Issue 100
November 2021

The Fourth State

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

100th Issue

Azadi Ka Amrit Mahotsav

TECHNOLOGIES FOR NEW INDIA@75

आज़ादी का अमृत महोत्सव

Journey From 1st to 100th Issue of IPR Newsletter

Dear Colleagues, the IPR Newsletter "The Fourth State" was revived in 2013 after a long, dormant period of over a decade. This newsletter strives to highlight achievements, activities and other news from our Institute and take them to all the current and retired staff members of this Institute. This will also be a kind of "family album" of IPR where staff can go back in time and re-live the events that took place in IPR. On the occasion of the 100th issue of the rejuvenated IPR Newsletter, the newsletter team wishes to thank all staff members of IPR. ITER-India, FCIPT and CPP-IPR for their contributions to this publication. We also fondly remember those staff members who left us for their heavenly abode. On behalf of the IPR Newsletter, we hope that staff members will continue to contribute to the contents of the newsletter and continue making it the keeper of IPR's history - *The IPR Newsletter Team.*

Collage of images from past issues of IPR newsletter

Messages on the Occasion of 100th Issue of IPR Newsletter

Dr. Shashank Chaturvedi (Director, IPR)

I am extremely pleased to release the 100th issue of our popular monthly newsletter "The Fourth State", which has enabled us to reach out to the non-academic community, by explaining our Institute's work in simple terms intelligible to non-specialists.

When this newsletter was started, we had the objective of opening a window into the activities of the institute and to explain, as far as possible, in layman terms, the progress and developments that were taking place in the field of our expertise. From the response and feedback that we receive from time to time, I am glad to note that we have succeeded in meeting our objectives. We continue to strive to get better with each issue and we value highly that any feedback the readers may like to give us to this end. Over the years, the institute has made remarkable progress through pure science research, R&D activities for technology development, and capacity building. Like many of our technologies, this Newsletter is very much a homegrown product. We write, we edit, we page-set and we publish.

I have great admiration for the dedication of each member of the newsletter team and for their diligence and tenacity in improving this offering of ours. It has not been easy to do this month after month for the last eight years, but they have stuck to the task to make the newsletter what it is today and in that process, sustaining the spirit. I also take this opportunity to thank the staff members for their contributions to the newsletter content. We look forward to scoring another century, and, in that process, keeping the flame alive.

Shri. Ujjwal Baruah (Director, ITER-India)

Congratulation to the IPR Newsletter on achieving this remarkable feat of the Centenary Issue! The Newsletter has established itself to be an informal but important communication channel within the institute as well as to the public. The content and composition of the web-magazine is continuously giving more exciting experience to readers. While ITER-India is striving to deliver the in-kind contributions, we are also getting closer to the start of operation of ITER. Our younger colleagues and students need to be aware of future opportunities with the exciting scientific experiments to be done in ITER. The main objective of Indian participation in the collaboration is creation of avenues for large number of Indian scientists being part of the inventions expected from ITER, and making the Indian Fusion Research flourish further with the access to generated knowledge. I take this opportunity to convey to readers of this exciting frontier of Plasma Physics that is going to open up soon. Best wishes!

Dr. Subroto Mukherjee (Dean Administration)

Bringing the 100th issue of IPR Newsletter is a great achievement. The Newsletter Team deserves a huge compliment from all of us. If we recollect the 1st issue, published in 2013, it covered various aspects of IPR's contributions in areas of plasma science and technology, at the national and at the international level. Major achievements reported in the 1st issue are the commissioning and formation of 1st plasma in SST1, developments in ADITYA tokamak, various technologies developed in FCIPT, developments in Helicon Thruster. The 1st issue is also special because it covered the visit by two very eminent visitors' to IPR. They are Dr Ratan Sinha, the then Secretary of DAE and Chairman - AEC and Prof. Osamu Motojima, the then Director General ITER. Today, when we celebrate the 100th issue, we see that IPR has fulfilled a major part its commitment to ITER and also made great strides in research in plasma science and deployment of plasma based technologies for societal benefit. I hope that in future the same trend continues. Lastly, I wish the Newsletter team all success and heartiest CONGRATULATIONS!

डॉ. प्रवीण कुमार आत्रेय (डीन - आर एंड डी)

शताब्दी अंक की यह उपलब्धि हासिल करने पर आई पी आर न्यूज़लेटर को बधाई । न्यूज़लेटर ने संस्थान के साथ-साथ जनता के लिए एक महत्वपूर्ण और अनोपचारिक संचार चैनल के रूप मे खुद को स्थापित किया है । वेब-पत्रिका की सामग्री और रचना लगातार पाठकों को अधिक रोमांचक अनुभव दे रही है ।

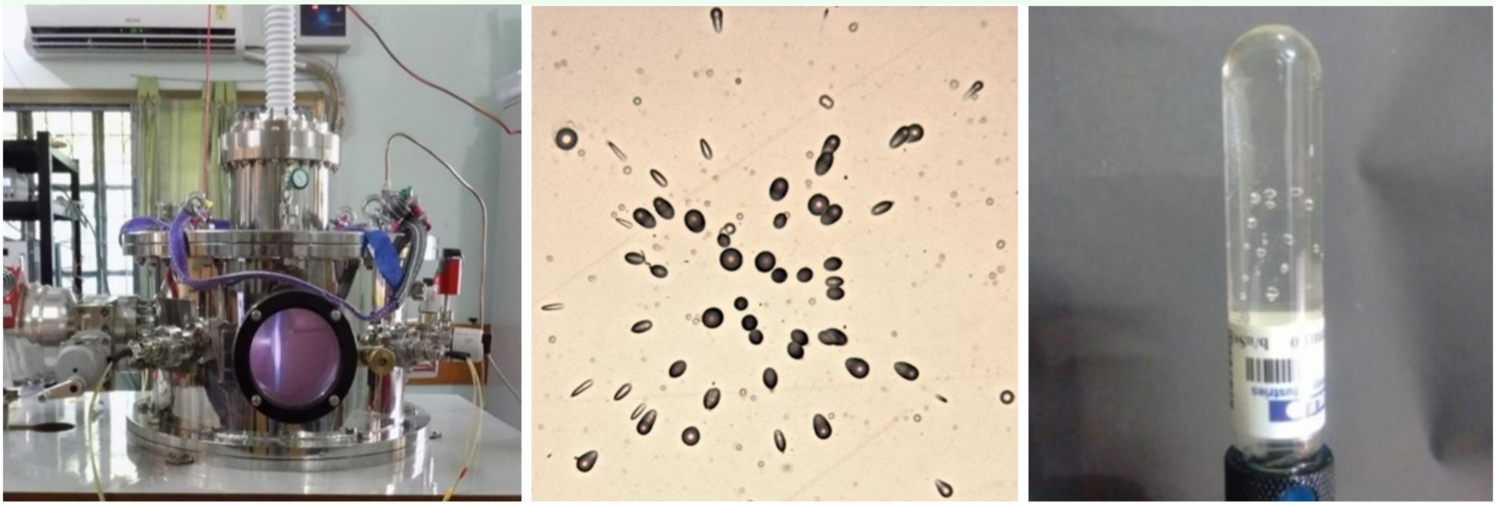
वैज्ञानिक गतिविधियों के अलावा संस्थान के जन-जागरूकता कार्यक्रम समाज मे वैज्ञानिक सोच को जाग्रत करने हेतु सफल सिद्ध हो रहे हैं। मैं इस न्यूज़लेटर के संपादक मंडल और लेखकों को बधाई देता हूँ । मुझे विश्वास है कि न्यूज़लेटर के द्वारा विज्ञान को सरल रूप मे परस्तुत करने के अभियान मे संपादक मंडल सदैव तत्पर रहेंगे और सभी पाठकगणं इससे लाभान्वित होंगे । धन्यवाद एवं शुभकांनाए ।

Dr. Sudip Sengupta (Dean Academics)

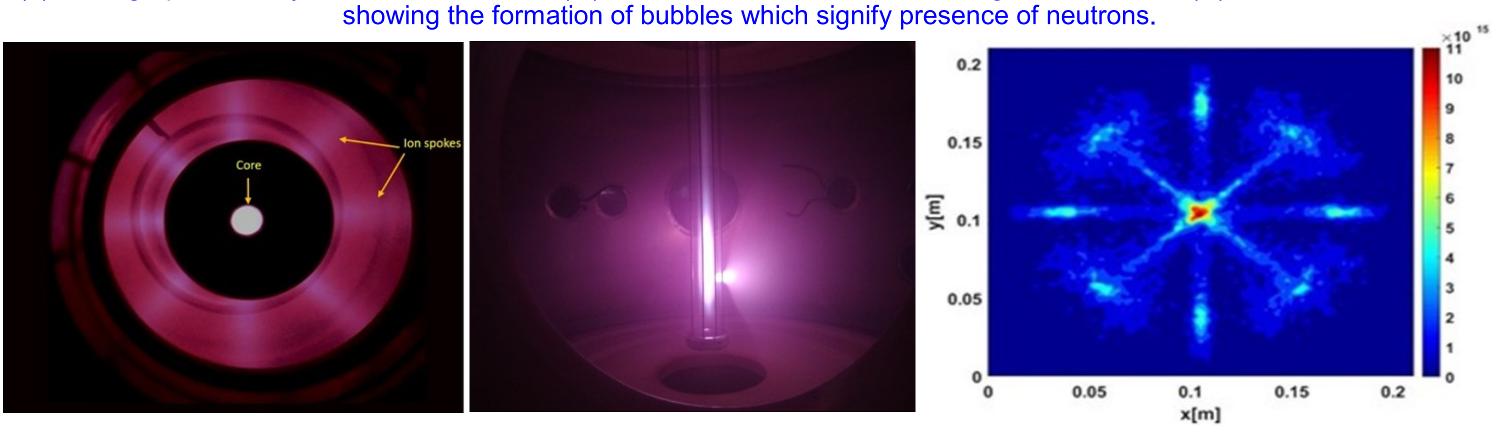
Basic research in all aspects of Plasma Science and Technology which includes Theoretical, Simulation and Experimental studies forms one of the important mandated activities of IPR. While creating scientific knowledge, basic research also prepares trained manpower for future scientific activities. Being the only Plasma Research center in the country which has two working experimental Tokamaks (SST-1 and Aditya) in addition to having several running basic plasma experiments, IPR is uniquely positioned to do research in frontier areas of plasma science and to train future generation of plasma scientists. Preparation of trained manpower has become even more important with our participation in the international ITER program where we have made several technological commitments. Over the years, Institute's academic program has been tailored to nurture a generation of first class plasma scientists who will eventually spearhead country's goal of searching for alternative source of energy through fusion. Through this brief message, I would like to express my heart felt gratitude to all my colleagues who, through their teaching and mentoring of students, are working tirelessly towards this goal. I finally thank the newsletter committee for their commendable job in reporting important scientific breakthroughs in a manner which is accessible to a wide spectrum of audience. This job which is of overriding importance in igniting the young minds.

Inertial Electrostatic Confinement Fusion Studies @ CPP-IPR

An inertial electrostatic confinement fusion (IECF) device installed back in the year 2014 at CPP-IPR is the first indigenously built device of its own kind in the entire India. The device is a neutron/proton/x-ray source which has found its applications in diversified fields. Medical isotope production, explosive or landmine detection, negative ion production, neutron/x-ray radiography, ion thruster, etc. are some of the major applications of the device. On the application of high negative potential of few tens of kV to the inner grid of the device, the deuterium ions overcome the coulomb barrier and fuse together at the central part of the device and emit neutrons, protons, etc. as the fusion product. So far, neutron yield of 10^6 n/s have been achieved from the cylindrical IECF device having a highly transparent cylindrical cathode grid, when operated at -80 kV voltage and 15 mA current. In order to detect the neutrons different electrical and non-electrical detectors such as, neutron area monitor, bubble dosimeter, He-3 proportional counter, and CR-39 nuclear track detector have been used. Since, ion flow characteristics play a vital role in this device, we have performed simulation as well as experiments in order to observe the ion dynamics. A PIC code named XOOPIC has been used for the simulation and electrostatic probes such as, single and double Langmuir probe, emissive probe, etc. has been used during the experiments. Again, we have performed experiments to display the applicability of the device both as a neutron and an x-ray source. The 10^6 n/s emitted by the device has been used for explosive detection. The gamma radiation peaks confirms the feasibility of use of our IECF device for explosive detection. Lastly, the continuous x-rays emitted from IECF device have been also used recently for radiography of electronic components as well as biological samples.



(L) Photograph of the cylindrical IECF device, (M) the CR-39 track detector showing neutron tracks (R) the bubble dosimeter showing the formation of bubbles which signify presence of neutrons.



