Issue 070

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The Fourth State

Newsletter of the Institute For Plasma Research, Gandhinagar, Gujarat (India)

SST-1 Update

Every tokamak researcher would first look at the soft X-ray detector signal for sawtooth oscillations. These oscillations are a fundamental instability that is associated with the repetitive slow increases and fast drops in both the core temperature and density. If this signature is observed, then one can say that the tokamak plasma is breathing ! Several months of coordinated efforts by the SST-1 team have brought renewed enthusiasm among the tokamak researchers as the machine is now active after a break of few months.

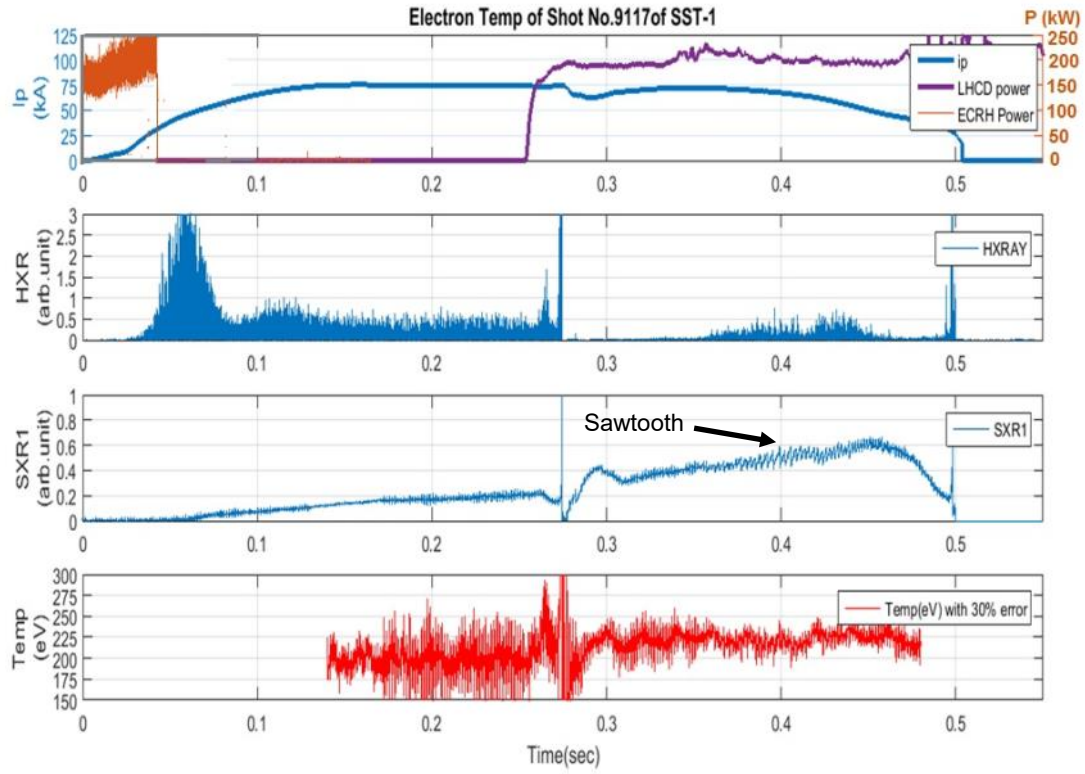
Highlights of the 24th experimental campaign in SST-1 are:

- Campaign duration: 26th March to 16th April, 2019
- TF coils in charged state, producing 1.5 Tesla magnetic field : 9 days
- Continuous operation time of TF coils in charged state : 6-8 hours/day.
- Total no. of experimental shots : 223
  - Shots with plasma current between 60 – 100kA **: 57%**
  - Plasma duration: 200-650 millisecond. Highest duration is 35% higher than best achieved ever before in SST-1
  - Longest pulse duration ~650ms (#9096) and max. plasma current 98kA (#9160)

View of the SST-1 control room during the 24th experimental campaign

SST-1 Update.. Continued

So, what was preventing good quality plasma discharges in the past? Magnetic NULL inside tokamak is a prerequisite for successful plasma formation. There was a gross error in Ohmic magnetic coil system (reverse winding of correction coil TR#3) which led to the poor quality of magnetic NULL in any of the past discharges. SST-1 team has taken an initiative to improve the region of magnetic NULL inside the vacuum vessel. After correcting the reverse connection of TR#3 coils, it was revealed from the computer simulation that 4 additional turns in another correction coil (TR#4) would significantly improve the quality of NULL near the plasma center!

