, Communication and Networking (ET2ECN-2012), Electronics and Communication Engineering Department, Sardar Vallabhbhai National Institute of Technology, Ichchhanath , Surat, India, 19-21 December 2012

Image Super Resolution - A Survey
Amisha J. Shah, Suryakant B. Gupta

24th National Symposium on Cryogenics (NSC-24), Nirma University, Ahmedabad, 21-24 January 2013

Batch testing of SST-1 toroidal field magnets
A.N. Sharma, S. Pradhan, U. Prasad, P.Varmora, K. Doshi, Y. Khristi, D.Patel, A.Panchal, P.Gupta, S.J. Jadeja

Recent technologies validation for SST-1 superconducting magnets
Upendra Prasad, A.N. Sharma, D. Patel, K. Doshi, P. Varmora, Y. Khristi, A. Panchal, P.Gupta and S. Pradhan
Different cooling schemes for DC HTS cables
N. Bairagi, D. Christian, V.L. Tanna, and S. Pradhan

Recent operational experience of cryogenic system for SST-1
V.L. Tanna, P. Panchal, R. Panchal, D. Sonara, R. Patel, G. Mahesuriya, N.C. Gupta, LN. Srikanth G, J.C. Patel, K. Patel, A. Garg, D. Christian, N. Bairagi, P. Shah, H. Nimavat, R. Sharma, S. Pradhan

Experience of superconducting current feeders system of SST-1
N.C. Gupta, A. Garg, D. Sonara, R. Panchal, R. Patel, G. Mahesuriya, P. Panchal, P. Shah, H. Nimavat, K. Patel, LN Srikanth G, D. Christian, R. Sharma, N. Bairagi, V.L. Tanna and S. Pradhan

Cryo plant preparedness protocols for SST-1 cool down
L.N. Srikanth G, P. Panchal, R. Panchal, D. Sonara, R. Patel, G. Mahesuriya, D. Christian, K. Patel, P. Shah, N. Bairagi, A. Garg, H. Nimavat, R. Sharma, J.C. Patel, V.L. Tanna and S. Pradhan

Liquid nitrogen consumption during the recent SST-1 cool down campaign
P. Shah, H. Nimavat, K. Patel, LN Srikanth G, N. Bairagi, A. Garg, J.C. Patel, V.L. Tanna, S. Pradhan

Mechanical performance degradation of glass fiber insulation material after neutron irradiation
Rajiv Sharma, V. L. Tanna, Mitul Abhangi, Rajnikant Makwana, Sudhirsingh Vala, C V S Rao and S. Pradhan

Finite Element Analysis of Room Temperature Helium Gas Network for Current Feeder System of SST-1
A. Garg, N. C. Gupta, P. Shah, V.L. Tanna and S. Pradhan

Enhance Response Time of Helium Leak Testing in Vacuum System using Cryogenic Pump
K.A. Jadeja, S.B. Bhatt, K. S. Acharya, P. M. Chavda, T. B. Purabia

Control System Design of Test Auxiliary Cold Box for Qualification Testing of ITER Cold Circulating Pumps
Ritendra Bhattacharya, Hitensinh Vaghela, Muralidhara Srinivasa, Himanshu Kapoor, Anuj Kumar Garg, Jotirmoy Das and Biswanath Sarkar

Seismic and Random Vibration Analysis of Internal Cryogenic Line of Cold Valve Box
Himanshu Kapoor, Jotirmoy Das, Uday Kumar, Hitensinh Vaghela, Ritendra Bhattacharya and Biswanath Sarkar

Development of Excel Based Static Simulator for Various Test Phases of ITER Prototype Cryoline
Nitin Shah, Ketan Choukekar, Mohit Jadon, Biswanath Sarkar

Performance Analysis of Cryogenic Cold Circulating Pump
Hitensinh Vaghela, Jyotirmay Banerjee, Hemant Naik, Biswanath Sarkar

Comparative Study of Different Configurations of Thermal Intercept for Test Cold Valve Box
Pratik Patel, Hitensinh Vaghela, Himanshu Kapoor, Vinit Shukla, Jotirmoy Das and Biswanath Sarkar

Development in Design of Test Infrastructure for ITER Prototype Cryoline Test
Ketan Choukekar, Ritendra Bhattacharya, Nitin Shah, Muralidhara Srinivasa, Himanshu Kapoor, Pratik Patel, Uday Kumar and Biswanath Sarkar

CRYOPUMP in the IN-TF for DNB
Ram Bilas Prasad, Mainak Bandhopdhyay, Mahendrajit Singh, Jaydeep Joshi, C. Rotti and A.K. Chakraborty