(L) the star mode, (M) the jet mode of discharge in the IECF device. (R) simulation showing the distribution of ion in a star

Members of the IECF group (L-R) Darpan Bhattacharjee, Lucky Saikia, Manoj Kumar Deva Sarma, Abhishek Maurya and S R Mohanty

Technology License Transfer of IPR Developed Technology

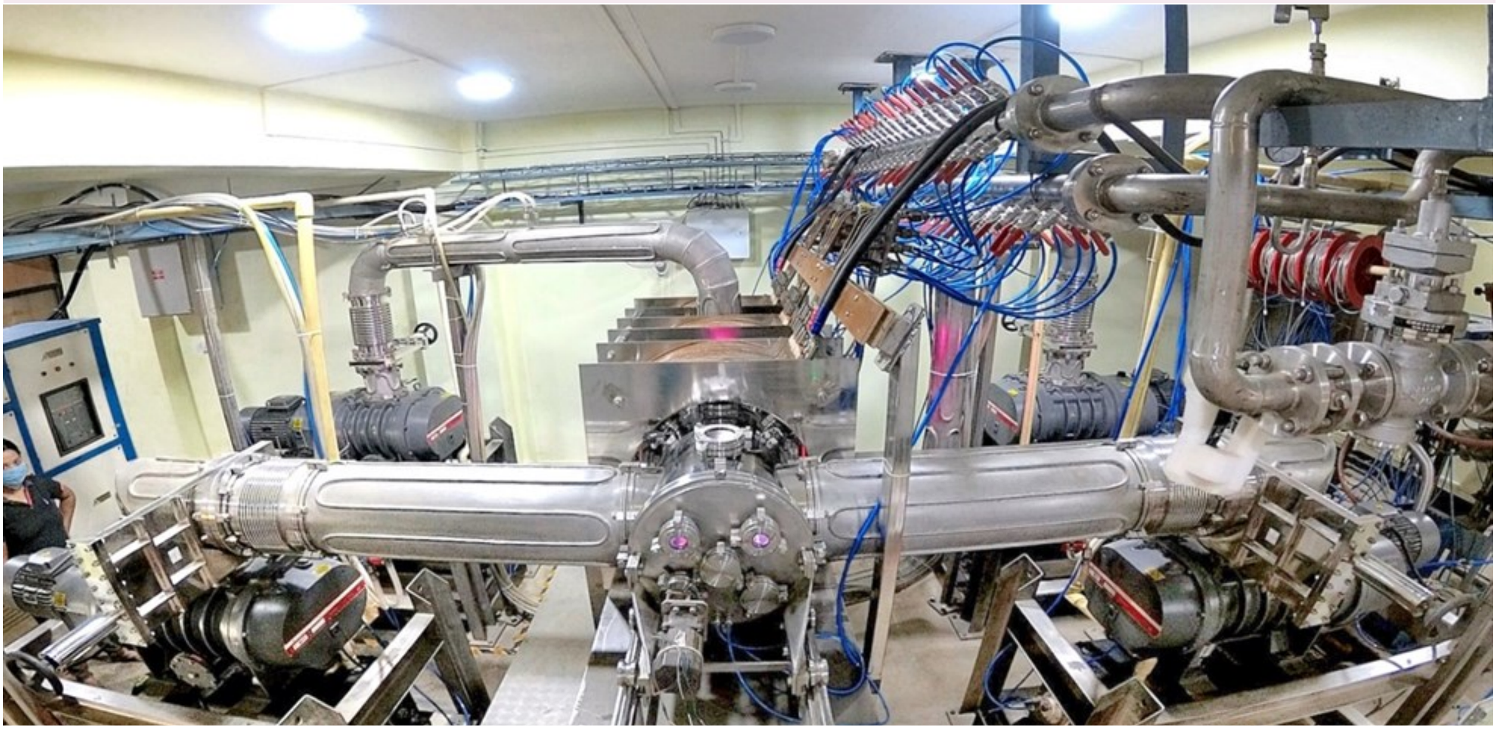
A technology knowhow and license agreement was signed by & between IPR and M/s Persapien Innovations Pvt. Ltd. on 6th Sept 2021 for a prototype system to generate plasma activated water, which is found to have anti-microbial properties. The agreement was signed by Director IPR and Dr. Shashi Ranjan, Managing Director & co-founder - Persapien Innovations Pvt Ltd., at IPR, main campus. Following the signing of the agreement, the team from the licensee industry underwent training for the knowhow transferred.

Images from the technology transfer function organized at IPR on 6th Sept, 2021

CPP-IPR High Heat Flux & CIMPLE-PSI Devices

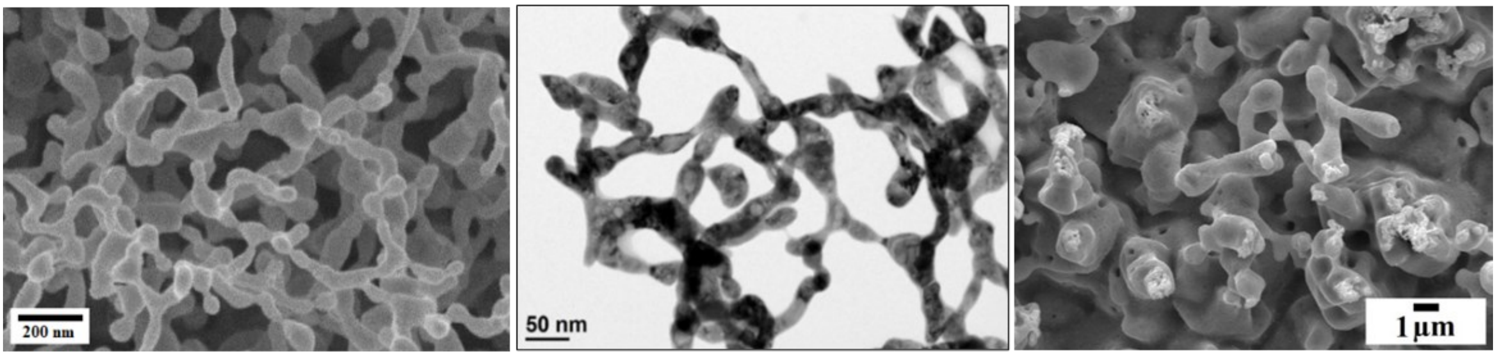
CPP-IPR commissioned its first linear magnetized plasma system for fusion related plasma surface interaction studies: the CIMPLE-PSI device in 2018. It operates up to 600 kW electrical power, pumped by four sets of roots/rotary vacuum pump combinations with more than 14,000 m3/h pumping speed. A segmented plasma torch produces a dense plasma jet, which propagates along the axis of a vacuum chamber and is collimated into a flowing plasma beam by an axial magnetic field (maximum 0.45 Tesla), produced with a water cooled copper electromagnet. The beam finally strikes the material target of interest (tungsten, RAFM steel, graphite etc.) that is attached to a water-cooled sample holder, for temperature control and biasing. It was largely an indigenously developed system, for example various components, like the segmented torch, electromagnet, vacuum chamber, were all designed independently in-house and fabricated locally.

A steady-state peak helium ion-flux and heat-flux of 1024 $m^{-2} s^{-1}$ and 5.1 MW m^{-2} respectively were measured in this device. With these parameters, CIMPLE-PSI device is one of the few simulator devices in the world that can reproduce extreme levels of both ion and heat flux simultaneously like those in the ITER Divertor region. In the report entitled "Indian Domestic Fusion Program" presented during the last "ITPA Coordination Committee meeting (December, 2020)", CIMPLE-PSI and studies conducted there were highlighted.



The CIMPLE-PSI device.

PSI Experiments in CIMPLE-PSI with tungsten: In order to study the effect of extremely high ion-flux and heat-flux, tungsten was exposed to helium plasma in the CIMPLE- PSI device, as representative of the divertor region in the ITER machine. Results confirmed formation of the so called "Tungsten Fuzz", which were also observed in tokamak devices. Inside a fusion device, fuzz may lead to the production of dust particles, which may severely influence the gas retention characteristics or other important surface properties of the tungsten walls. Electron microscopy shows gas bubbles were embedded inside the tungsten-fuzz structures, which are actually considered to be the basic precursors that lead to the growth of those one dimensional surface nano structures.

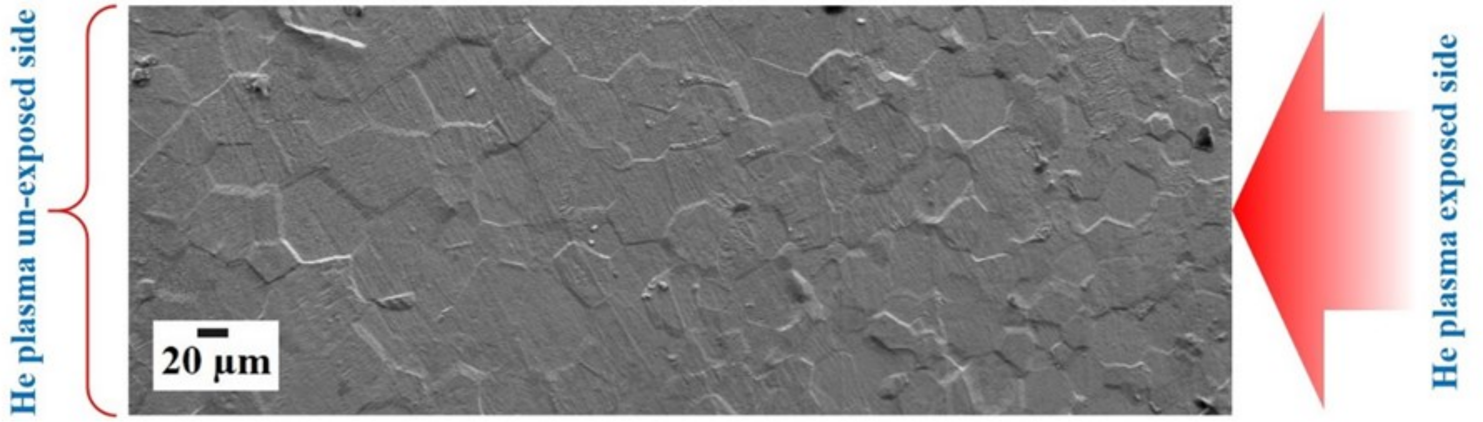


(L) FESEM micrograph of the nano fuzz on helium plasma exposed tungsten, (M) HRTEM micrograph of the fuzz, shows the embedded helium bubbles, (R) FESEM micrograph showing fiber-form structures on helium plasma exposed IN-RAFM steel.

PSI Experiments with India developed IN-RAFM steel: The Indian Test Blanket Module (TBM) for ITER and the Lead Lithium Ceramic Breeder (LLCB) blanket for the Indian DEMO will be made of India specific RAFM (IN-RAFM) steel. It is therefore essential to understand their surface properties when exposed to tokamak divertor like low temperature plasmas. For the first time ever, IN-RAFM steel was exposed under helium plasma in CIMPLE-PSI device, with wide variation of different plasma parameters. With electron microscopy, it was confirmed that morphology of the top surface of the steel transformed immensely, structures like pinholes, fiber-form structures and hollow fibers were observed.

ITER Relevant Plasma Surface Interaction Studies at CPP-IPR CIMPLE-PSI Device

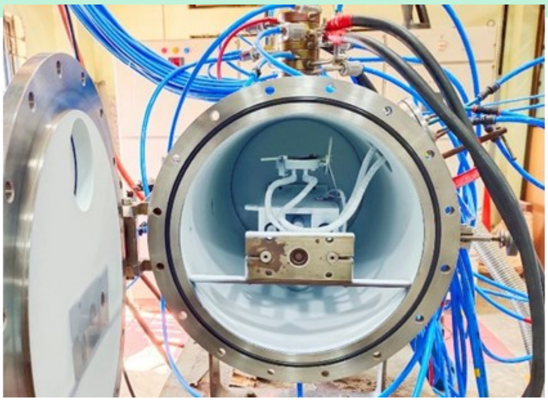
Studies on Tungsten Recrystallization (Grain Growth): In ITER, tungsten plates will be heated up to very high temperature, which in turn will lead to grain-growth and deterioration of its surface hardness. We have studied this possible situation in CIMPLE-PSI by exposing tungsten plate targets to very high temperature (1600˚C) along with maintaining other fusion like extreme plasma parameters. An interesting observation was grain-growth was less on the plasma exposed surface compared to the opposite surface heated up almost to the same temperature. It is likely that diffused helium into the tungsten had obstructed the motion of the grain boundaries. This study is ongoing.

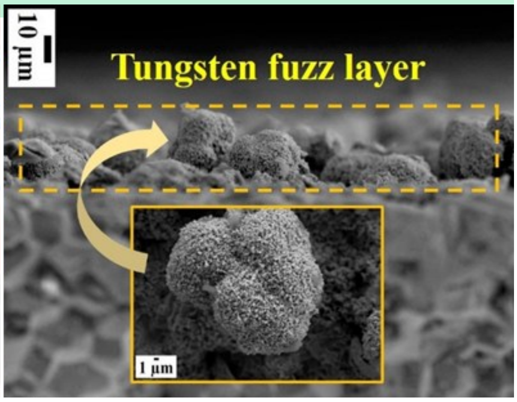


FESEM micrograph shows cross-sectional view of the helium plasma exposed tungsten target in CIMPLE-PSI, grain sizes on the exposed size are smaller than the opposite side

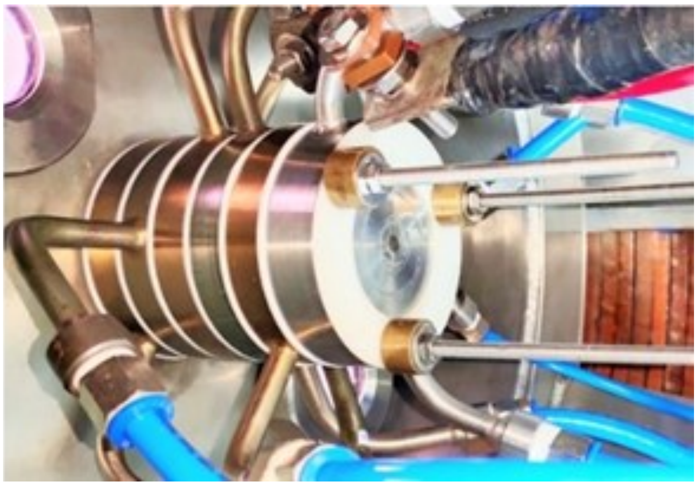
Spinoff of fusion relevant PSI research: bulk synthesis of metal oxide nanomaterials: An existing plasma high heat flux system was modified to produce defect engineered nano-sheets of molybdenum oxide, maximum up to 750 g/h, through a one-step continuous process. The blue-black coloured exfoliated metal-oxide, very efficiently absorb radiation in the IR region, capitalizing on which we have demonstrated it may be used for treatment of cancer by photo-thermal therapy and for treatment of waste-water by photo-catalytic degradation of dyes and other organic contaminants. Another important observation was, the material is ferromagnetic at room temperature, which may lead to their application in Spintronic or allow manipulation with a magnetic field in remote drug delivery applications.

Spinoff of fusion relevant PSI research: Tungsten-fuzz converted to oxide for photo-catalysis: Tungsten fuzz created before, having very good crystallinity and porous morphology, is being converted to oxides, which are likely to be very efficient for environmental applications. This study is ongoing.