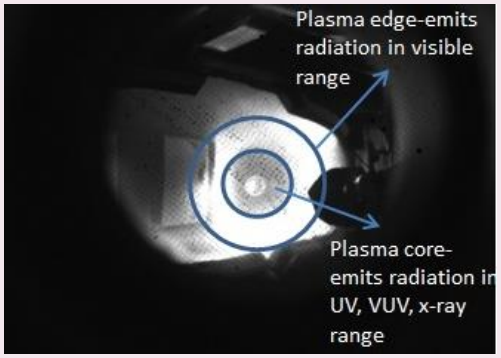


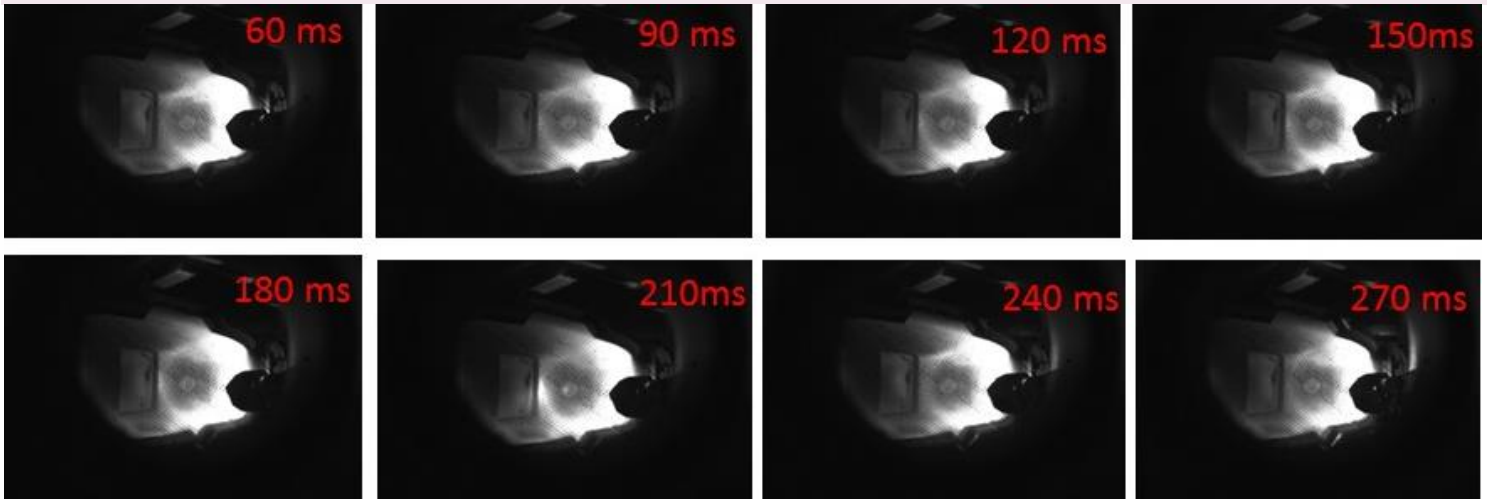
These corrections were done and the recent experimental campaigns witnessed that new configuration has really improved the quality of plasma startup and discharge parameters. Operational pressure window has significantly enhanced from 8-9 x 10^{-6} mbar to 1.0 - 1.8 x 10^{-5} mbar. That means the higher plasma density & fewer runaway electrons during the current startup. Also, in earlier SST-1 discharges, ECR & loop voltage had to be maintained almost throughout the plasma pulse, since ionization used to be incomplete. In the new configuration, even a small pulse of ECR is sufficient to produce better plasma startup, and loop voltage can be reduced significantly, allowing longer pulse with same ohmic transformer.

Non-inductive current drive (e.g. LHCD in SST) is essential for long duration operation of plasma. In old SST-1 discharges (2015), LHCD was inefficient due to improper target plasma

Some of the technical achievements during this experimental campaign were;

- First time in SST-1, ICRH, LHCD and ECRH were injected into the plasma in a single shot.
- Demonstrated long-duration plasma using both (i) Single long-pulse LHCD (ii) Multiple short-pulse LHCD
- TF coils kept in charged state, producing 1.5 Tesla field, for 8 hours with reliable operation of cryo plant system over 9 days
- For the first time in SST, a plasma discharge was produced with TF coils charged and PF3 coils in superconducting state. In future campaigns, we plan to produce shaped plasma by charging PF3 coil pair along with the TF coils set. This requires Liquid Helium (LHe).
- Improved cryo-insulation & optimal operation of the cryo plant has allowed production of 50-60 liters/hour of Liquid Helium along with cooling of TF and PF3 coils. This has demonstrated that LHe availability should not be an issue.