Data Acquisition Systems for Cryogenics Experiments at IPR
Pankaj Varmora, A.N. Sharma, U. Prasad, D. Patel, K. Doshi, Y. Khristi and S. Pradhan

Sensor Instrumentation for Superconducting Magnet System of SST-1
K. Doshi, Y. Khristi, B. Parghi, A. Sharma, U. Prasad, P. Varmora, D. Patel, S. Pradhan
Integration of cryopump instrumentation for SST-1 NBI
Laxmi Kant Bansal , Paresh J Patel, K. Qureshi, Sanjay Parmar, V. B. Patel, L.N. Gupta, D. P. Thakkar, C. B. Sumod, V. Vadher and U.K. Baruah

Recent improvements of the cryogenic components of the Neutral Beam Injection system of SST-1
A. K. Sahu, B. Pandya, V. B. Patel, L. K. Bansal, S. K. Sharma, Ch. Chakrapani, B. Choksi, N. Contractor, S. Parmar, BVVSNNP Sridhar, V. Prahlad, P. Patel and U. K. Baruah

Design and implementation of precise detection logic for quench detection system of SST-1 magnets
Yohan Khristi, A.N.Sharma, Kalpesh Doshi, Moni Banaudha, Upendra Prasad, Pankaj Varmora, Dipak Patel and Subrata Pradhan

National Conference on Innovative & Emerging Technologies (NCIET-2013), Mehsana, Gujarat, 24-25 January 2013

Spectroscopy Data Management System based on Linux Server
Aniruddh Mali, Malay Bikas Chowdhuri, Ranjana Manchanda, Nilam Ramaiya, Niral Chanchapara and Joydeep Ghosh

Second International Symposium on Semiconductor Materials and Devices (ISSMD-2), University of Jammu, Jammu Tawi, 31 January-2 February 2013

Preparation and Characterization of Antimony Doped Tin Oxide Thin Films Synthesized by Co-evaporation of Sn and Sb using Plasma Assisted Thermal Evaporation
C. Jariwala, M. Dhivya, P. A. Rayjada, N. Chauhan, R. Rane, P. M. Raole and P.I. John

Severe Accident Analysis and Management Symposium (SAAM-2013), Indian Institute of Technology Kanpur, India, 1-3 February 2013

Modification of RELAP/SCDAPSIM/MOD4.0 for LLCB TBM Safety analysis
K. T. Sandeep, SatyaPrakash, Vilas Chaudhari, Ashok Khanna, Prabhat Munshi, E. Rajendra kumar

National Welding Seminar (NWS- 2013), Indian Institute of Welding, Bangalore, 7-9 February 2013

Optimization of Multipass TIG Weld Process Parameters for Weld Distortion and Tensile Properties with Taguchi method
B. Ramesh Kumar, Himanshu P Gambhire, Suresh Akella

Heat Flux for Welding Processes: Model for Laser Weld
Suresh Akella, B. Ramesh Kumar, V. Harinadh, B Suresh Babu

Effect of Heat Treatments on Jacket Material for Fusion Relevant Superconducting Magnet
Mahesh Ghate, Piyush Raj, Narendrasinh Chauhan, Yogendra Singh, Subrata Pradhan

4th International Conference in Recent Advances in Composites Materials (ICRACM-2013), International Center, Goa, 18-21 February 2013

Mechanical, Electrical Evaluation and Test Results of Composite Insulation Materials at Cryogenic Temperature
Rajiv Sharma, V. L. Tanna, S. Falnikar and S. Pradhan

DST-SERC School on "Tokamaks and Magnetised Plasma Fusion", Institute for Plasma Research, 25 February-15 March 2013

Waves in Plasma in Large Volume Plasma Device
A. K. Sanyasi, S. K. Singh, P. K. Srivastava, A. Chavda, K. Raval, R. Sugandhi and L. M. Awasthi

12th ISMAS Triennial International Conference on Mass Spectrometry, Goa, March 3-8, 2013

Surface Analysis of different type of coating on Graphite tiles for Tokamak Aditya
S. B. Bhatt, P. A. Rayjada, B. K. Das, K. A. Jadeja, K. M. Patel, Ajai Kumar and Aditya Team

2nd Annual International Conference on Materials Processing and Characterization (ICMPC-2013), GRIET, Hyderabad, India, 16-17 March 2013

YBCO Superconductor Characterization under Shear Strain
Ziauddin Khan, Ananya Kundu, Yuvakiran Paravastu and Subrata Pradhan

IUVSTA Workshop on Ultra High Vacuum Techniques for Large Volume Devices (IUVSTA-LVD), Institute for Plasma Research, Gandhinagar, 19-22 March, 2013

Design of a VUV Assisted Advanced System for Testing and Calibration in Vacuum the VAASTAV Facility
Prabhat Kumar, Kumudni Tahiliani, Ratneshwar Jha, M.V. Gopalakrishana.