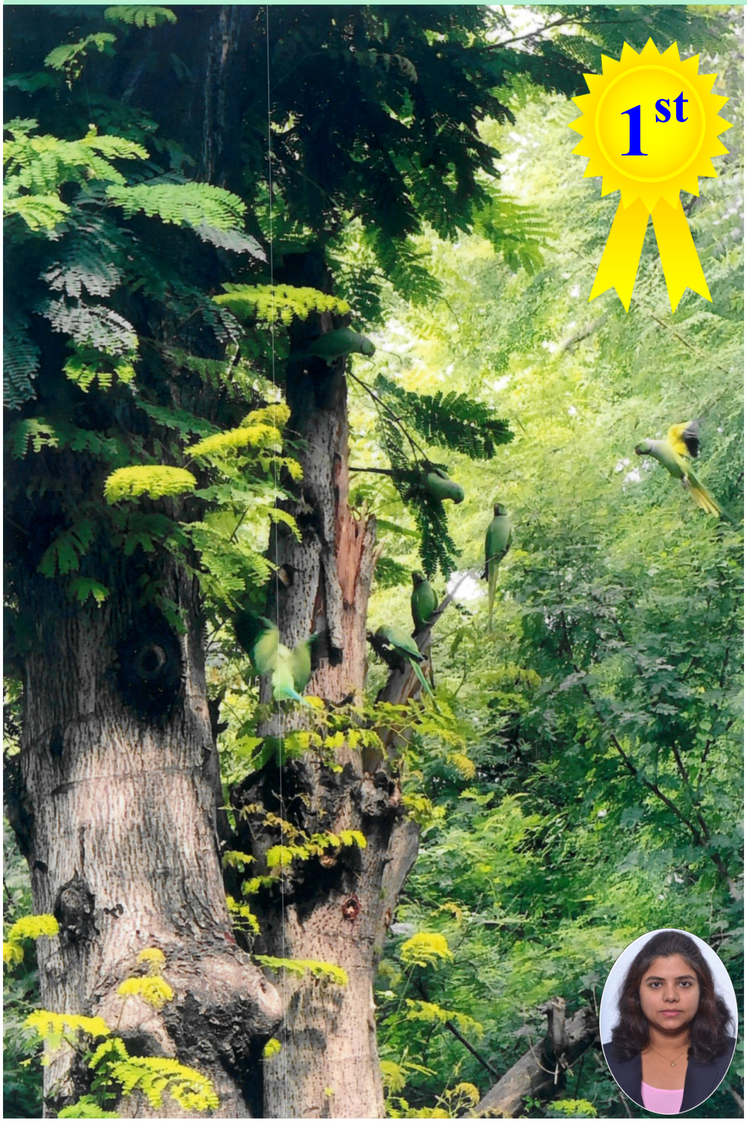
(L) A laminar plasma jet heats up a large molybdenum plate for oxidation reactions, (M) thick layer of moly-oxide nanomaterials deposit inside a novel reactor system after brief operation, (R) Thick (about 15 micrometres) tungsten-fuzz produced in CIMPLE-PSI, designed for environmental applications

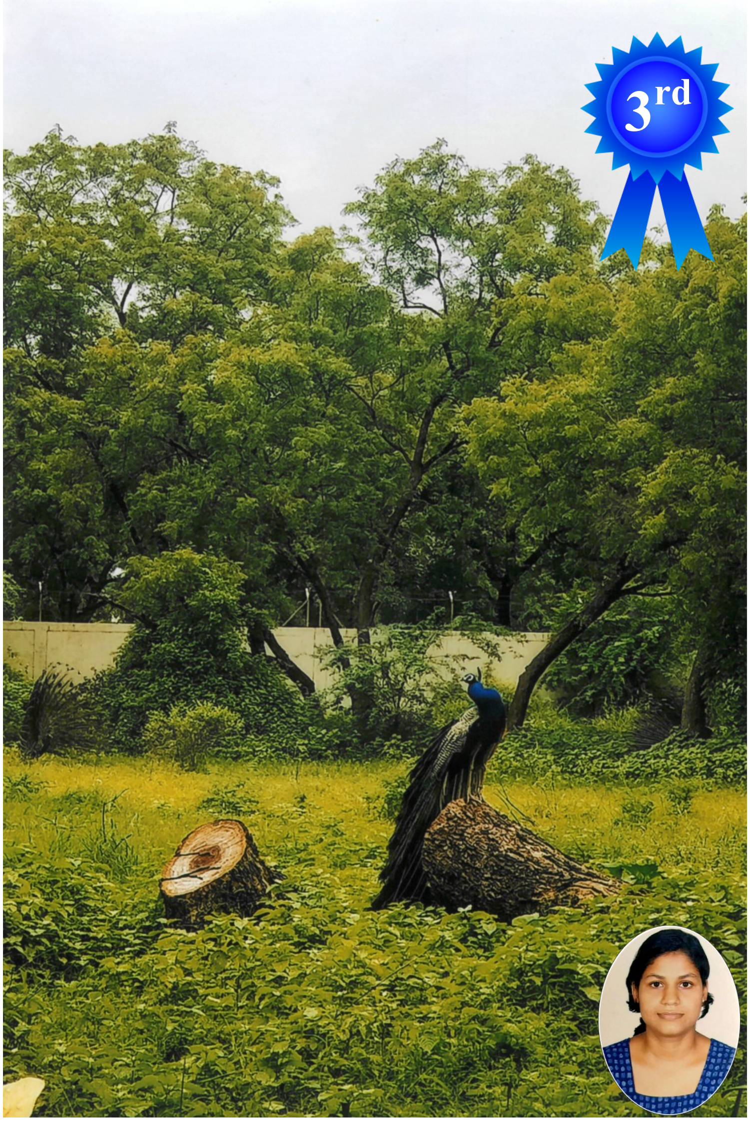


(L)) Photograph of the cascaded thermal plasma torch (R) Members of the CIMPLE-PSI Laboratory (L-R) Kandeswar Deka, Sabir Chetri, Mizanur Rahman, and Mayur Kakati

Winners of the Staff Club Photography Competition

To mark the **World Photography Day – 2021**, IPR Staff Club organized a Photography Contest for staff members with a theme "**Flora and Fauna at Workplace**". Over 40 entries were received from staff from IPR, FCIPT and ITER-IN.





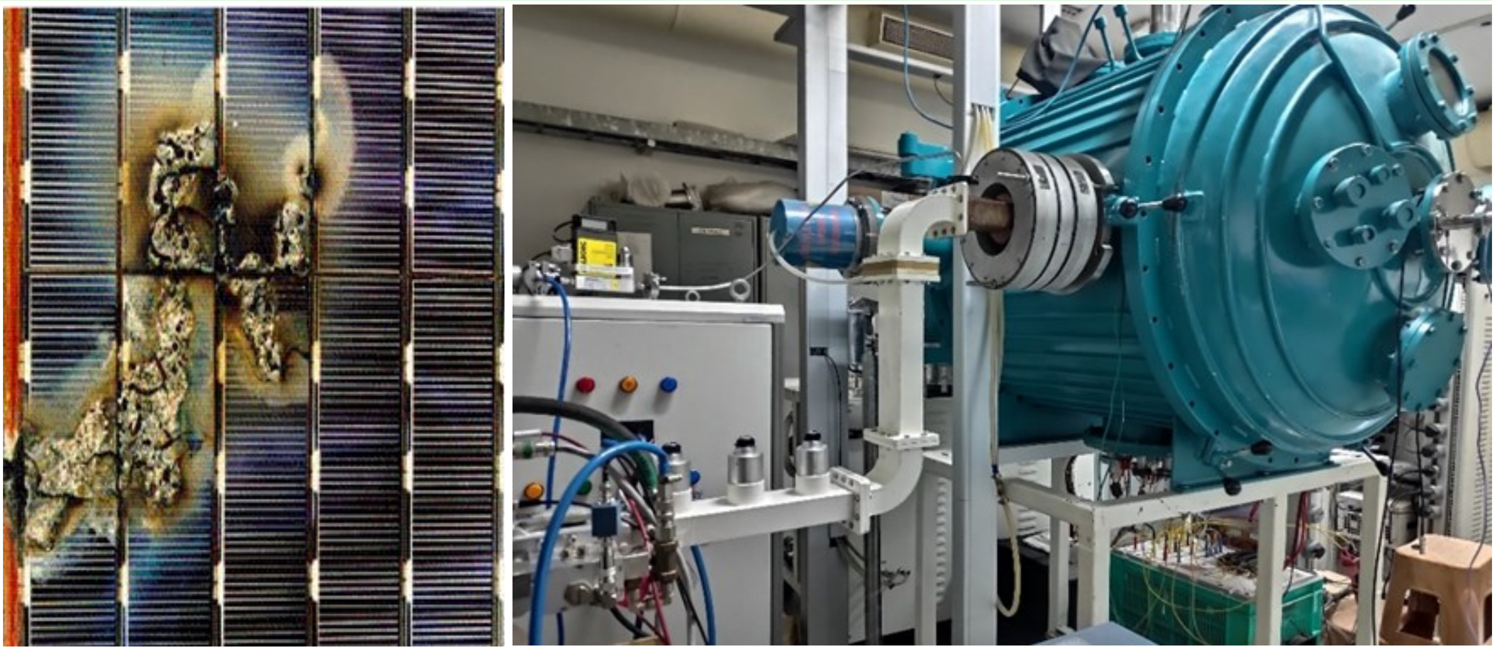
(L) First Prize : Bhoomi Sandeep Gajjar (R) Third Prize : Kalyani Swain

Second Prize : Anshika Chugh

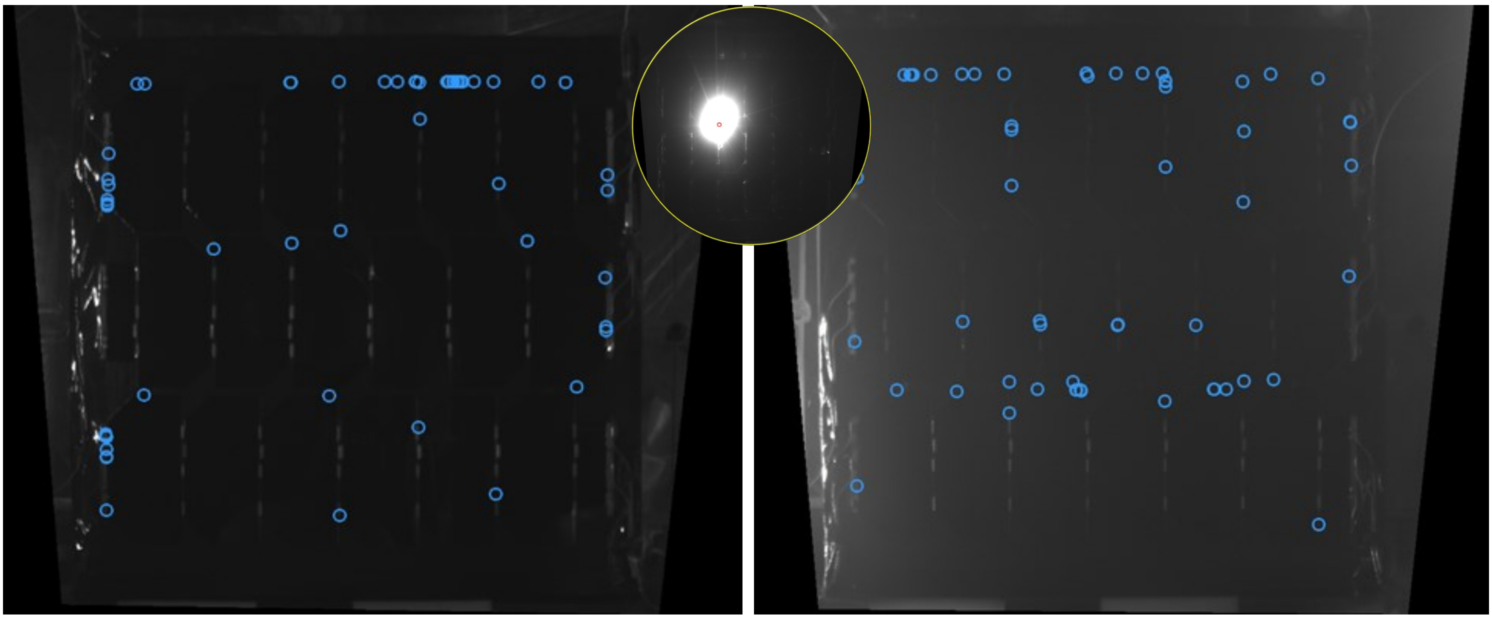
Plasma Source For The Ground Testing of Satellite Solar Panels

To fulfil the growing demand from various users, it is essential to place more transponders in a single satellite which essentially requires high power. In order to reduce satellite weight, it is desirable to furnish power at higher voltages and lower currents. The high voltage satellite power systems suffer the drawback of arcing on the satellite solar panel surface. In some cases, such arcing can cause complete disruptions of satellite power system. This is a serious financial and strategical loss to the space industry. Therefore, in order to ensure reliable operation of satellite solar panels in the space at elevated voltages, a consortium of National Aeronautics and Space Administration (NASA), Office National d'Etudes et Recherches Aérospatiales (ONERA), European Space Agency (ESA) and Japanese Space Agency (JAXA), follows a scheme for the ground testing of satellite solar panels before launching into space. Being a strategic application, very limited information about this scheme exists in the public domain.

Considering the importance of higher bus voltages, URSC - ISRO approached Institute for Plasma Research (IPR) to develop a ground test facility for LEO and GEO like space environments. To study the detrimental effects of arcing on the satellite solar panels, IPR has successfully developed an indigenous Spacecraft Plasma Interaction eXperiment (SPIX) facility at FCIPT. Test results obtained from SPIX facility matches with the similar experiments performed in the above mentioned space laboratories. In the first phase, a low energy filament based plasma source and a flood beam electron gun have been used to resemble the LEO and GEO like space environment respectively. To overcome the few limitations of existing filament based plasma source, an indigenous and import substitute ECR plasma source has been developed successfully. This ECR plasma source is capable to create space like ESD conditions on the satellite solar panel surface in the laboratory.



(L) Image of satellite solar panel damaged due to arcing (R) The SPIX facility with ECR plasma source.



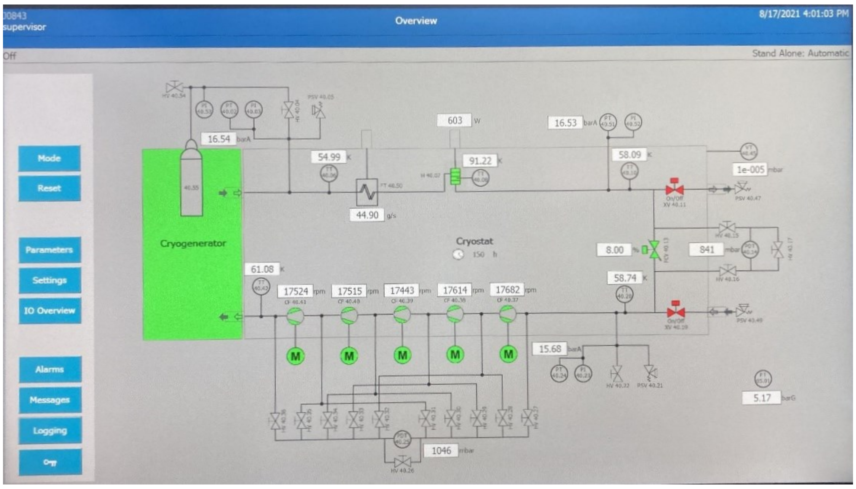
LEO primary arc experiment performed using (L) Filament plasma source (R) ECR plasma source. INSET : Arc (ESD) on satellite solar panels in simulated space-like environment.

Cryocooler Based Helium Circulation System at 55K @ IPR

Cryocooler based Helium Circulation System at 55K was successfully installed at IPR. The main purpose of this system is to cool the High Temperature Superconductor (HTS) applications (i.e. HTS cables, coils, transformers etc.) at 55K with forced flow cooling method. The SPC-4 Cryogenerator, a Cryocooler which is based on Stirling cycle, is used to generate the low temperature in the system. The five numbers of cryofans (aka cold circulators) in series combination generate required pressure head for Helium gas mass flow at low temperature into HTS application. The system does not use liquid nitrogen as pre-cooling to achieve low temperature. Hence, this system is employed for HTS applications where the continuous supply of liquid nitrogen is not available.