Evolution of the plasma in shot no. 9160 as seen through the visible camera

Visit to IPR

Shri. Gopal Baglay, Joint Secretary, PMO, visited IPR on 13th April, 2019. He visited SST-1 and observed the 24th campaign in progress. He also visited the IPR Computer Centre where the new High Performance Computing System (HPC) system is currently being installed. Shri Bagley also interacted with IPR staff during his visit.

Shri Gopal Baglay at the SST-1 Control Room

During his visit to SST-1

Shri Gopal Baglay at the IPR Computer Center

IPR Technology Transfer

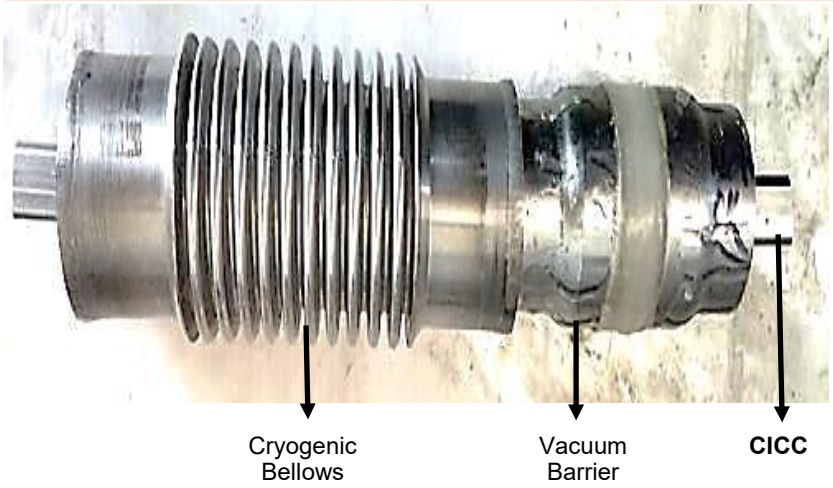
A technology knowhow and license agreement was signed between IPR & RUBAMIN Ltd., Vadodara on 5th March 2019 at IPR, Bhat, Gandhinagar premises. The agreement covered the license of patented knowhow on 'Metal oxide nano powder production technology' on non-exclusive basis to M/s Rubamin Ltd. The meeting started off with a introductory session and a presentation about IPR technologies and specific introduction to the metal oxide nanopowder production technology. Subsequently, Rubamin made a presentation on their company profile and discussed how they intend to commercialize the nano zinc oxide powders using the licensed technology. Zinc oxide nano powders have immense applications in the field of pharmaceuticals, paints & chemicals, fertilizer & agri-nutrients, animal health etc. Since this technology will foster production of zinc oxide nano powders in India, this agreement contributes directly to the '**Make-in-India**' programme of Government of India.

Technology knowhow and license agreement signed between IPR & M/s Rubamin Ltd. Signatories exchanging the agreements with each other in presence of Director – IPR and Chairman – M/s Rubamin Ltd., and other team members from both the organizations.

In-house Development of Vacuum Barrier for Superconducting Feeder System

The vacuum barrier (VB) used as a barrier between two vacuum sections and for electrical isolation purpose up to 0-5 kV DC. In-house design, development and fabrication done (1/2" and 1.5" NB size). It is a replica of existing ceramic vacuum barrier which is installed in current feeder bus bar system of SST-1.

Dissimilar materials joining technique was developed for fabrication of VB using SS 316, S-glass fibre insulation and in-house developed cryo epoxy resin system. The following performance tests were performed to validate the component : (a) Helium leak tightness at 300 K and after 5 thermal cycles at 77 K, 5 bar Helium gas pressure : < 1.2x10-6 mbar-/s in sniffer condition (b) Electrical DC voltage test from 100 V to 5 kV range, at 5 kV insulation resistance: ≥ 100 GΩ, Leakage current : $5x10^{-8}$ Amp. The values have found within an acceptable limits. The in-house developed component costs significantly less than a similar imported component. Also, this developed component mitigated the chances of brittle failure aspects at cryogenic temperature**.** [Rajiv Sharma, SST-1 Cryogenic division**]**



Vacuum Barrier for Superconducting Feeder System developed at IPR (L) the feeder system (R) prototype VB systems.