Vacuum System for Superconducting Current Feeders System of SST-1
N.C. Gupta, A. Garg, D. Sonara, R. Panchal, P. Shah, H. Nimavat, D. Christian, R. Patel, G. Mehsuria, V.L. Tanna, S. Pradhan, K. Patel, N. Bairagi, R. Sharma, G.L.N. Srikant, S. Jorge, F. Khan, Z. Khan

Cryosorption Cryopump: DeGassing Measurement Studies Carried Out for Various Forms of Activated Carbon
Sapna Guru, Samiran Mukharjee, Pratik Nayak, V.S. Tripathi, Jyoti Agrawal, Ranjana Gangradey

Differential Pumping System for Single Pellet INjector System (SPINS)
Ranjana Gangradey, Ravi Prakash. N, Samiran Mukherjee, Pratik Nayak, Paresh Panchal

Conductance Calculation and Experimental Verification for the Negative Ion Source Experiments at IPR
K.Pandya, G.Bansal, J.Soni, R.Yadav, H.Mistry, M. Bandyophyay, A. Gahlaut, K.G. Parmar, V. Mahesh, R. Pandey, B. Prajapati and A. Chakarborty

ITER Cryostat-A Large Volume High Vacuum Vessel
Bhart Doshi, Han Xie, Caipin Zhou, Meekins Michael, Carlo Sborchia and ITER –India Cryostat team

Installation and testing of 77 K Thermal Shields inside Experimental Cryostat for Fusion Relevant Superconducting Magnets
Dhaval Bhavasar, Arun Panchal, Siju George, Dipak Patel, Mahesh Ghate and Subrata Pradhan

Foreseeing Vacuum Issues during the Construction of LIGO like Detectors
Sunil S.

The Role of Cryogenic Vacuum Pumping in the Operation of Neutral Beam Injector
B. Choksi, S.K. Sharma, A.K. Sahu, B. Pandya, L.K. Bansal, P. Bharthi,N. Contractor, S. Parmar, V. Prahald, P.J. Patel, U.K. Baruah

Estimation of Partial Pressure of Residual Gasses in High Vacuum System from QMA data
Paritosh Chaudhuri and D. Chenna Reddy.

Software Based Closed Loop Gas-feed Control in Vacuum System
Kiran Patel, K.A. Jadeja, P.M. Chavda, Dushyant Agrawal, S.B.Bhatt and Ajai Kumar

Technical Challenges for LIGO –India UHV System
Manoj Kumar Gupta, Rakesh Kumar, Dharmesh Patel, D C Raval, S.B. Bhatt, Ajai Kumar

Vacuum Control and Monitoring System or LIGO-India Project
Amit K. Srivastav, Arnab Das Gupta, D.C. Raval, S.B.Bhatt and Ajai Kumar

Outgassing Rate Study of SS304L Material for LIGO-India UHV System
Kaushal Joshi, D C Raval, Manoj Kumar Gupta, S B Bhatt, Ajai Kumar

Vacuum Design for Two Driver Source Experiment at IPR
Ravi Pandey, S.Shah, M.Bandyopadhyay, G. Bansal, A. Gahlaut, Deepak Parmar, K.G. Parmar, V. Mahesh, K.Pandya, B.Prajapati, J. Soni, R. Yadav, H.Mistry and A. Chakraborty

High Vacuum Devices for the Generation of Mega Watt Level RF and Microwave Systems for Fusion Reactors
S.V. Kulkarni

PATENT APPLIED

Apparatus for Production of microwave plasma
Vishal Jain, Anand Visani, Bhupendra K Patel, Promod Kumar Sharma, Chirayu Patil, Pucadyil Ittoop John, Sudhir Kumar Nema, Subroto Mukherjee, Vivek Agarwal
Patent application no.: 3740/MUM/2012

An Apparatus for treating matter using Inductively Coupled Plasma
Vishal Jain, Anand Visani, Bhupendra K Patel, Chirayu Patil, Sudhir Kumar Nema, Pradyumansinh Balvirsinh Jhala, Vivek Agarwal
Patent application no.: 269/MUM/2013

AWARDS and ACHIEVEMENTS

Role of fluctuations in the generation of intrinsic poloidal flows in a simple toroidal plasma
T. S. Goud, R. Ganesh, Y. C. Saxena, and D. Raju ***got best poster*** presentation award at International Topical Conference on Plasma Science (ITCPS-2012), University of Algarve, Faro, Portugal, 24-28 September 2012