The Cryocooler based Helium circulation system is mainly equipped with Stirling Cryocooler, special heat-exchangers, five nos. of cryofans, mass flow meter, electrical heater, valves, vacuum pump and chiller. PLC based automation system with Human Machine Interface (HMI) touchscreen panel is employed to operate the complete system. The system provides cold helium mass flow rate of > 23 g/s with pressure head of ~800 mbar at 55K and 16 bar(a) to HTS application. The performance of the Cryocooler based Helium circulation System at 55K is found satisfactory and this system becomes one of the start of art facility for research and development activities in the field of HTS at IPR.

(L) The SPC-4 Cryogenerator with cryostat and five cryofans (R) Chiller for the Stirling Cryocooler (SPC-4)



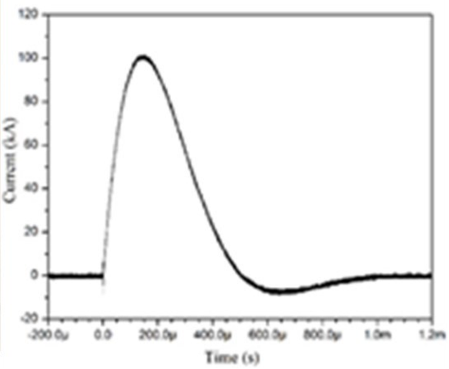
(L) Snapshot of HMI Panel of the Cryocooler based Helium circulation system at 55K (R) Top view of the cryostat

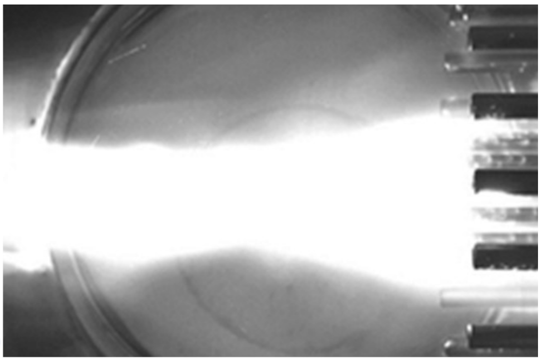
(L) The cryogenerator system (R) Members of the SST-1 Cryogenics Division

Pulsed Plasma Accelerator Laboratory (PPAL) @ CPP-IPR

Accelerated plasma beam or the plasma jet, that is formed by applying high voltage pulsed, has been attempted for many applications. These includes probable re-fueling into fusion reactor, mitigation of disruption in tokamak or electromagnetic plasma thruster. In this connection, it can be mentioned here that the plasma produced in International Thermonuclear Experimental Reactor (ITER) involves a transient heat load event, namely the Type-I ELMs (Edge localized modes) and consequently the researchers from all over the world has been trying to study plasma matter interaction using heat sources that of more or less similar nature to the Type–I ELM. These heat sources mimic the plasma mater interaction phenomena that will occur due to the ELM. In this case, it can be mentioned that the higher density, high speed plasma beam of pulsed plasma accelerator (PPA) can be used as heat generating source when allowed to fall on any material surface. The plasma beam formed in a PPA possess a relatively higher density of $10^{21\text{-}22}/m^3$ and it moves in a speed of several kilometers per second. It is logical to think that the plasma beam interaction with matter is closer to the ELM interaction with matter since both of them involves plasma in the interaction. On this note, a project was undertaken in the year 2012-13 at CPPIPR to develop a Pulsed Plasma Accelerator. It was planned to build a 200 kJ Pulsed Power System (PPS) to drive the PPA. The 200 KJ pulsed power system mainly consists of two 100 kJ module capacitor bank, with each capacitor bank module being a club of five 20 kJ capacitors. An ignitron switch was connected to each capacitor bank module to transfer the energy from the bank to the load. Towards the end of 2015, we could complete the test firing of one 100 kJ capacitor module and the test firing of 200 KJ PPS was done in the mid of 2016. In April, 2016 the plasma accelerator chamber was coupled with the 200 KJ PPS and in the same year the gas injection valve (GIV) was fitted to the chamber. For sustaining the plasma beam for longer durations (>0.5ms), gas has to be inserted during the pulsing time using a gas injection valve. From 2016, the PPAL group has been studying the characterization of the plasma beams of different gases like Argon, Nitrogen, Hydrogen and Helium produced from the PPA. Diagnostics like Triple Langmuir Probe (TLP), double plate probe (DPP), calorimeter, high speed camera and spectrometer have been used to monitor the plasma. A typical plasma beam from this facility is found to have a velocity in the range of 20 km/s to 30 km/s with beam density around $10^{21}/m^3$. The heat energy density of a nitrogen plasma beam is found to be 0.3 MJ/m^2. At present, the spectroscopic investigation of the plasma beam for density, temperature, velocity, impurity estimation etc. are going on in different experimental conditions. Further, the hydrogen plasma matter interaction with tungsten metal will also be carried out in the coming months.


(L) Assembly of the capacitors (R) Modules of 100 kJ capacitor bank



(L) The 200 KJ PPS (M) Discharge current signal (R) Typical H_2 plasma beam coming out of the electrodes of the PPA


(L) The PPA system (R) Members of the PPAL Group (L-R) Azmirah Ahmed, N. K. Neog, T. K. Borthakur, Dhiraj Baishya, Sumit Singha and Suramoni Borthakur

Activities of LIGO-India Division @ IPR

LIGO-India project is mandated to construct, install & commission to operate 4 km long laser interferometer based Gravitational Wave detector in India in collaboration with LIGO Laboratory, USA. The LIGO India project will be jointly executed by institutes of India named *RRCAT Indore, IPR Gandhinagar, DCSEM Mumbai and IUCAA Pune*. About 22 sites across the country were initially identified and surveyed for locating the project. Finally, Aundha, near Hingoli, Maharashtra state has been selected as the location of the project after confirming this location as most suitable for this project.

The LIGO Division at IPR is responsible for following work.

- Verify design, procure, install and commission vacuum system operating in UHV ($\approx 10^{-9}$ mbar) range. Total envelope of the vacuum system is approximately 10,000 m^3 volume which is essential for functioning of LIGO India detector.
- Design, develop, install and commission Control and Data System (CDS) for LIGO India.

Activities towards development of Vacuum and Mechanical systems

The outgassing measurement system is necessary to qualify stainless steel material that goes into the fabrication of LIGO-India beam tube. Small Coupons of steel cut from steel coil after air baking at 440 degree C. The expected outgassing rate of steel is < $1e^{-14}$ mbar $l/s/cm^2$. The outgassing measurement test facility has been setup in LIGO laboratory at IPR.

After successful factory acceptance testing, BSC and HAM 1:1 size prototype chambers (1 each) are delivered to RRCAT. This task has been accomplished with in delivery schedule despite COVID'19 pandemic. The final acceptance at RRCAT site after delivery is expected to be completed by mid of October in coordination with RRCAT colleagues.

The procurement for setting up LIGO-India – Vacuum Integrated System Test Assembly (LI-VISTA) facility has been initiated by LIGO-Division. Procurement tenders for supply of 20m Integrated Vacuum Vessel and 80K Cryo-pump assembly have been launched. Successful effort have been made to develop two prototype (scale 1:1) bellows of SS304L for LIGO India beam tube. This fabricated bellow is of nonconventional type in terms of thickness and size, fabricated by expanding mandrel forming process.

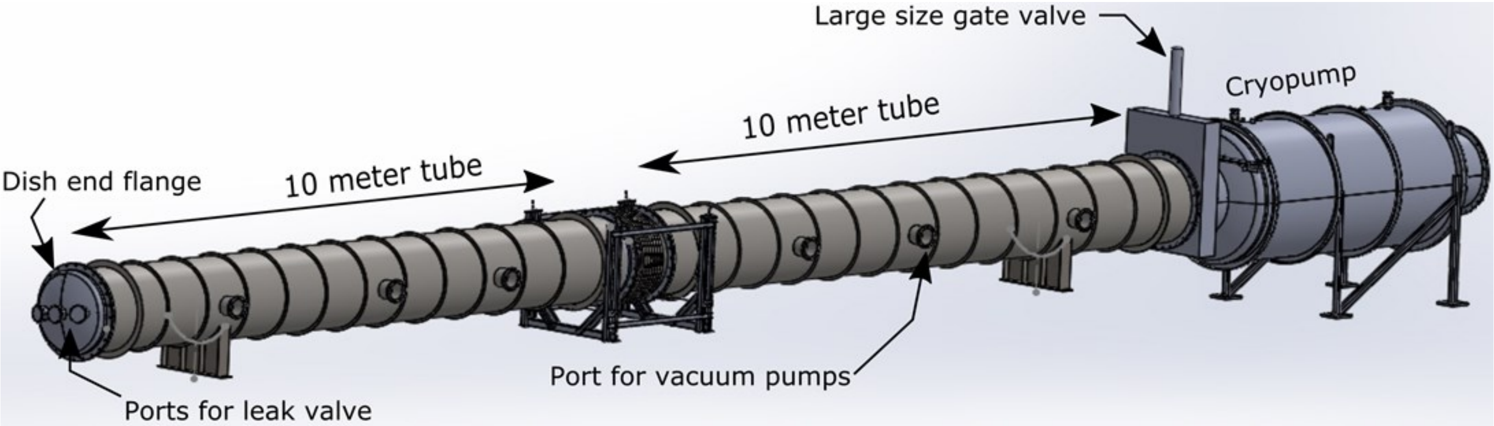
The space in New Laboratory building has been provided to setup LIGO-Laboratory where Outgassing measurement test setup, Baking Furnace. SOLIDWORKS based CAD facility, CDS/VCMS prototype test racks with computers/workstations have been established.

BSC and HAM (1:1) size prototype chambers (1 each) recently delivered at RRCAT

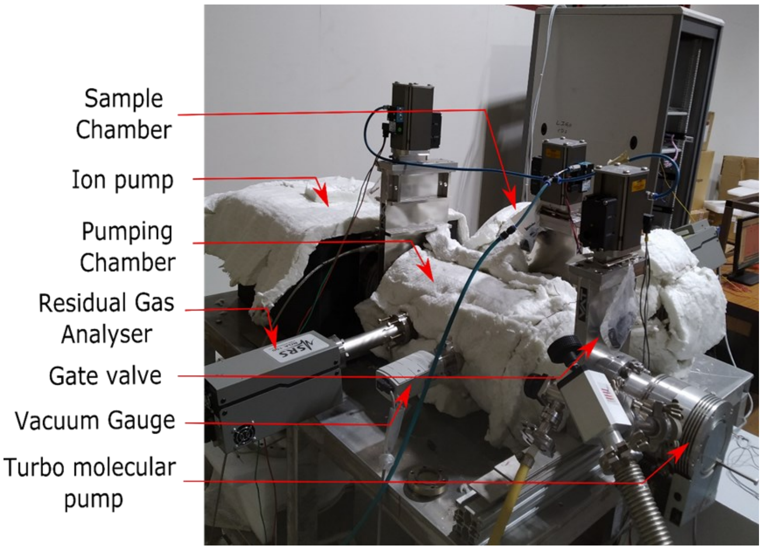
Activities of LIGO-India Division @ IPR

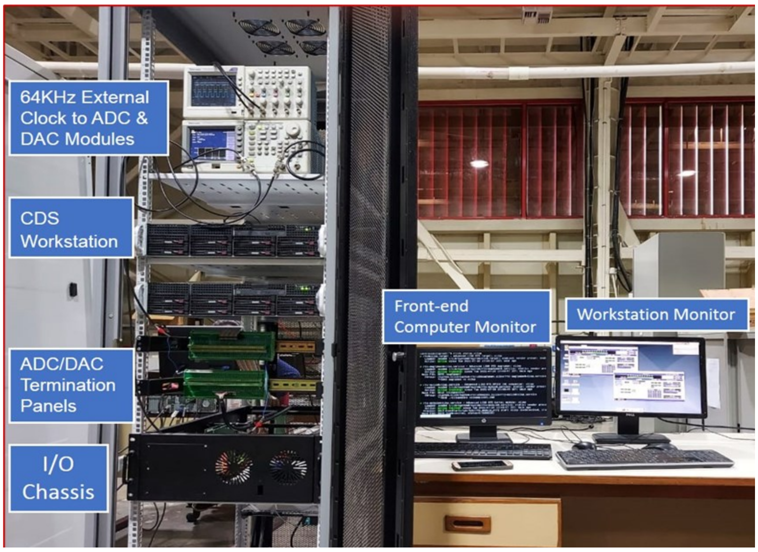
The LI-VISTA facility will be established after culmination of ongoing procurement tenders in delivery of the supplies.

The Vacuum System Requirement Design Document (VSRD) has been developed by IPR, reviewed and approved by LIGO-USA. The preparations for LIGO-India Vacuum System Final design review (FDR) by IPR has been initiated with the target to complete this by end of this financial year (2021-22).