Outreach : IPR Visits

Educational Visits to IPR/FCIPT – March-April, 2019		
Name Of the Institution	**Date**	**Number of visitors**
Marwadi University Rajkot	20-Mar-2019	40 students, 4th Semester BTech (CS)
RK University, Rajkot, Gujarat.	20-Mar-2019	20 students, 4th Semester BTech (CS)
Marwadi Unisversity , Rajkot, Gujarat.	27-Mar-2019	53 students, MTech (CS)
Bhagwan Mahavir College of Engg. & Tech., Surat.	5-Apr-2019	54 students, BTech (Mechanical and Automobile)
DPS Gandhinagar	12-Apr-2019	30 students of class XI
Raksha Shakti University, Gandhinagar	12-Apr-2019	30 students of Security Management
SarvaJanik College, Mehsaana	25-Apr-2019	54 students, 3rd year BSc Physics
Riverside school, Ahmedabad	26-Apr-2019	24 students of class X
Kendriya Vidyalaya , Cantonment, Ahmedabad	30-Apr-2019	32 students of class X

Students from Raksha Sakthi University, Gandhinagar, during their visit to IPR

Students from SarvaJanik College, Mehsaana during their visit to FCIPT

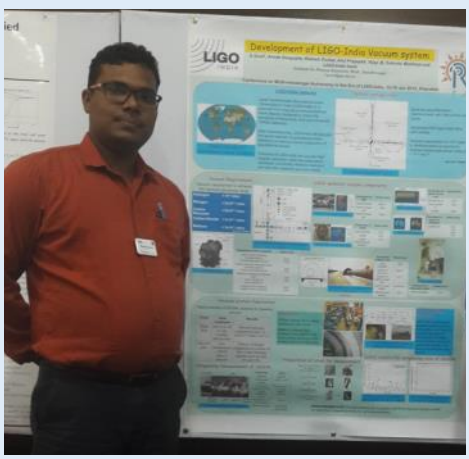
IPR @ Conferences

Mr. Gaurav Kr. Singh, Research Scholar gave an oral presentation entitled "*Design of Experimental Setup for Visualization Studies of Two Phase Liquid Nitrogen*" at the 12th International Conference on Thermal Engineering: Theory and Applications (ICTEA-2019), held at the Pandit Deendayal Petroleum University (PDPU), Gandhinagar, during February 23-26, 2019. He received the "best paper award for this presentation.

Dr. S. Sunil of LIGO-India gave an oral presentation entitled "*Vacuum requirement and outgassing setup development for LIGO-India"* at the conference Multi-messenger astronomy in the era of LIGO-India, held at Khandala during 15-18 Jan, 2019.

Prof. S. Mukherjee of LIGO-India gave an oral presentation entitled "*Vacuum system for LIGO-India*" at the conference, Multi-messenger astronomy in the era of LIGO-India, held at Khandala during 15-18 Jan, 2019.

Shri. Amit Srivastava of LIGO-India gave an oral presentation entitled "*LIGO Data Acquisition & Control System*" at the Multi-messenger astronomy in the era of LIGO-India, held at Khandala during 15-18 Jan, 2019.



Shri Rakesh Kumar of LIGO-India gave a poster presentation entitled "*Development of LIGO-India Vacuum System* " at the Multi-messenger astronomy in the era of LIGO-India, held at Khandala during 15-18 Jan, 2019.

Mr. Hiteshkumar R Kavad of the Large Cryogenic plant and Cryo Systems Design Division gave an poster presentation entitled "*Test Results of Indigenous Prototype 3-Stream (He/He/He) Plate-Fin Heat Exchanger of He Plant*" at the 27th National Symposium on Cryogenics and Superconductivity at IIT Mumbai on 16 Jan 2019.