Development of Image processing based Arc Location Identifier
Rashmi S. Joshi, Suryakant B. Gupta got ***best presenter*** award at 12th International Conference on Electromagnetic Interference and Compatibility (INCEMIC 2012), Bangalore, India, 4-7 December 2012

Observation of Electromagnetic Turbulence in the Energetic Electron Belt Region of LVPD Plasma
A.K. Sanyasi, L.M. Awasthi, S.K. Mattoo, S.K. Srivastava, R. Singh and P.K. Kaw won ***best paper*** award at 27th PSSI National Symposium on Plasma Science and Technology on Challenges of Power Generation & Lighting 21st Century (PLASMA-2012), Pondicherry University, Puducherry, India, 10-13 December 2012

Design, Installation and Testing of Pulsed Localized Vertical field coils for runaway Suppression in Aditya Tokamak
R.L. Tanna, J. Ghosh, P.K. Chattopadhyay, M.B. Kalal, D.S. Varia, Pintu Kumar, Vaibhav Ranjan, A. Amardas, V.K. Panchal, R. Jha and the Aditya Team ***won first prize of the Z.H. Sholapurwala Best Poster*** Presentation Award for Fusion Research at 27th PSSI National Symposium on Plasma Science and Technology on Challenges of Power Generation & Lighting 21st Century (PLASMA-2012), Pondicherry University, Puducherry, India, 10-13 December 2012

Design of High Power Co-axial Transmission Line for Ion Cyclotron System
Harsha Machchhar, R.G. Trivedi, Raghuraj Singh, Kumar Rajnish, J.V.S. Hari, P. Ajesh, Gajendra Suthar, Manoj Patel, Dipal Soni, Kartik Mohan and Aparajita Mukherjee won ***second prize of the Z.H. Sholapurwala Best Poster*** Presentation Award for Fusion Research at 27th PSSI National Symposium on Plasma Science and Technology on Challenges of Power Generation & Lighting 21st Century (PLASMA-2012), Pondicherry University, Puducherry, India, 10-13 December 2012

Synthesis, characterization and application of silver nanoparticles grown by plasma techniques
K. Patel, M. Ranjan, B. Desai, N. Chauhan, S. K. Nema, S. Mukherjee ***won best presentation*** award in the conference Current Trends in Research and Applications of Physical Sciences in Gujarat (CTRAPSG-12), Sardar Patel University, Vallabh Vidyanagar, Gujarat, 29-30 December 2012

Preparation and Characterization of Antimony Doped Tin Oxide Thin Films Synthesized by Co-evaporation of Sn and Sb using Plasma Assisted Thermal Evaporation
C. Jariwala, M. Dhivya, P. A. Rayjada, N. Chauhan, R. Rane, P. M. Raole and P.I. John got ***first prize award for poster*** presentation at Second International Symposium on Semiconductor Materials and Devices (ISSMD-2), University of Jammu, Jammu Tawi, during 31st January-2nd February 2013.

Surface Modification of Steel Materials by Active Screen Plasma Nitriding
J.V. Mathew, A.K. Christie and B. Ganguli won **first prize** at FootPrints X3, Metallurgy Department, MSU, Baroda, 22-24 February 2013

IPR Hindi Magazine "Plasma Jyoti" has won the "**Best Official Language Magazine**" award, in the DAE Aided Institutes category for the year 2011-12.

E.4 Invited Talk Delievered by IPR Staff

S.V. KULKARNI

Gave an Invited talk on "High Power RF Systems on Aditya and SST-1 for Heating and Pre-ionization Experiments in ICRF Range" at 6th ITER International School on RF Heating and Current Drive (IIS-2012), IPR, Gandhinagar, 2-6 December 2012

R. SRINIVASAN

Gave an Invited talk on "Recent progress in Indian fusion program" at Fusion Power Coordination Committee meeting at IEA, Paris, France, 8-9 February 2013

S. K. KARKARI

Gave an Invited talk on "Resonance hairpin probe for measuring electron density and its possible application in ion hall thruster" at Lectures on selected topics on atomic and molecular physics, Indian Institute of Space Science and Technology, Trivandrum, 2-3 April 2012

B. SARKAR

Gave an Invited talk on "System Engineering and Cryogenic Engineering – How do they embrace?" at DAE-BRNS Theme Meeting on Liquid Helium Plants, Cryogenic systems and their Applications (LHeP-CSA),VECC, Kolkata, 25-26 February 2013

Gave an Invited talk on "Status of ITER Cryolines, warm lines and Cryo-distribution system: ITER-India perspective" at National Institute of Fusion Science, Toki, Japan , 3 July 2012

Gave an Invited talk on "System engineering and supply chain management of ITER Cryolines and Cryo-distribution system" at CEA, Grenoble, France, 15 June 2012