Proposed LI-VISTA Test Facility at IPR (under procurement)



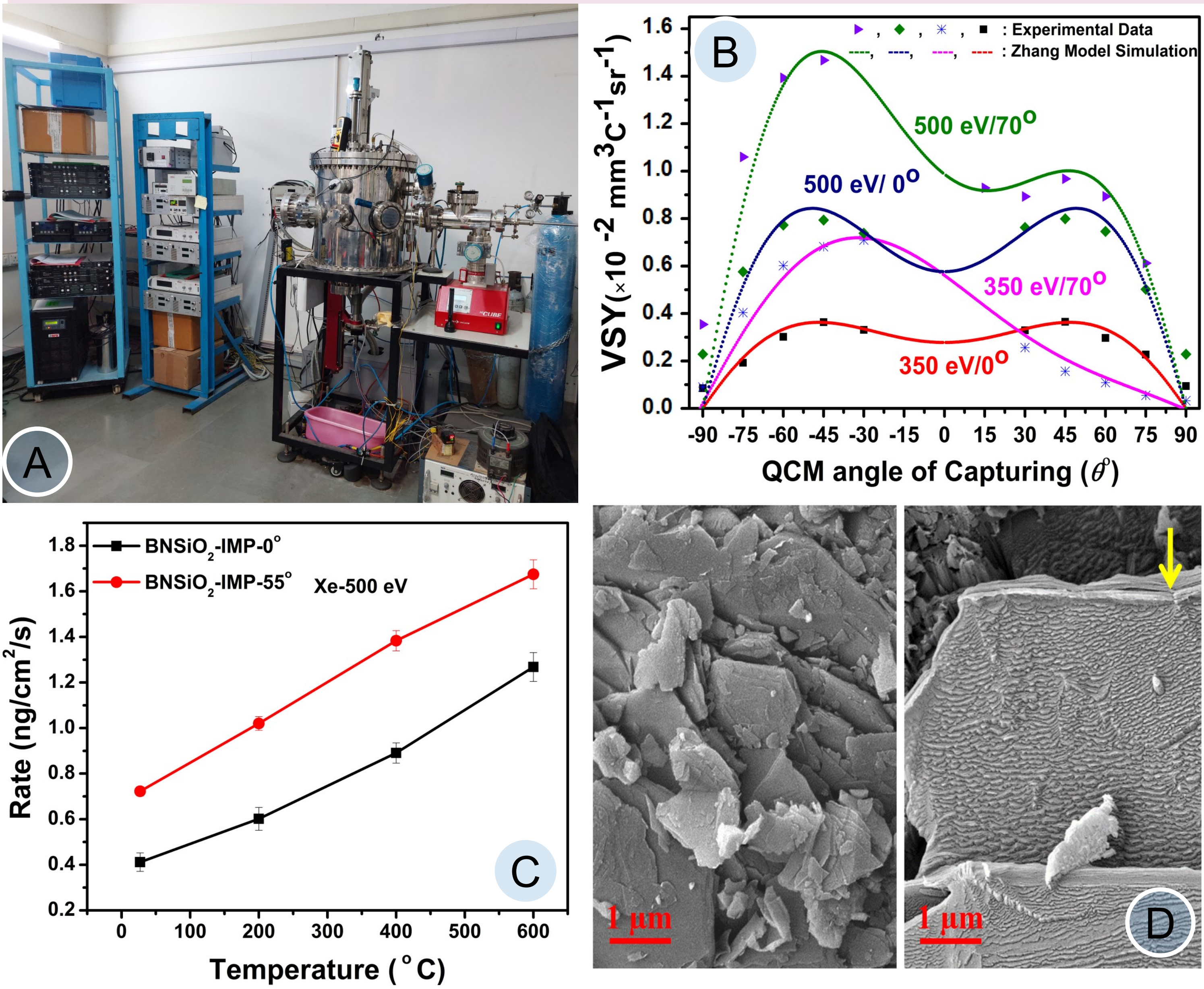


(L) Outgassing measurement system setup and (R) Preliminary CDS Test rack setup at the LIGO Lab at IPR

Members of LIGO Division, IPR. (L-R) Arnab Dasgupta, Hitesh Gulati, Vijay Bedakihale, Amit Srivastava, Atul Kumar, Naresh Chand Gupta, Rakesh Kumar, S. Sunil and Subroto Mukherjee)

Completion of VSSC/IPR MoU on Hall Thruster

Hall Effect Plasma Thrusters (HEPT) are under investigation as a technology aiming to achieve thrust with high exhaust velocities in satellites. In HEPT plasma forms in a narrow annular channel and interact with inner ceramic wall. Ejected ions can erode the ceramic at the ejection point edge. The eroded material may eventually deposit on the crucial parts of the satellite and degrade their efficiency most prone in this case are solar cells. Erosion can also expose the underlying magnetic yoke, causing the magnetic field profile to be altered and change HEPT functionality. Therefore, the investigation of thruster anode liner erosion and choice of material is very important for its long and stable operation. **PSED/IPR** group has recently completed a MoU with Vikram Sarabhai Space Centre (VSSC)/ISRO, Thiruvananthapuram. Under this MoU, a Low Energy Ion Beam facility was developed at FCIPT/IPR to investigate the erosion properties of the ceramic material developed by VSSC/ISRO to be used as Anode Liner Material in HEPT. *in-situ* experiments were performed to investigate the material erosion behavior at various energies, fluence at elevated temperature under this project. With joint efforts of IPR and VSSC, this material has been approved to be used in the indigenously developed HEPT for Indian Satellites. This project was carried out by a team consisting of Akshay Vaid, Basanta Parida, Vivek Pachichigar, Sooraj K. P. and Mukesh Ranjan.



(A) Low Energy Ion Beam Facility (B), Volumetric Sputtering Yield (VSY) profiles (C) Variations in Erosion rate with temperature (D) SEM images of sample before and after irradiation

Members of PSED (L-R) Sooraj K.P., Basanta Parida, Akshay Vaid ,Vivek Pachichigar and Mukesh Ranjan

Activities of Plasma Surface Engineering Division @ IPR

Plasma Surface Engineering Division (PSED) is involved in developing several plasma based technologies using different plasma sources for societal applications. Surface activation by plasma on different material surfaces has also enabled this division to work for strategic applications.

Strategic Applications:

Spacecraft Plasma Interaction eXperiment (SPIX) facility: For the ground testing of arcing on satellite solar panels surface under simulated Low Earth Orbit (LEO) and Geosynchronous Equatorial Orbit (GEO) like space environmental conditions, an automated Spacecraft Plasma Interaction eXperiment (SPIX) facility has been designed and developed indigenously under the MOU with U R Rao Satellite Centre (URSC), ISRO. Based upon a series of experiments conducted in this facility, new arc mitigation techniques have been proposed to ISRO that would be helpful in designing high power satellite for the future space missions.

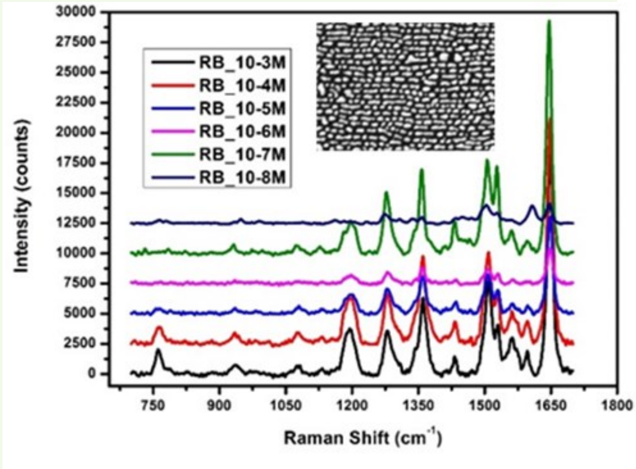
Low Energy Ion Beam facility : A Low Energy Ion Beam facility was developed under the MOU, with VSSC, ISRO to investigate the erosion properties of the ceramic material developed by VSSC/ISRO to be used as anode liner material in Hall Effect Plasma Thrusters (HEPT). This facility can also be used for surface nano patterning of various materials. With joint efforts of IPR and VSSC, the developed material is now approved to be used in the indigenously developed HEPT for Indian Satellites.

Spacecraft Plasma Interaction eXperiment (SPIX) facility

Societal Applications:

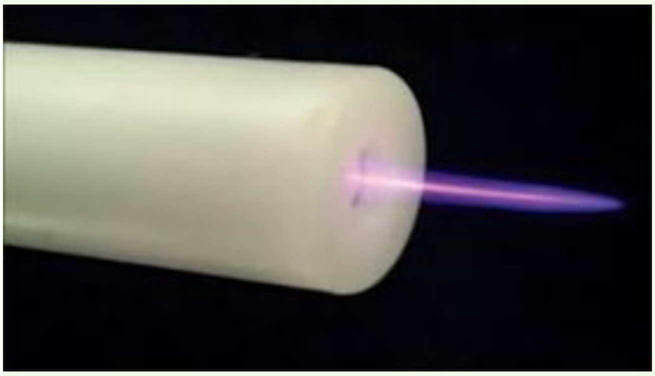
SERS Applications : Surface Enhanced Raman Scattering (SERS) spectroscopy is a powerful method for detecting various molecules with the help of nanoparticles. In our approach nanoparticle arrays are grown on ion beam produced patterned substrates for SERS based detection. With this process we have shown detection of hazardous pesticides, dyes in spices, glucose from blood, and detection of various biomolecules.

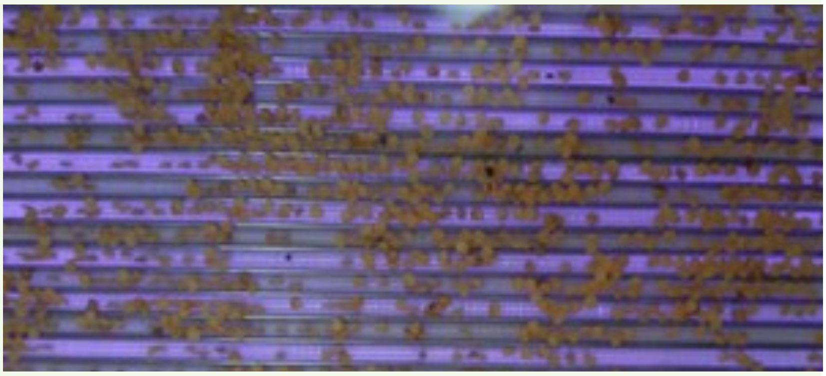
Atmospheric Pressure Plasma Jet (APPJ) : Atmospheric Pressure Plasma Jets have been developed for various bio-medical applications. These jets are given to AIIMS, New Delhi, ACTREC, TMC, Mumbai, and BARC, Mumbai to study the interaction with brain tumor, oral cancer, and lung cancer cells respectively. The results show an increased ROS concentration by about 50% after the plasma treatment on brain tumor tissues, while the cell viability is found to be around 80% in the case of lung cancer cells. At ACTREC, after studying the cell viability on oral cancer cell lines in vitro, the experiments are also conducted on animal models and it is found that after the treatment the tumor volume goes down.



SERS spectra of Rhodamine B dye used in chilli powder with detection levels up to 10^{-8} M.

Non thermal plasma for treatment of seeds : Plasma treatment of seeds is a physico-chemical method which has potential to improve germination yields and kill fungal spores carried on seed coats. A dielectric barrier discharge (DBD) based atmospheric pressure plasma system has been developed to improve germination. This system does not require costly vacuum pumps as well as very high frequency power supplies for plasma generation. The plasma treated (3 min.) capsicum seeds showed around 30-40 % improvement in germination percentage.





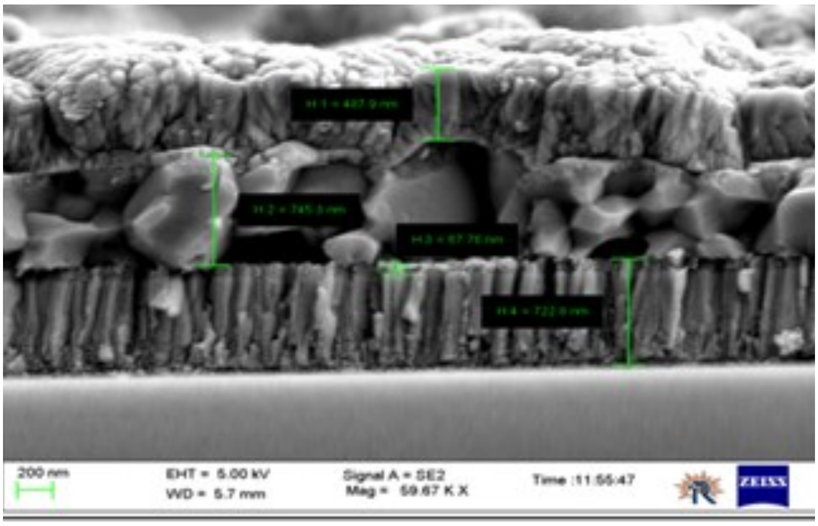
(L) APPJ developed for biomedical applications (R) Plasma treatment of Capsicum seeds

Multi magnetron sputtering facility to develop cheap solar cell : Copper Zinc Tin Sulfide (Cu2ZnSnS4, i.e., CZTS) is one of the promising materials as an absorber layer in thin film solar cells because of its excellent material properties. It has a direct band gap of 1.45eV, and has a high absorption coefficient (104 cm-1). An indigenous user friendly and low cost technology for solar photovoltaic applications is being under development using magnetron sputter deposition process. Magnetron sputtering process is chosen for this purpose as it is a well proven technology in industry for large area coatings for different application including solar cell applications (for CdTe and CIGS). So far, ~5% efficiency of the solar cell has been achieved and further improvement is under research.

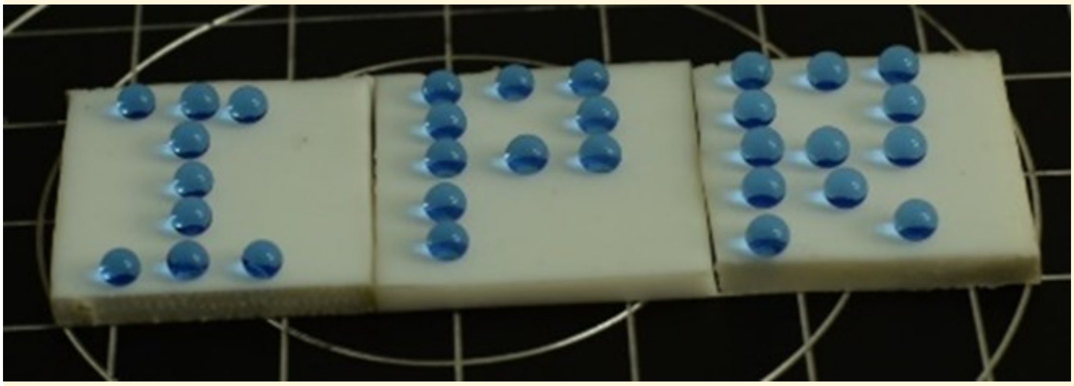
Activities of Plasma Surface Engineering Division @ IPR

Plasma Nitriding facility : Plasma nitriding, a surface hardening process is carried out using a gas mixture of nitrogen and hydrogen gas at sub atmospheric pressures hence, making it eco-friendly in nature. A glow discharge is generated around the parts during plasma nitriding which allows modification of the surface layers and hardness profiles by changing the gas mixture and temperature. The wide applicable temperature range enables a multitude of applications, beyond the possibilities of gas or salt bath processes.

This has led to numerous applications of this process in industries such as the manufacture of machine parts for plastics and food processing, packaging and tooling, as well as pumps and hydraulic machine parts, crankshafts, rolls and heavy gears, motor and car construction, cold and hot working dies and cutting tools. Plasma nitriding facility is developed for demonstration to industries and is available to them for job working on chargeable basis.



(L) Cross section image of a solar cell device (R) Material immersed in plasma during plasma nitriding process



Water droplets resting on a super hydrophobic Teflon sheet

A process to generate large area super-hydrophobic teflon surface using plasma treatment has recently been developed in this division. In this process the energetic ions inside the plasma bombards on the surface and creates micro/nano structures. As a result the surface becomes super hydrophobic. The contact angle measured on the surface was around 155°.