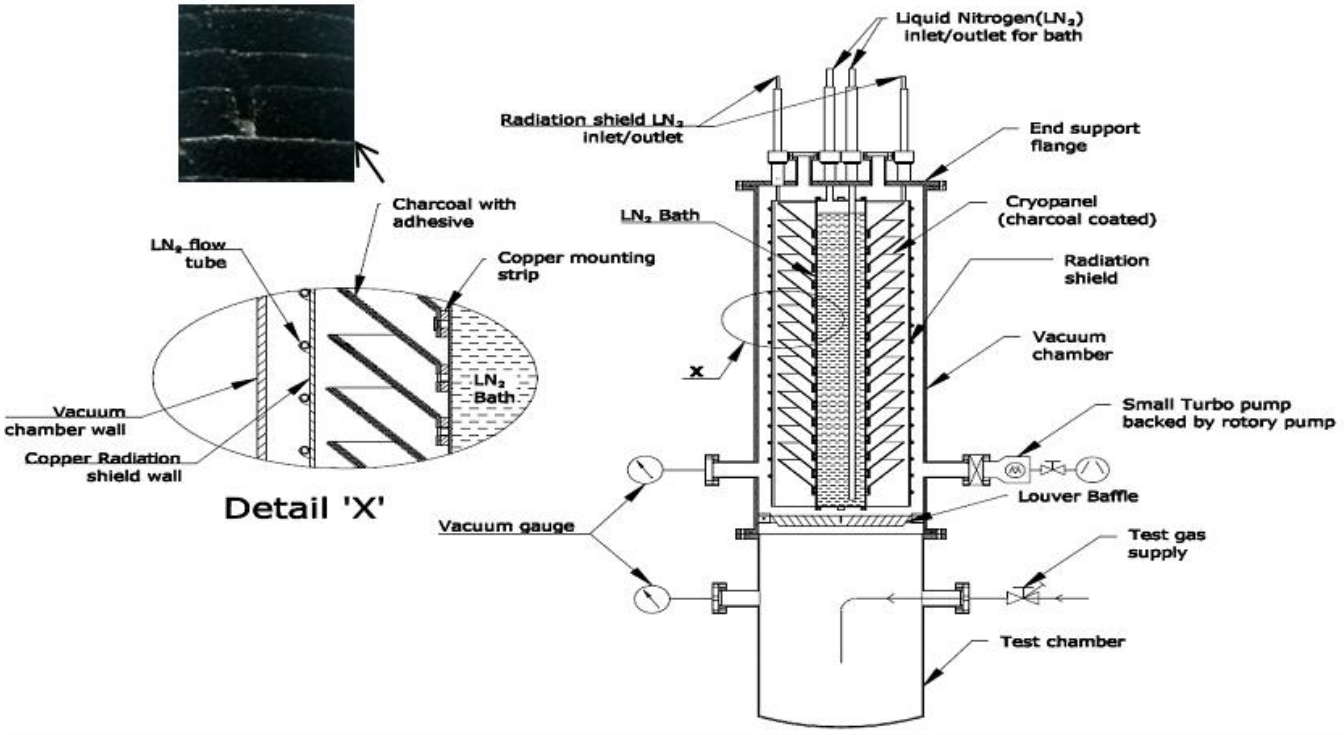
Cryopump Development @ IPR

IPR has developed a novel Cryogenic Vacuum Producing System CVPS. It is liquid Nitrogen based cryopump specifically developed for pumping gases like air, nitrogen and water vapour *etc.* The IPR CVPS has also been awarded a patent. Some specialties of developed CVPS are ;

- It uses the sorbent as coconut shell charcoal. Novelty is in its charcoal which through special process of activation is made in way that most of its pores of 2 nm to 5 nm size which makes it micro porous to absorb gases.
- The adhesive used is cryogenic grade, low outgassing, thermally conductive and developed within the country. At present cryogenic compatible low outgassing adhesives are imported.
- It has no moving parts. All connections are static. The flow tubes carry cryogen. Hence there is no wear and tear. Thus it is a sturdy and rugged system requiring very less maintenance.
- Below 10^{-3} mbar pressure, the developed pump uses cryogens to cool down and hence in operating conditions does not require any electrical power.

Cryopump Development @ IPR … Continued

- At continuous gas dosing of Nitrogen gas of $1x10^{-2}$ mbar lit/sec, it is observed that liquid nitrogen based pump runs continuously for more than 54 hours giving constant pumping speed of around 5000 l/s. Commercial pumps of the same dimension give pumping speed of 3000 l/s at 20 K for Nitrogen.
- It offers better performance compared to its import substitutes with respect to pumping speed, and regeneration (it can be baked to 2000C) and as developed in India is cheaper also reduces the dependency on import.
- Since all the technologies used are developed within the country, any maintenance required can be done easily at a nominal cost



Layout diagram of the CVPS developed by IPR, showing the different components

Along with applications in fusion research, CVPS also finds vast applications in in the fields of space research and semiconductor industry. Cryoadsorption cryopump catering to the requirement of application in environmental test facilities of space application was developed and an MoU was signed between ISRO, Space Application Centre (SAC), Ahmedabad and IPR for supply of 8 cryoadsorption cryopumps.