S.L. RAO

Gave an Invited talk on "EC power Source System for ITER, Indian in-kind Contribution" at 6th ITER International School, Ahmedabad, 2-6 December 2012

M. BANDYOPADHYAY

Gave an Invited talk on "INdian Test Facility (INTF) a test bed for DNB" at 23rd ITPA TG on Diagnostics, Gandhinagar, 27th November 2012

Gave an Invited talk on "NBI heating" at DST-SERC School on "Tokamaks and Magnetised Plasma Fusion", Institute for Plasma Research, 25 February-15 March 2013

Gave an Invited talk on "Activities of IPR" in four Universities: Calcutta University, Jadavpur University, Kalyani University, Bidyasagar University, West Bengal to attract bright students for PhD and TTP

SANJEEV VARSHNEY

Gave an Invited talk on "X-ray Crystal Spectroscopy for ITER: an overview of IN-DA deliverables" at Laser Plasma Division, Raja Ramanna Center for Advance Technology, Indore, 13th March 2013

HITESH B PANDYA

Gave an Invited talk on "Controlled Nuclear Fusion, ITER Project and role of Engineers" at Gandhinagar Institute of Technology, Vadsar, Gandhinagar, 5th March 2013

L. M. AWASTHI

Gave an Invited talk on "Electron Temperature Gradient Turbulence" at 39th European Physical Society Conference on Plasma Physics & 16th International Congress on Plasma Physics, Stockholm, Sweden, 2-6 July 2012

Gave an Invited talk on "Experimental Observation of ETG Turbulence in LVPD" at University of Marseilles, France, 12th July 2012

PARESHKUMAR J. PATEL

Gave an Invited talk on "Multi megawatt Regulated High Voltage Power Supplies (RHVPS) for Fusion and Accelerator applications (up to 100 kV, 130 A)" at Nirma University, Ahmedabad, 12th January, 2013

B. GANGULY

Gave an Invited talk on "Plasma Nitriding-Advanced Heat Treatment Process", at workshop on "Heat Treatment of Metals & Alloys", Indian Institute of Metals, Baroda Chapter, 27th October 2012

P.M. RAOLE

Gave an Invited talk on "The perspective on Indian Fusion Materials program and activities" at 2nd IAEA-ITER Technical Meet on Analysis of ITER Materials at the Institute for Plasma Research, Gandhinagar, 11-13 December 2012

Gave an Invited talk on "R & D of Fusion Reactor Materials -An Indian perspective" at International Workshop on "Fusion for Neutrons"(F4N), at IPR, Gandhinagar, 13 February 2013

Gave an Invited talk on "Fusion Materials - Choices and Development - Part I & Part II" at DST-SERC School on Tokamaks & Magnetized Plasma Fusion, Institute for Plasma Research, Gandhinagar, 8th March 2013

Gave an Invited talk on "Surface analysis of plasma processed and fusion related materials" at IUVSTA Workshop on Ultra High Vacuum Techniques for Large Volume Devices (IUVSTA-LVD), 19-22 March 2013

C. JARIWALA

Gave an Invited talk on "Mixed Phase Hydrogenated Silicon Thin Film Processing by Very High Frequency Plasma Enhanced Chemical Vapour Deposition for Photovoltaic applications" at Second International Symposium on Semiconductor Materials and Devices (ISSMD-2), University of Jammu, Jammu Tawi, 31st January-2nd February 2013

Invited talks given at International Conference on Complex Processes in Plasmas and Nonlinear Dynamical Systems (ICCPPNDS-2012), Institute for Plasma Research, Gandhinagar, India, 6-9 November 2012

PREDHIMAN K. KAW gave an Invited talk on "Let There be Light... Till the Dust Returneth"

RAJARAMAN GANESH & MADHUSUDAN RAGHUNATHAN gave an Invited talk on "Nonlinear Electrostatic Perturbations in Vlasov Plasmas with Nonextensive Distributions"

SUDIP SENGUPTA gave an Invited talk on "Breaking of Relativistically Intense Longitudinal Space Charge Waves: A Description using Dawson Sheet Model"

PINTO BANDYOPADHYAY, D. SHARMA, U. KONOPKA and G. MORFILL gave an Invited talk on "Experimental Observation of Shear Driven Instability in a Magnetized RF Plasma"

RATNESHWAR JHA gave an Invited talk on "Intermittent Structures in Fusion Plasmas"

PRABAL CHATTOPADHYAY, KSHITISH BARADA, J. GHOSH, SUNIL KUMAR AND Y.C.SAXENA gave an Invited talk on "Study of Helicon Plasma in a Diverging Magnetic Field"