Group members of the Plasma Surface Engineering Division

Indigenously Developed 80 K Sorption Cryopump For SST-1

Cryopump developed at Institute for Plasma Research, Bhat, Gandhinagar finds its applications in Fusion and Space Research Programme of the country. A liquid nitrogen cooled sorption cryopump having 500 mm opening is developed to pump the gases evolved from the vacuum vessel of SST-1 during its baking cycle. To attain a vacuum of the order of 10^{-8} mbar in the vacuum vessel, the Plasma-Facing Components (PFCs) are baked to a temperature of 250° C and the vacuum vessel is baked to a temperature of 150° C to remove impurities present inside the system. Therefore, the gases to be pumped are hot and mainly comprises of water vapour. According to the requirement of SST-1, the pump is conceptualized, designed and fabricated. This pump contains an LN_2 bath for maintaining the level of LN_2 providing the efficient cooling to the array of the charcoal coated panels during operation. The pump is tested as per the AVS method for the pumping speed of water vapour with a dosing rate of 2.66×10^{-2} mbar.l/s maintaining vacuum level of ~1×10^{-6} mbar. The measured pumping speed was ~ 26000 l/s and tested for the gas dosing capacity of 560 mbar.l for 6 hours with no variation in vacuum level. The dosing time to reach saturation was a few days. This pump is capable to operate for 18 hours without refilling of the bath. During the baking process, the system can be operated for upto 6 hours under a high heat load condition (300 W). To create the baking conditions of the SST-1 vessel, four heaters are mounted on the black painted (emissive: 0.92) copper plate inside the dome to collectively heat up the plate upto150° C. Pumping test for nitrogen gas is also performed and pumping speed is found to be ~ 3300 l/s and tested for the dosing capacity of 1120 mbar.l. For the dosing of 1×10^{-3} mbar.l/s, this system can pump water vapour for 6.5 days and nitrogen gas for 13 days without regeneration as per the capacity tests performed at Cryopump lab, IPR. The pump is ready for the installation on the SST-1 machine.

Team members of Cryopump Division, SST-1 Vacuum and Cryogenics Division along with the developed cryopump

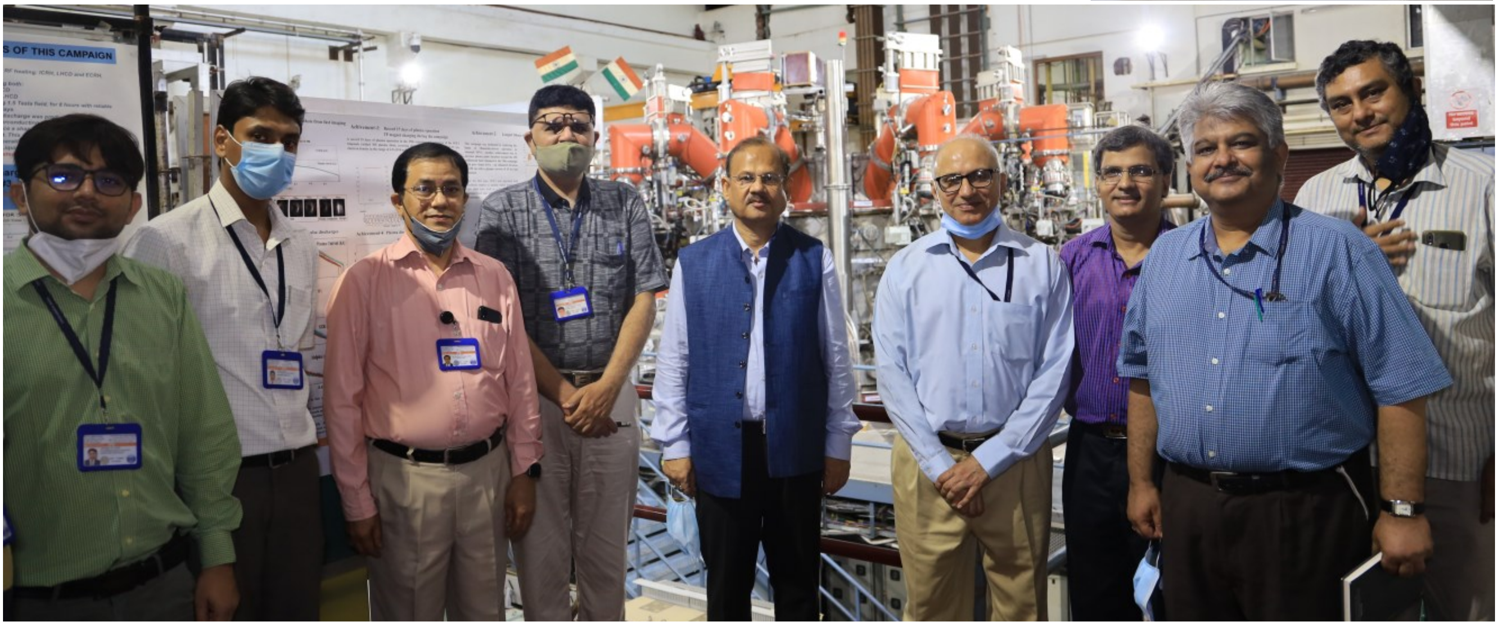
Activities Of The Fusion Interdisciplinary Science Division (FISD)

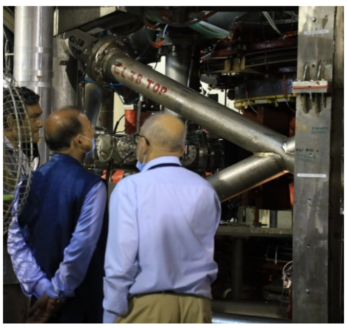
Fusion research has inherently an interdisciplinary character as several diverse areas like, physics of plasmas, fusion nuclear science, material science, engineering, systems analysis and control, and technologies like handling extreme heat loads, RF, NBI, superconducting magnets, cryogenics, tritium-breeding, radwaste management and power extraction/conversion. At present FISD has 6 members (including 1 Post-doc and 2 Ph.D. students). FISD activities include: (a) systems code development for compact fusion reactors, (b) irradiation experiments on tungsten materials and their modeling for better understanding of role of tungsten in fusion reactors, (c) Creation of better models for ICRH antenna-plasma coupling, (d) simulation of tokamak plasma dynamics to understand the ongoing experiments, (e) simulation studies on tokamak reactor heat-extraction and power conversion and (f) applying insights from tokamak plasmas to astrophysical situations (thermonuclear fusion bursts in accreting neutron star atmospheres).

Members of the FISD group (L-R) A. Chattopadhyay, P. N. Maya, S. Deshpande, Richa B., Anoop Singh, Piyush Prajapati

Visit of Member Finance, DAE to IPR

Shri Talleen Kumar, IAS, Member Finance, DAE visited IPR on 29-Sept, 2021. He had discussions with Director and senior faculty members of IPR and also visited some of the laboratories in IPR main campus.

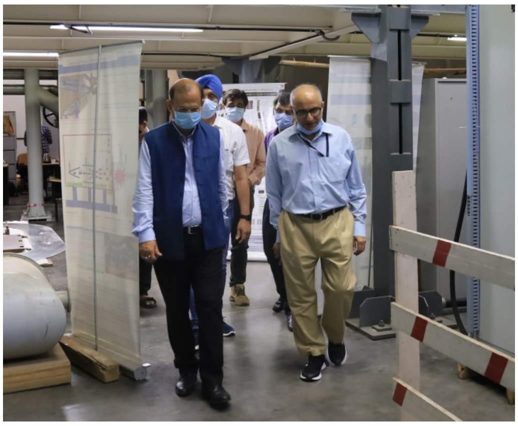
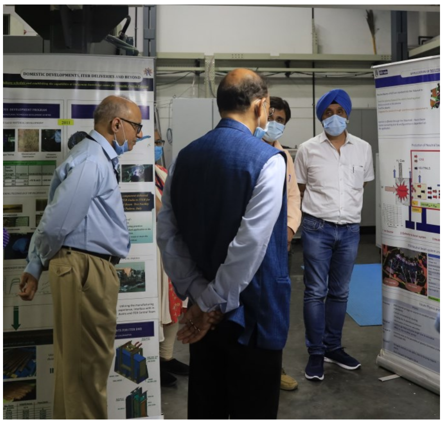
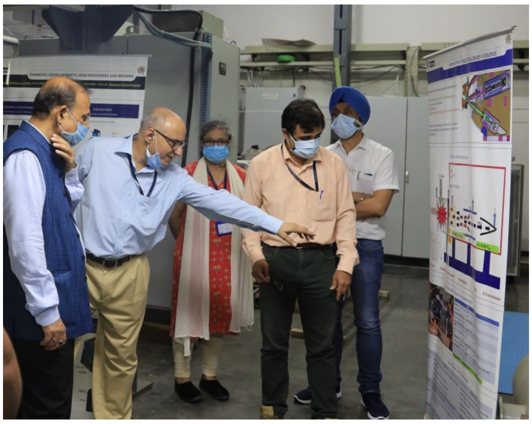




Visit of Member Finance (DAE) to IPR

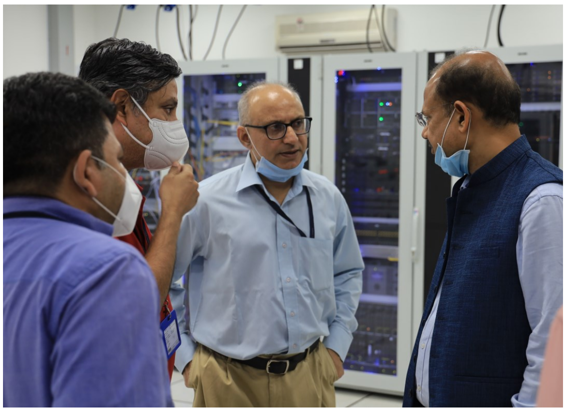
Visit of Member Finance, DAE to IPR







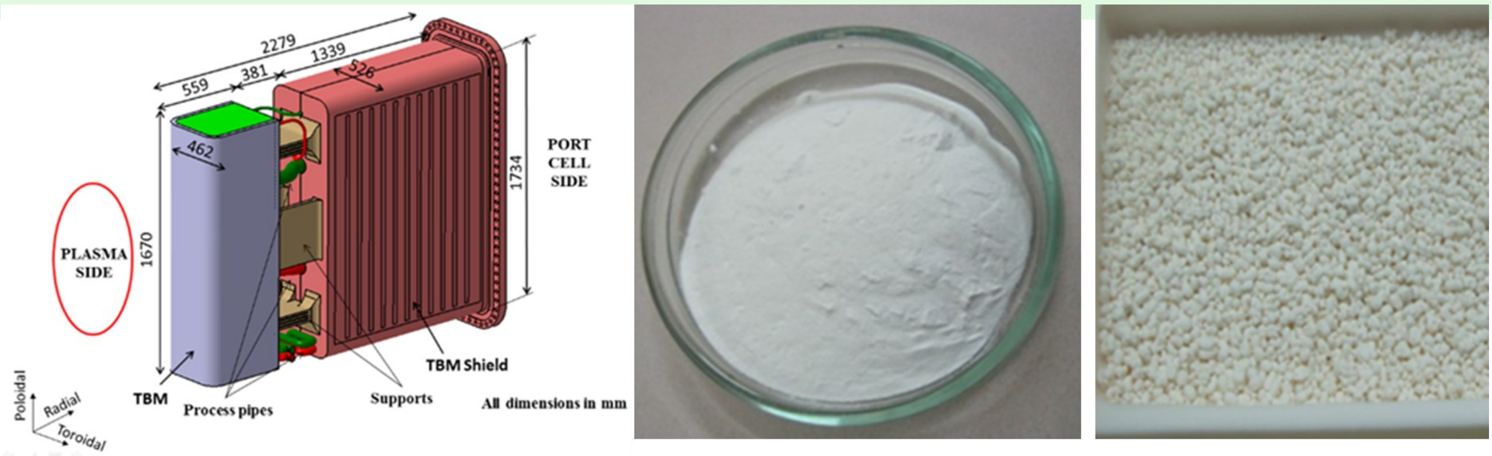


Visit of Member Finance (DAE) to IPR

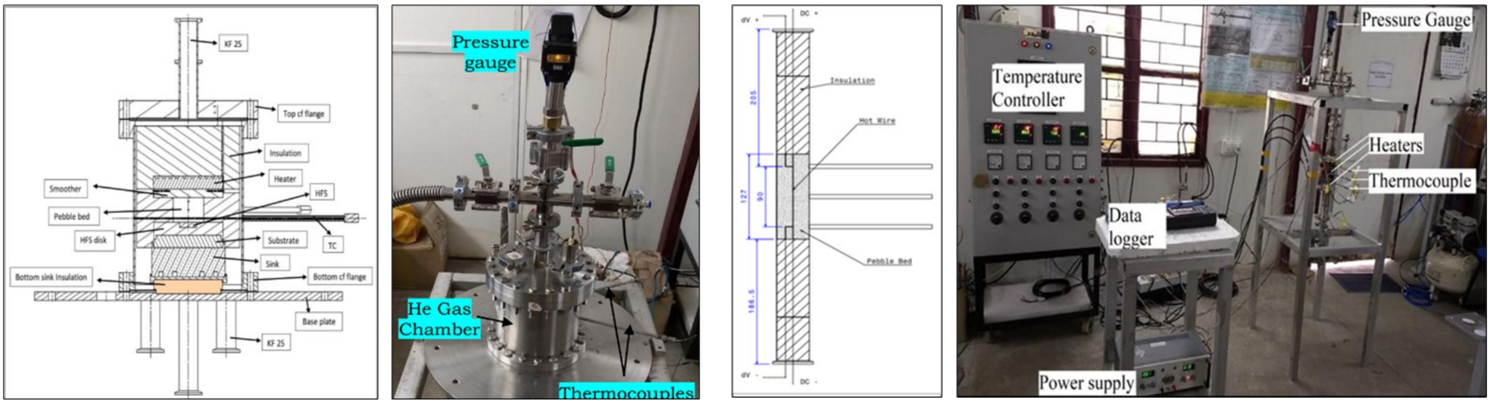
Activities Under Breeding Blanket for Fusion Reactor @ IPR

IPR has been involved in the design and development of Indian Test Blanket Module (TBM) for ITER and future fusion reactors. It has successfully completed the Conceptual Design Review (CDR) for Lead Lithium cooled Ceramic Breeder (LLCB) TBM in September 2015. The TBM structure, being subjected to various load combinations like high temperature and high pressure loads, electromagnetic loads during plasma disruption, and seismic loading conditions, has to demonstrate the structural integrity by carrying out detailed thermal-hydraulic and thermo-mechanical analysis.

Lithium ceramic is used as the tritium breeder material in fusion reactor. India has developed and prepared Li2TiO3 by solid state reaction using LiCO3 and TiO2 followed by ball-milling and calcination. From this powder, small pebbles of size ~1 mm are made by Extrusion and Spheronization method. At every stage of preparation, powder and pebbles are extensive characterized to meet the desired properties. These pebbles were also characterized under the Round Robin test performed independently several times in different ITER partner's lab (Germany, Japan, China, Korea) and met the required parameters.