ITER-India Update

The sub-assembly lower cylinder of Cryostat, one of the four major sections of the Cryostat, has been successfully completed at ITER site, France in February 2019. This is a major achievement of the project made possible with the sustained and coordinated efforts of ITER-India, ITER Organization and industry (L&T). The 12 sectors of the Upper Cylinder of Cryostat manufactured at the industry (L&T), have been dispatched from Hazira and will reach ITER site during May 2019. Further subassembly activities will be carried out in the Cryostat workshop at ITER site.

(L) Cryostat Lower Cylinder-subassembly completed at Cryostat workshop, ITER site, France (R) 12 such sectors of Upper Cylinder dispatched from India

IPR Participation in the Conference and Exhibition on "Application of Nuclear Energy in Food & Agriculture, Water, Industry and Sewage treatment“

A two-day conference and exhibition, wherein, DAE had showcased products & technologies developed at BARC & IPR for societal benefits, was held on March 25-26, 2019 at the Pandit Deendayal Petroleum University, Gandhinagar. The conference was held to discuss the enhancement of Nuclear Agriculture, Food Irradiation and Preservation, Pollution control and municipality waste management in Gujarat. The conference was organized by BARC, BRNS, IPR, DST and GUJCOST.

From IPR, Dr. S .K. Nema gave a talk on “*Industrial Technologies Developed at Institute for Plasma Research : Ready for Commercialization*” and Dr. Alphonsa Joseph gave a talk on “*Industrial Applications of Plasma*”. IPR also participated in the exhibition, which was part of the event, and exhibited working and non-working models of various societal, medical and industrial applications of plasma developed by IPR.

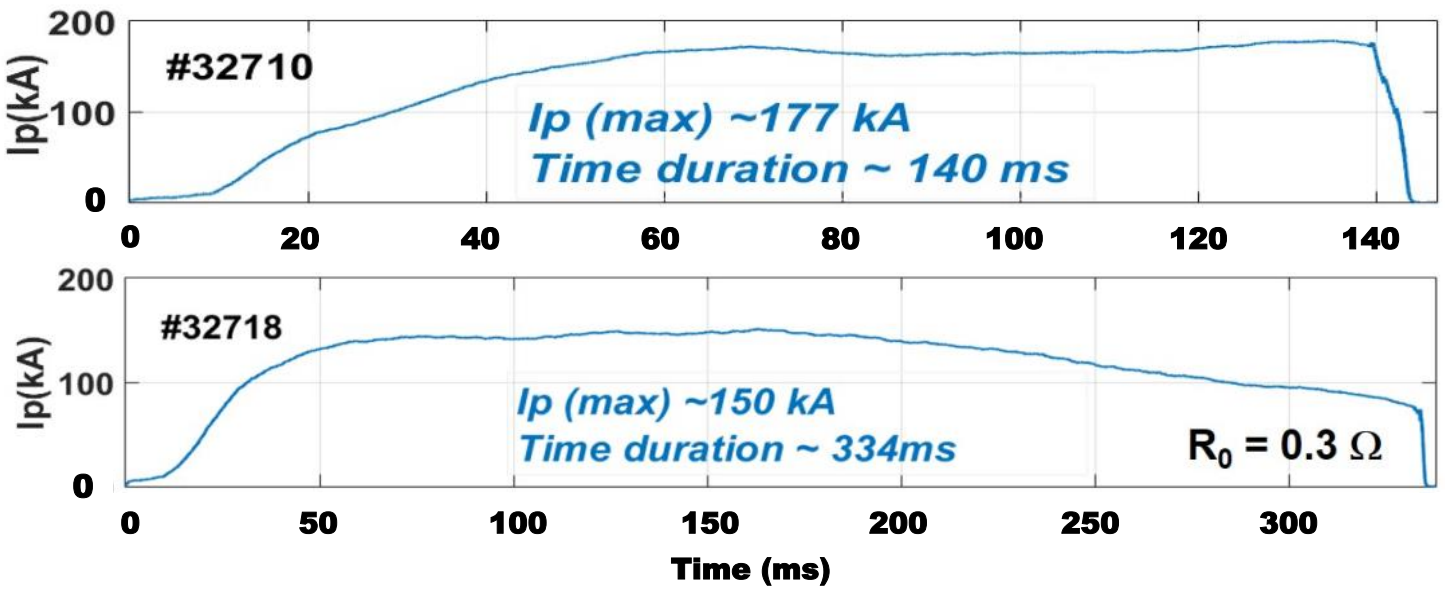
Participants of the Conference "Application of Nuclear Energy in Food & Agriculture, Water, Industry and Sewage treatment”.

(L) The exhibition being inaugurated by Shri. K. N. Vyas, Chairman AEC and Secretary, DAE. (R) IPR’s exhibition stall.