SHISHIR P. DESHPANDE gave an Invited talk on "India's Participation in ITER Collaboration"

S.BENKADDA, O.AGULLO, M.MURAGLIA, A.POYE, X. GARBET, A.SEN, M. YAGI gave an Invited talk on "Multiscales mechanisms of magnetic islands generation by drift interchange turbulence"

Invited talks given at 27th PSSI National Symposium on Plasma Science and Technology on Challenges of Power Generation & Lighting 21st Century (PLASMA-2012), Pondicherry University, Puducherry, India, 10-13 December 2012

V.P. ANITHA gave an Invited talk on "System for Microwave Plasma Experiments (SYMPLE)"

A.K. CHAKRABORTY gave an Invited talk on "Indian Programme in R&D on Negative Ion Neutral Beams for Fusion Devices"

H.C.JOSHI gave an Invited talk on "Laser Produced Plasma: An Atomic Analysis Perspective"

S. MUKHERJEE gave an Invited talk on "Role of Plasma Technologies in Harnessing Solar Energy"

S.K. NEMA gave an Invited talk on "Plasma Surface Modification of Metals and Polymers"

S.V. KULKARNI gave an Invited talk on "Role of Pre-ionization in Superconducting Steady State Tokamak Operation"

KUMUDNI TAHILIANI gave an Invited talk on "Radiation Power Loss Measurement in Tokamaks"

Invited talks given at IUVSTA Workshop on UHV Techniques for Large Volume Devices (IUVSTA-LVD), Institute for Plasma Research, Gandhinagar, 19-22 March, 2013

HARSHAD PUJARA, VISMAY RAULJI, RACHANA RAJPAL, K.A. JADEJA and S.B. BHATT gave a special talk on "Prototype ADITYA Vacuum Control System Based on CCS"

GIRISH K GUPTA, ANIL BHARDWAJ gave an Invited talk on "ITER Cryostat"

SANJAY V. KULKARNI gave an Invited talk on "High Vacuum Devices for Generation of Mega Watts Level RF and Microwave Systems for Fusion Reactors"

E.5 Talks Delivered by Distinguished Visitors at IPR

Dr. Partha Guha, Mathematical Phys.Group, S N Bose National Centre for Basic Sciences, Kolkata gave a lecture on "Darboux integrability and Hamiltonization for 3D dynamical systems"

Dr. Ajay Deep Kachhvah, Indian Institute of Technology Madras, Chennai gave a lecture on
"Weight Bearing Hierarchical Networks: Avalanche, Statistics and Transport"

Dr. Bhawna Pandey, G.B. Pant University of Ag. & Tech., Pantnagar gave a lecture on "Neutron Cross-Sections Relevant to Nuclear Energy Program"

Dr. Bhimsen K. Shivamoggi, University of Central Florida, Orland, gave a lecture on "Beltrami States in Plasmas"

Mr. Aakash Sahai, Duke University Durham, gave a lecture on "Laser Plasma Acceleration using Relativistic Transparency"

Dr. G. Thejappa, Astronomy Department, University of Maryland, College Park gave a lecture on "Identification of Four- and Three-wave Interactions in Solar Type III Radio Bursts Using Higher Order Spectral Techniques"

Mr. K.Satpathy, IGCAR, Kalpakkam gave a lecture on "Studies on Gas Entrainment Inception in Hot Pool of Liquid Metal Fast Breeder Reactors through CFD Approach"

Dr. Devang A. Joshi, R.C. Technical Institute, Ahmedabad gave a lecture on "Crystal Growth and Anisotropic Magnetic Properties of Some Rare Earth Intermetallics"

Dr Paresh Prajapati, MSU, Vadodara gave a lecture on "Studies of neutron-induced fission and nuclear reaction for AHWR and ADS applications"

Dr. Prasad Perlekar, Department of Applied Physics, Eindhoven University of Technology, Netherlands gave a lecture on "Life at high Reynolds number"

Dr. Bhupesh Kumar, IIT, Kanpur gave a lecture on "Laser ablation at solid-liquid interface: Formation of nanoparticles"

Mr. R. K. Gangwar, Dept. of Physics, Indian Institute of Technology, Roorkee gave a lecture on "Electron-impact excitation and plasma modeling of inert gas atoms"

Prof R. Shanker, Atomic Physics Laboratory, Banaras Hindu University, Varanasi gave a lecture on "Fragmentation Dynamics of Multiply Charged Molecules of Atmospheric Intesrest under Impact of Kev- Electrons by Ion-Ion Coincidence Technique"

Shri Arup Jyoti Choudhury, Complex Plasma Laboratory, Yokahama National University, Japan gave a lecture on "Prospective on plasma in surface protection and functionalization of materials"