(L) The LLCB TBM set (R) Li_2TiO_3 powder and pebble prepared at IPR



Schematic and experimental setup for (L) The measurement of effective thermal conductivity of Li_2TiO_3 pebble bed using Steady State Axial Heat Transfer method (R) The measurement of effective thermal conductivity of Li2TiO3 pebble bed using transient hot wire method

The group members of the Blanket Material Section

Activities of the Data Acquisition & Control Division

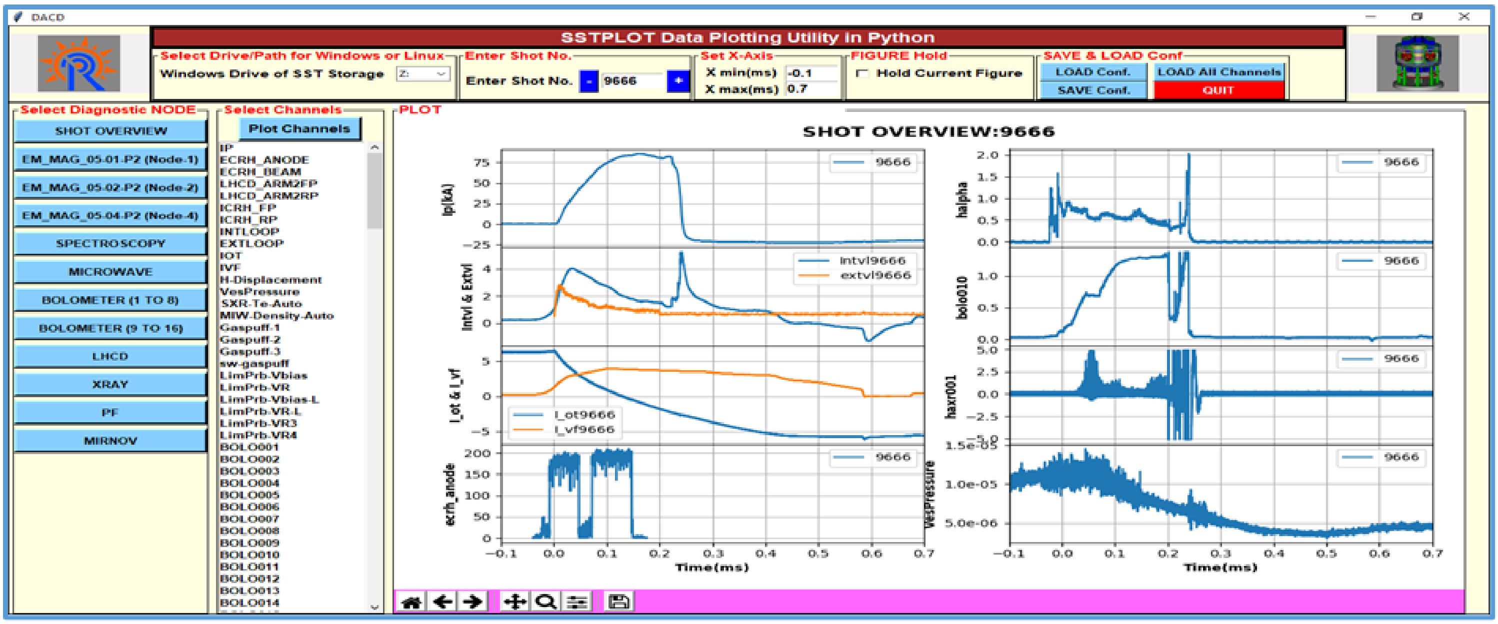
DAC Division comprises together a bunch of diversified & experienced engineers that are motivated towards in fulfilling the very motif of in-house implementing & supporting the Data Acquisition & Control Systems & Application Software solutions developments for various projects at the institute.

Members of the DAC division (L-R) Imran Mansuri, Vishnu Patel, Srinivas Rao, Atish Sharma, Kirti Mahajan, Manisha Bhandarkar, Priyadarshini Gaddam, Hitesh Chudasama, Jignesh Patel and Harish Masand

A lot of activities have been taken up by the division towards fulfilling the requirements coming from various Scientific Projects like SST-1 & Aditya Tokamaks, Basic Plasma Physics Experiments, Neutron Generation Facility, Plasma Antenna, LSCP, EML etc. Apart from majorly doing the scientific activities, the division is also contributing in activities like establishing & maintaining the CCTV Security Systems for Campus Security, Body-Temperature Screening System at Entry Gates, developing Open Source OMR S/w for evaluating Exam Answers sheets, and in Project Management Activities etc.

License free open source software development in scientific projects: To reduce dependency on commercial third party software, various initiatives have been taken by the division to develop in house applications using license free open source software. Some of the major projects undertaken and delivered successfully are as follows. A Python based plotting & analysis software, SSTPLOT was developed for SST-1 data analysis purpose. Similarly MDSplus which is widely used in Fusion Community for data acquisition & managing complex scientific data purpose, has been deployed for nearly ~300 SST-1 channels which can be can be accessed & analysed remotely using jScope & Webscope tool.

Operation, Monitoring & Control of various scientific projects: Towards objective of contributing in operation, monitoring & control of various scientific projects at institute, the division has developed a Personal and Radiation Safety Interlock Control System (PRSICS) for Neutron Generator facility at IPR. The PRSICS is for protecting personal & environment from radiation hazards and assisting operators in ensuring a safe operation of "Accelerator based 14-MeV Neutron Generator (ANG)". The developed interlock system monitors all the safety devices and controls permission signals for each & every subsystem of ANG in accordance with the given safety interlocking constraints.
Also in co-operation with SST-1 cryogenics division, a web based monitoring system (Fig.-3) is developed for monitoring cryogenics plant system parameters from both SST-1 and IPR network. The designed HMI screens of the utility are at par with the commercial supplied screen. In addition to live data monitoring it serves as a historian.

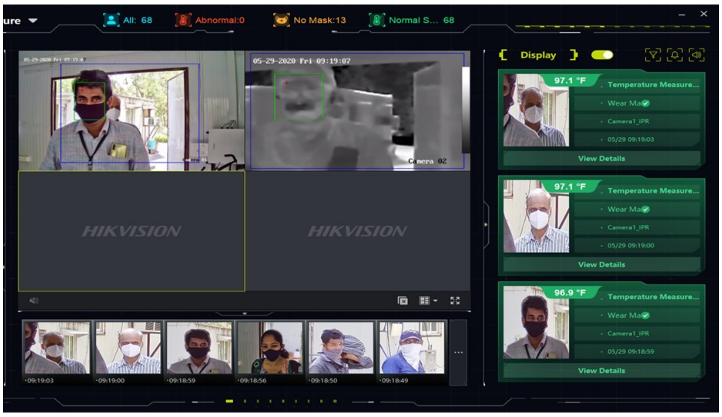


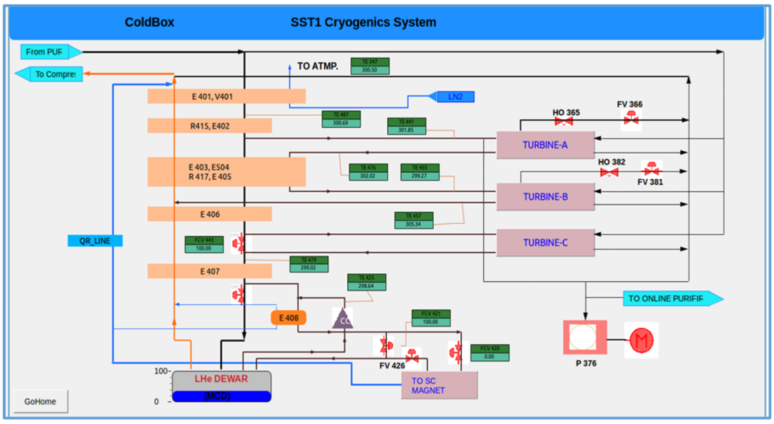
SSTPLOT, Open Source Software developed by DACD

Activities of the Data Acquisition & Control Division

Apart from several major and core software application developments as stated above, several other Data Acquisition & Analysis open source utilities are developed for various diagnostics divisions, few of them are for LaBr3(Ce) H-RAY Diagnostic, Ka-band Reflectometer & Michelson Interferometer (MI) Diagnostic etc.

DACD is also involved with RF Application division in automation of Plasma column experiments and DVB-T trans-reception system. Automation of Plasma column transmission/reception at varied frequency and power has been done using Labview.





(L) Temperature Screening System implemented at Access Control Room (R) SST-1 Cryogenics System HMI, based on Open Source Software

Dusty, Negative Ion and Low Temp Plasma Labs @CPP-IPR

The dusty plasma lab was the first high vacuum lab of CPP. The experimental facility consisted of three chambers, namely the dust evaporation chamber, the plasma chamber and a diagnostic unit. All were placed one above the other with multi-cusp magnetic confinement system and different diagnostics. The impressive part of the experimental setup was the fine collimated dust beam produced by maintaining a differential pressure between the dust and plasma chambers in a dynamical process. Plasma is produced in the system by a hot cathode discharge technique with two magnetic cages of different strengths. In 2007, this setup was used to prove a novel concept of production of negative hydrogen ions using caesium coated tungsten dust. Recent research outcomes are related to the development of a simple and efficient technique for production of two electron temperature plasma in a controlled fashion, dust charging and the effect of magnetic field in the propagation of ion-acoustic waves in two temperature electron plasma.

(L) Dusty plasma experimental system (R) Members of the Dusty, Negative ion and low temperature plasma labs

Negative Ion Laboratory : The experimental results on the production of negative hydrogen ions by surface assisted volume production mechanism in the dusty lab gave rise to the possibility that these ions could be extracted, and this could play an important role in fusion research and even for particle accelerator system. FTo explore these possibilities, the Negative Ion Lab was setup in 2013. The entire experimental system has been developed in a phased manner to enhance the production as well as the extraction process. The ion source is floated with respect to the extraction chamber with a potential difference of 30 kV DC. A grid assembly consisting of three numbers of grids, namely plasma grid, extraction grid, and acceleration grid with three numbers of extraction apertures has been designed and fabricated and installed into the extraction chamber. Two high voltage DC power supplies are specifically designed, fabricated and commissioned for extraction and acceleration of the negative ions. A Faraday cup has been designed and fabricated to measure the negative hydrogen ion beam current. A ~200 channels PXI based data acquisition and control system (with real time controller) with fibre optic link modules has been particularly designed and commissioned for the experiment. Proper algorithms have been developed for data acquisition, control and interlocks and implemented with Graphical User Interface in LabVIEW 2020.

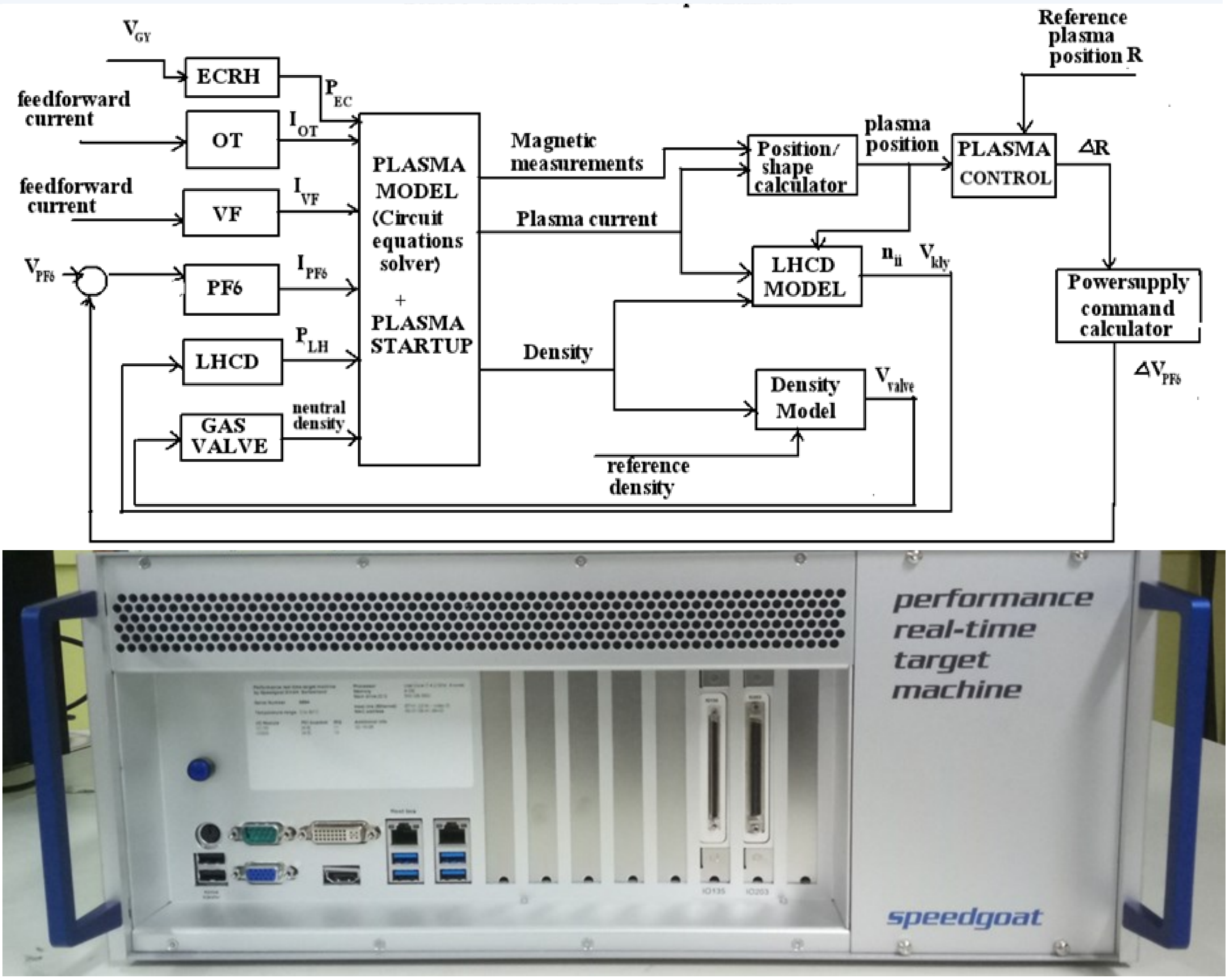
Dusty, Negative Ion and Low Temp Plasma Labs @CPP-IPR

Low Temperature Plasma Laboratory: Recently, a new lab is being setup with the aim of conducting R&D in the field of societal applications of plasma in food and agriculture.