Shri. K. N. Vyas, Chairman AEC and Secretary, DAE, during his visit to IPR’s exhibition stall.

Aditya-U Update

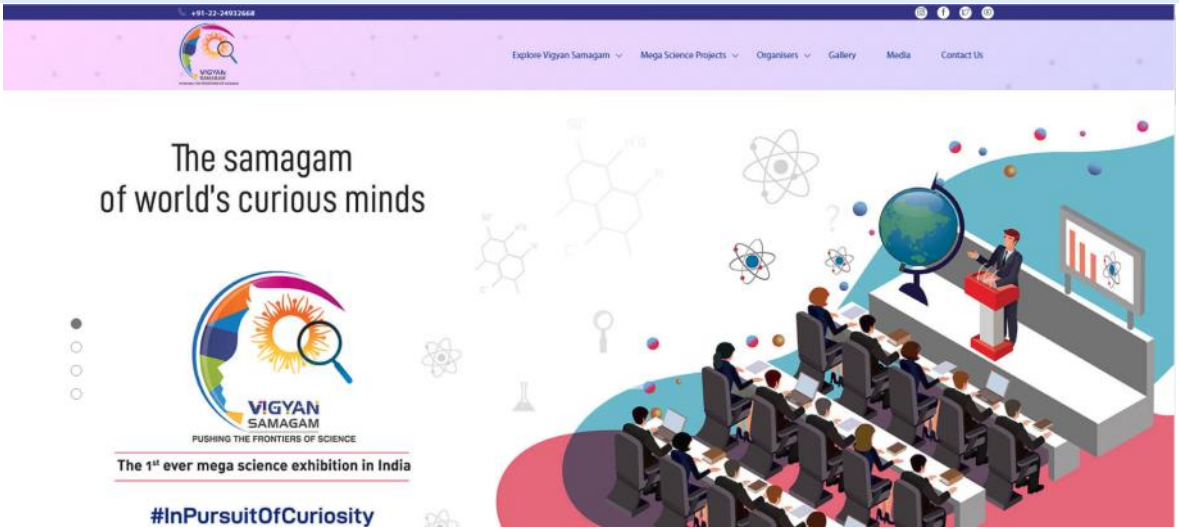
The discharge duration of the confined plasmas has been prolonged beyond 300 ms in ADITYA-U Tokamak for the first time. Repetitive such discharges has been obtained in ADITYA-U by maintaining very high vacuum in the vessel (~ 10^{-9} Torr in volume > 1 m^{-3}) using vessel baking and extensive discharge cleaning, by proper controlling of the plasma horizontal movement and with application of periodic fuel gas puffs of appropriate amount to control the plasma density. The maximum plasma current is ~ 175 kA at a toroidal magnetic field of ~ 1.3 Tesla.



Time evolution of the plasma current from Aditya-U shots

Vigyan Samagam - 1st Mega Science Exhibition in India

DAE, DST and CERN, in collaboration with the National Council for Science Museums (NCSM) are organizing a series of four exhibitions entitled "***Vigyan Samagam***" to be held at Mumbai, Bengaluru, Kolkata and Delhi from May 2019 to March 2020. This exhibition will showcase Indian participation in various mega projects such as ITER, LIGO, CERN, FAIR, INO, TMT and SKA. This exhibition will be on display at each of the cities for a period of two months. During this 2-month period, each of the participating institutions will get a week to organize their own scientific outreach. IPR will hold its scientific outreach at the event in Mumbai from 20-26 May 2019. Interactive exhibits on plasma and its applications will be on display during this event. More details can be obtained from the website of the event (http://vigyansamagam.in)



Place	Date	Venue
Mumbai	8-May to 07-Jul, 2019	Nehru Science Centre, Worli, Mumbai
Bengaluru	29-Jul to 28-Sep, 2019	Visvesvaraya Museum, Bengaluru
Kolkata	04-Nov to 31-Dec, 2019	Science City, Kolkata
Delhi	21-Jan to 20-Mar, 2020	National Science Centre, Delhi