Dr. Klaus Ellmer, Thomas Welzel, Helmholtz-Zentrum für Materialien und Energie, Dept. solar fuels, Hahn-Meitner-Platz 1, 14109 Berlin, Germany gave a lecture on "Reactive Magnetron Sputtering of TCO Thin Films: Role of Energetic Particle (Ion) Bombardment"

Dr. Deepak Kumar, Physics and Astronomy, Johns Hopkins University, Baltimore, gave a lecture on "What can we learn from space resolved VUV to SRX measurements"

Mr. Keshav Walia, NIT Jalandhar, gave a lecture on "Theoretical Investigations of Some Nonlinear Phenomena in Plasma"

Dr. Sunil Rawat, BARC, Mumbai, gave a lecture on "Behaviour of solids under high strain rate deformation"

Dr. Imant Bucenieks, Institute of Physics, Latvia University, gave a lecture on "IPUL experience in design and construction of EM induction pump (based on permanent magnets) for liquid metals"

Mr. Baudewijn Vangucht, Microtherm Group, Belgium, gave a lecture on "High Performance Thermal Insulation Solutions"

Dr. Saikat Chakraborty Thakur, Center for Energy Research, University of California at San Diego, La Jolla, gave a lecture on "Suppression of drift wave turbulence and zonal flow formation by changing axial boundary conditions in a linear plasma device"

Dr. Matthew Evans, LIGO Scientific Collaboration, Massachusetts Institute of Technology, USA, gave a lecture on "Squeezing the Most from a Gravitational Wave Detector Network"

Mr. Alessandro Tesini, Section Leader, Remote Handling, ITER Organization, gave a lecture on "ITER Remote Handling System"

Dr. Satish Tailor, Malaviya National Institute of Technology, Jaipur, gave a lecture on "Development and Characterization of Plasma Sprayed Aluminum based Nano Composite Coatings"

Dr. Remmelt Haange, Deputy Director General – ITER Organization, gave a lecture on "Lessons Learnt from W-7X"

Dr. Lorne Horton, Culham Center for Fusion Energy, UK, gave a lecture on "Experimental campaign on JET Tokamak for 2013"

Prof. Francesco Romanelli, Culham Center for Fusion Energy, UK, gave a lecture on "European Union Fusion Road Map"

Prof. Stan Whitcomb, LIGO Laboratory, Caltech, USA, gave a lecture on "Potential future directions for the development of interferometers"

Dr. Jannie S.J. van Deventer, University of Melbourne, Australia, gave a lecture on "Why we need to rethink the extraction of precious metals"

Mr. K.T. Patel, Electrical Research and Development Association (ERDA), Baroda, gave a lecture on "EMI and EMC of electical and electronic equipments with special reference to RF interference"

Prof. Saulius Juodkazis, Head of Nano-lab & Deputy Director of Centre of Microphotonics, Swinburne University of Technology, Australia, gave a lecture on "Nano-advantaged surfaces for sensing applications"

Mr. Anil Srivatava, Director, Systems Dynamics, Ahmedabad, gave a lecture on "Human expertise mapping and people matching"

Mr. Bhubanesh Bhatt, Wolfram Research, gave a lecture on "Numeric, Symbolic, Probability and Statistics"

Prof. Victor Malka, Laboratoire d'optique applique (LOA), Ecole Polytechnique Palaiseau France, gave a lecture on

"High quality electron and X-ray beams produced with laser plasma accelerators"

E.6 Colloquia Presented at IPR

Dr. Utpal Sarkar, Physical Research Laboratory, Ahmedabad on "Neutron-Antineutron Oscillation and Project X" (Colloquium #221)

Dr. Onuttom Narayan, University of California, Santa Cruz, on "Energy transport in low dimensional systems" (Colloquium #222)

E 7. Scientific Meetings Hosted by IPR

National Instruments India Celebrated Technology Day with Institute for Plasma Research, at IPR on 15 June 2012

International Conference on Complex Processes in Plasmas and Nonlinear Dynamical Systems (ICCPPNDS-2012) was held at Institute for Plasma Research in Gandhinagar, India, 6-9 November 2012

ICCPPNDS-2012 was held to honor the illustrious career and wide ranging contributions in plasma physics and nonlinear dynamical systems of Professor Abhijit Sen. The conference presented latest developments in basic plasma physics and nonlinear dynamical systems with applications to thermonuclear fusion, space plasmas and complex nonlinear dynamical systems. The topics broadly fall in the areas in which Prof. Sen worked and those areas that have implications from his work.