Past Events

- Mr. Chandan Danani, Institute for Plasma Research, Gandhinagar, gave a talk on "Computational modeling of tritium release from porous Lithium ceramic pebbles" on 27th March 2019
- Dr. Jayarao Gorinta, National Institute of Technology, Rourkela, gave a talk on "Development of Li4SiO4-based Ceramics for Solid breeder and CO2 Absorption Applications" on 27th March 2019
- Mr. Rupak Mukherjee, Institute for Plasma Research, Gandhinagar, gave a talk on "Turbulence, flows and magnetic field generation in plasmas using a magnetohydrodynamic model" on 29th March 2019
- Mr. Krishan Kumar Gotewal, Institute for Plasma Research, Gandhinagar, gave a talk on "Effects of variations in micro-geometry on the stresses and other parameters of an External-Internal Spur Gears pair" on 8th April 2019
- Mr. Sandeep Kumar, Institute for Plasma Research, Gandhinagar, gave a talk on "Collective structures in two-dimensional strongly coupled dusty plasmas" on 22nd April 2019
- Mr. Atul Kumar, Institute for Plasma Research, Gandhinagar, gave a talk on "Study of novel features in laser-plasma interactions" on 22nd April 2019

Upcoming Events

- 28th IEEE Symposium on Fusion Engineering (SOFE 2019), Florida, USA, 2-6 June 2019 http://sofe2019.utk.edu/
- Partially Ionised Plasmas in Astrophysics (PIPA2019), Palma de Mallorca, Spain, 3-7 June 2019 http://solar1.uib.es/pipa2019/
- 24th International Symposium on Plasma Chemistry (ISPC 2019), Naples, Italy, 9-14 June 2019 https://www.ispc24.com/
- Astrophysics of hot plasma in extended X-ray sources, Madrid, Spain, 12-14 June 2019 https://www.cosmos.esa.int/web/xmm-newton/2019-workshop
- 74th International Symposium on Molecular Spectroscopy (ISMS 2019), Champaign-Urbana, Illinois, USA, 22-26 June 2019 http://isms.illinois.edu/Archive.php
- IEEE Pulsed Power and Plasma Science Conference (PPPS 2019) and 46th International Conference on Plasma Science (ICOPS), Orlando, Florida, 22-28 June 2019 USA http://www.ppps2019.org/
- International Symposium on Atomic Structure and Oscillator Strengths for astrophysical and fusion plasma research (ASOS-13), Shanghai, China, 23-27 June 2019 https://asos2019.fudan.edu.cn/

Know Our Colleagues

Mr. Chandan Danani joined IPR as a technical trainee in 2001 and then appointed as Scientist - SC in Modelling group at IPR. He holds a M. Sc. degree in Physics from University of Rajasthan, Jaipur and currently pursuing Ph.D. in Tritium release from solid breeder blanket of fusion reactors. He was initially involved in the PF coil current optimization, plasma equilibrium evaluation for SST-1. He joined TBM in 2008 and was responsible for the nuclear design of Indian blanket concepts and Indian TBM in ITER. He coordinated for all ITER TBM neutronics requirements. He played a crucial role in the development of Indian breeding blankets: Lead Lithium cooled Ceramic Breeder (LLCB) and Helium Cooled Ceramic Breeder (HCCB). Since 2007, he was engaged in the development of facilities for neutronics simulation at IPR and CPP-IPR. During 2014-15, he worked on the conceptual design of Indian LLCB TBM in ITER. Currently, he is involved in the development of a small scale Spherical Tokamak (ST). His areas of expertise include radiation transport analyses using Monte Carlo technique, neutron activation analyses, development of breeding blanket for fusion & fusion-fission machines, radiation damage in materials, tritium release from solid breeders. He has good working knowledge of several programming languages such as FORTRAN, C, MATLAB, PYTHON, Linux Shell-Scripts. Several neutronics related codes have been developed under his guidance.

Mr Vishnu R Chaudhari joined IPR as Technical Assistant in July 2001 in the Laser Diagnostic section. During his service, he also completed M.Tech. in Communication Engineering in 2011 from NIT, Surat. As part of his work, he developed several systems such as the low noise front end electronics for Thomson scattering diagnostic, Laser Blow off diagnostic and for Lithium Oven diagnostics, timing and control system for Thomson Scattering diagnostic for SST-1, FPGA based timing and synchronization system for pulse power system and machine vision acquisition system for visible imaging diagnostics. During April 2015 to March 2016, he was deputed to work for WEST tokamak in France, and during his tenure there, he developed Wall Monitoring System (DWMS) for PFC protection of Tore-supra (WEST) Tokamak. He has also guided ME, BE and Diploma students for different electronics related projects. . His current areas of work are low noise and wide bandwidth analog electronics for Opto-electronic sensors, mixed signal electronics design, FPGA based control and timing system, LabVIEW based software development, PLC / SCADA and micro-controller based interlock system, Ethernet based data processing system.

The IPR Newsletter Team

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