23rd Meeting of the ITPA Topical Group on Diagnostics at Gandhinagar, ITER-India, IPR, Gandhinagar, India, 27-30 November 2012

6th ITER International School (IIS-2012), IPR, 2-6 December 2012

2nd Joint IAEA-ITER Technical Meet on Analysis of ITER Materials and Technologies at the Institute for Plasma Research, Gandhinagar, Gujarat, India, 11-13 December 2012
T*he meeting was hosted by the Institute for Plasma Research at the Gateway Hotel Ummed Ahmedabad. The first meeting in the series was held at the principality of Monaco (2010).*

The Objective of this Technical Meeting was to contribute to the development of a knowledge base of properties, processes and technologies relevant to ITER structural and plasma-facing materials/components and energetic particles and radiation effects on ITER materials.

The meeting was mainly devoted to ITER materials and technologies. Also, studies related to the materials and technologies for DEMO were included in this meeting. Topics of discussion included:

1. Fabrication technologies of ITER structural and plasma facing materials/components
2. Irradiation effects on ITER structural and plasma facing materials
3. Plasma-material interactions in ITER conditions
4. Synergistic effects of plasma-material interactions and irradiation in ITER and modelling of structural and plasma facing materials/components behaviour in ITER conditions
5. Simulation experiments of structural and plasma facing materials/components behaviour in ITER conditions
6. Development of new fabrication technologies or materials for ITER
7. Databases of material properties for ITER
8. DEMO materials and technologies.

There were in total 46 presentations (six invited, ten oral and thirty posters). Apart from participants from representatives from IAEA and ITER-ORGANIZATION and various foreign countries, large number of participants were from DAE organizations, mainly from IPR, BARC, IGCAR and from other non-DAE Institutes and Universities in India. The selected papers presented in this meeting will be published in the Fusion Science and Technology Journal.

24th National Symposium on Cryogenics, Institute for Plasma Research, 21-24 January 2013
The 24th National Symposium on Cryogenics (NSC-24) has been organized by Institute for Plasma Research, Bhat, Gandhinagar, at Institute of Management, Nirma University, Ahmedabad, during January 22-24, 2013. The purpose of NSC-24 was to bring together researchers from universities, institutes and industries, to stimulate the fruitful exchange of

information and ideas in cryogenic engineering & superconductivity, to outline actual trends and to discuss present and future developments.

The theme of NSC-24 was "Cyogenics for mankind". The symposium was inaugurated by the chief guest, Dr. Remmelt Haange, PDDG, ITER Organization, Cadarache, France. Four numbers of theme talks, by leaders in their respective areas were delivered along with six plenary talks by experts from India as well as abroad. Nine special talks outlined the present status of various activities related to the Cryogenic and Superconductivity in India along with eight of invited talks.

The symposium was preceded by short courses on Jan 21, 2013 at Institute for Plasma Research, Gandhinagar. The courses were conducted by Dr. Christian Day, Dr. Macije-Chorowskii, and Prof. Parthasarathi Ghosh, on Cryo Pumps, Cryo-biology and Cryogenic Process and heat exchangers, respectively and attended by about 40 participants. The Symposium has attracted a very good response from the Cryogenics & Superconductivity community from Universities, Research Institutes and Industries. More than 180 contributed papers were presented reflecting the growing strength of the community. Two hundred and fifty participants participated in the symposium (NSC-24). Eleven Industries showcased their products and the activities during the symposium.

Workshop on Fusion for Neutrons (F4N), Institute for Plasma Research, 11-13 February 2013

DST-SERC School on "Tokamaks and Magnetised Plasma Fusion", Institute for Plasma Research, 25 February-15 March 2013

In this school the following special lectures were delivered by distinguished scientists.

Nonlinear plasma waves - recent results
Prof. H Bailung, IASST, Guwahati

Active control of plasma processing devices
Prof. PI John

Non linear dynamics
Prof. Abhijit Sen

ISROs Mars Orbiter Mission
Prof. SVS Murty, PRL

Intense Laser Plasmas with Nanoclusters
Prof M. Krishnamurthy, TIFR - Mumbai

Forensic Science: The Unique and Comprehensive Science of Criminal Investigation
Dr. G. Rajesh Babu, Inst. of Forensic Science, Gujarat Forensic Sciences University, Gandhinagar

Indus Synchrotrons and their Applications
Dr. Tapas Ganguli, Raja Ramanna Centre for Advanced Technology, Indore

Laser - Matter Interaction
Prof P.K. Kaw

Why India needs nuclear fusion
Prof D Bora

IUVSTA Workshop on Ultra High Vacuum Techniques for Large Volume Devices (IUVSTA-LVD), IPR, 19-22 March 2013

Organized the Fusion Reactor Design Course for M.Tech. in Nuclear Science and Technology of Delhi University (March –April 2013)

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