(L) The negative hydrogen ion extraction system and HV power supplies (R) PXI based DAQ & control system

Hardware-In-Loop (HIL) Testing System FOR SST-1

Hardware-in-loop (HIL) system is widely used for designing the Control Systems. In SST-1 tokamak, we are planning to design Plasma control System (PCS) which would involve various subsystems providing the real-time control of plasma position, shape and density in a close loop. Requisite hardware has recently been procured and is under commissioning phase with SST-1 Operations Division.



(Top) Schematic (bottom) Hardware for the of the HIL testing system to be implemented on SST-1

Activities of ECRH Division

Electron Cyclotron Resonance Heating (ECRH) system helps tokamak for reliable plasma start-up, heating, current drive and instability control. The ECRH system consists of high power microwave source (Gyrotron), corrugated waveguide based transmission line and mirror based quasi-optical launcher. The Gyrotrons are high power microwave source capable to deliver megawatt level of continuous power at high frequencies varies from 28GHz to 170GHz.

The 42GHz-500kW ECRH system has shown remarkable achievements on the tokamaks SST-1, Aditya and Aditya-U. The Gyrotron delivers 500kW power at -50kV beam voltage, 20A beam current and +20kV anode voltage. This Gyrotron is installed on a cryomagnet which is cooled at liquid helium temperature while carrying out experiments on tokamaks.

(L) The 42GHz-500kW ECRH system (R) The ECRH system on Aditya-U

In SST-1, the 42GHz ECRH system has been emerged as an essential system for the tokamak start-up. This system has been used to carry out ECRH assisted plasma breakdown, start-up and current drive experiments at fundamental (1.5T magnetic field) and second harmonic (0.75T magnetic field). In order to carry out various experiments in SST-1, ECRH power is varied from 150kW to 300kW for 70 ms to 400ms duration. This power is launched around 10 ms before the loop voltage and successful plasma discharges are achieved with plasma current close to 100kA and plasma duration up to 0.65s.

The same 42GHz system has been commissioned on tokamak Aditya and later on Aditya-U by extending the transmission line from SST-1 to Aditya. Approximately 75 meter long transmission line is used to transmit power from the Gyrotron (in SST-1 hall) to Aditya tokamak. Several ECRH experiments on low loop voltage start-up and plasma heating have been carried out on tokamak Aditya and Aditya-U.

Members of the ECRH Division (L-R) Dharmesh Purohit, Hardik Mistry, Harshida Patel, Braj K Shukla, Jatin Patel and Kanubhai G Parmar

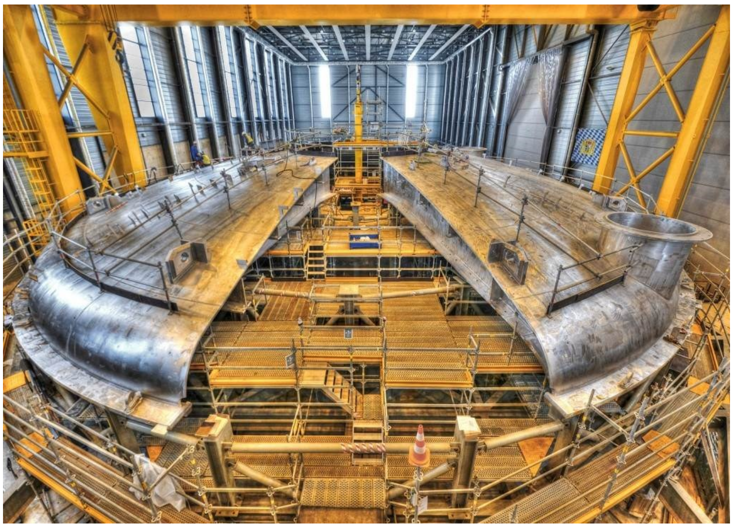
A Decade And A Half Of ITER India At ITER

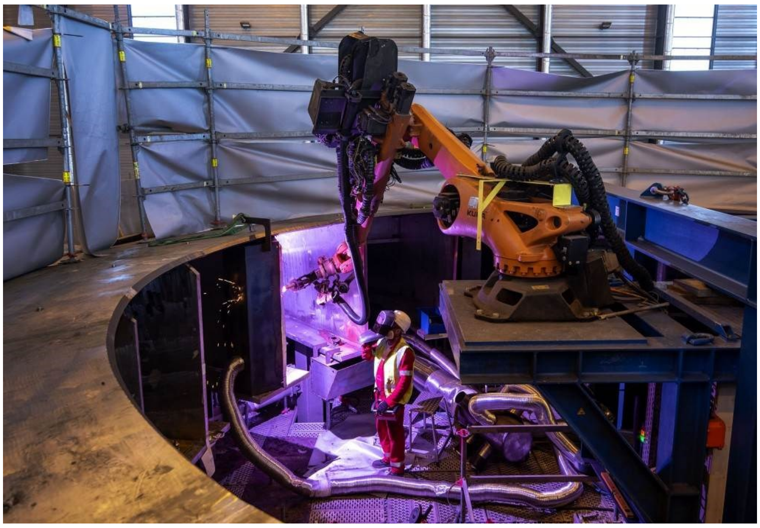
ITER is under construction in the south of France under a joint agreement of seven participating nations with India being a 9 % contributing partner like China, Japan, Korea, Russia, and United states and with the remaining ~50% contribution from European Union. Till date 75% of the construction activities have been completed as it marches steadily towards its goal of first plasma in the ITER machine by the end of 2025.

India's vision and goal of joining ITER has started to bear fruits with India completing nearly 100% of deliveries of 4 out of the 9 packages thereby supporting ITER towards maintaining its first plasma goal. These important contributions relate to the outer shell of the ITER machine called the cryostat, the cooling water system, the Cryolines and cryo-distribution system and the in-wall shield blocks.

The cryostat is a 30 m tall 30 m diameter large thermos and the biggest vacuum vessel ever built to shield the super conducting magnets and the machine, the cooling water system removes about 500 MW of heat load from the various machine components during operation, the Cryolines and cryo-distribution system is the interface between the cryo-distribution plant and the super conducting magnets and other auxiliaries like the cryopumps to transport croygens and cool to the components to sub-zero temperatures and the in-wall shields sandwiched between the walls of the double walled vacuum vessel act as neutron absorbers.

The ITER – India team



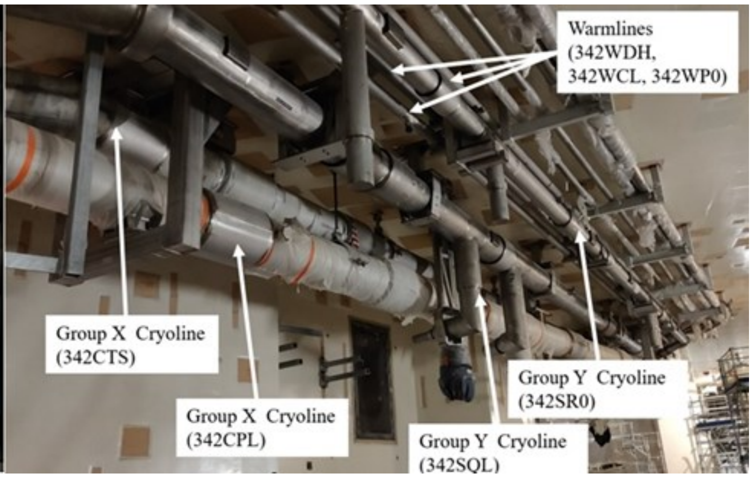


Left to right: Top lid segments of the cryostat top lid under assembly at ITER-India cryostat workshop in ITER prior to welding. Welding of the segments underway with a robotic arm

A Decade And A Half Of ITER India At ITER

All the above components have been manufactured in the premises of Indian industries and their sub- contractors. During the process many prototypes had to be built to establish the first of kind components with special demands on materials, machining, welding and testing requirements to adhere to the strict French quality standards of the a nuclear establishment. This year was also marked by the first and the heaviest component of the ITER machine, the cryostat base being installed in the tokamak pit followed by the lower section. Several kilometers of the cooling water pipeline and the cryoline have been installed at ITER and the in-wall shield blocks are uninstallation in the vacuum vessel sectors in Korea and the European Union. By effecting these deliveries India stands tall and proud on an international platform and at the same time marches steadily towards acquiring self-reliance in the area of nuclear technology development for future fusion devices. It has also been the platform for Indian industries to showcase their capabilities and participate in contract bids globally.


(L) In-wall shield blocks supplied by India under installation in the vacuum vessel sectors in Korea

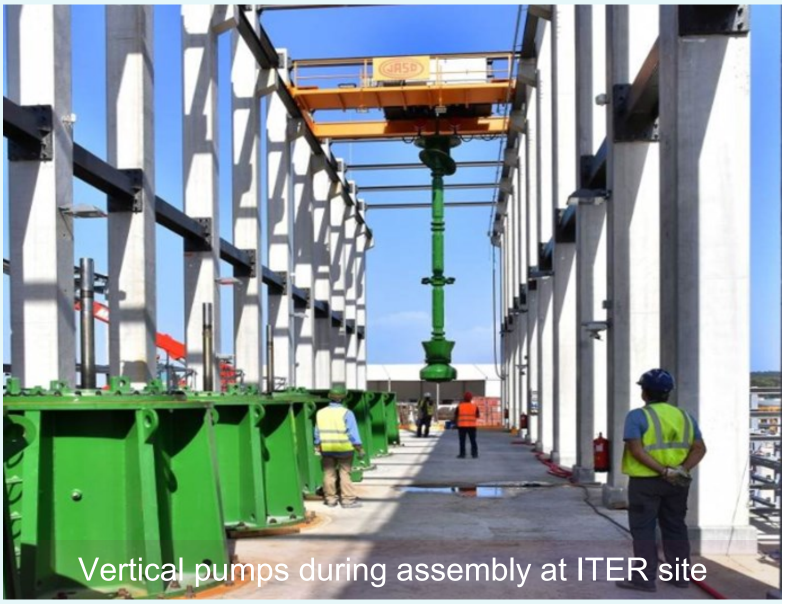



Cryolines with multi feed pipes supplied by India under installation at the ITER site

Cooling plant installation nearing completion at ITER site with all components supplied by India

India's contribution to ITER Cooling Water System

The heat generated in the ITER Tokamak along with the heat generated by auxiliary heating systems and supporting systems amounting to ~ 1150 MW will be transferred to the atmosphere with the help of Cooling Water System (CWS), which consists of sub-systems namely Tokamak Cooling Water System (TCWS), Component Cooling Water System (CCWS), Chilled Water System (CHWS) and Heat Rejection System (HRS). Among these sub-systems, the supply of CCWS, CHWS and HRS is part of India's in-kind contribution to ITER project. ITER organization provided the concept along with functional specifications and ITER-India had then carried forward and developed preliminary design and final design & engineering. Subsequent to the completion of design by successfully clearing final design reviews, ITER-India accomplished procurement, manufacturing, testing of equipment and components and delivered them at ITER site, Cadarache (France).



Vertical pumps during assembly at ITER site

The common optimized design considering key requirements of pulse operation, different operational scenarios, flexible operational provisions, etc. posed challenges during design, apart from the challenging design requirements of buried process pipe qualification and severe meteorological design conditions. In the process of developing the executable piping design, ITER-India had to introduce innovative pipe-in-pipe concept to qualify hot water buried piping against excessive thermal stresses at the joints. The unique 'hot basin – cold basin concept' using precise dynamic thermal management with the help of variable frequency drives led to optimized utilization of cooling tower which led to huge saving in the cost of equipment as the capacity of cooling tower was reduced to 510 MW from 1150 MW. Being interface-sensitive and also due to the constraints imposed by concurrent engineering of other stakeholders, the realization of a viable engineering solution was a demanding task.

Installed cooling tower at ITER site

The key equipment delivered by ITER-India includes cooling tower of 510 MW heat rejection capacity constructed of FRP structures with dimensions 80m (L) X 32m (W) X 20 m (H), plate type heat exchangers of capacity upto 70 MW each, water cooled chillers of 1200 TR each, pumps with flow rates upto 1.87 tonnes/sec each, electrical motors upto 1.4 MW capacity each, soft starters of 6.6 kV/ 800 kW capacity each, variable frequency drives of 6.6 kV/ 750 kW capacity each, E-house of size 21m (L) X 7m (W) X 4m (H), piping of ~16.5 km length with sizes upto 2m diameter - supplied as fabricated ~4500 spools involving one lakh inch-dia welding, 900 MT of piping supports, ozonators, 1400 nos. valves (different types and sizes), cables of ~61 km length, water polishing units, various instruments, stop log gates, bellows, pressurizers, panels, heat tracing components, etc.

As the piping fabrication complying to ITER requirements took considerably longer duration than envisaged, multiple parallel fabrication setups were established to meet ITER construction schedule. Since the scope of ITER-India is limited to 'only supply', stringent quality norms and close tolerances were implemented to have seamless site integration. The quality aspects were extensively managed with the investment of over 1,20,000 inspection man-hrs. All the equipment and piping were seismically designed and manufactured/fabricated complying to applicable European Directives and Notified Bodies were involved, where required. ITER-India has successfully completed the delivery of all the equipment and components in May 2021. Most of the equipment have been installed and pre-commissioning activities are underway at ITER Site by the contractors hired by ITER.

MCCs under energization

The core team successfully executed the task include Aditya Prakash Singh, Ajith kumar, Dinesh Gupta, Gumansinh Gohil, Hiren Patel, Jinendra Dangi, Lalit Sharma, Mahesh Jadhav, Mohit Kumar, Nirav Patel and Rakesh Ranjan, with the continuous and appropriate supports from Arun Chakraborty, Ujjwal Baruah and Shishir Deshpande.

Activities of the Vacuum Engineering Services Division

Vacuum Engineering Services Division (VESD) is responsible for the operation and maintenance of vacuum systems for tokamaks, design and analysis of vacuum systems for IPR, FCIPT and ITER-India projects, qualification of materials to be used in ultrahigh vacuum systems, calibration of vacuum gauges and helium leak detection for IPR experiments, procurement of high value vacuum related items and annual maintenance of major vacuum equipment in IPR.

Major achievements of the division has been obtaining desired vacuum parameters in the SST-1 vacuum vessel and cryostat chambers after several iterations of leak detection, repairs and long duration pumping and wall conditioning procedures, measurement of outgassing rates of a large number of samples of different materials including the testing of recently approved Boron carbide to be used in ITER as a high energy shielding material, testing and calibration of a large number of vacuum gauges, commissioning of vacuum systems of several experimental set ups in IPR, designing of vacuum systems for IPR experiments and procurement of vacuum equipment for different divisions of IPR. Following facilities have been developed by the division:

- Measurement of outgassing rates of samples by throughput method.
- Calibration of vacuum gauges by comparison with a spinning rotor gauge.
- Facility to weld copper and aluminium wires.
- Facility to spot weld wires and sheets of tungsten, molybdenum, SS and Copper.
- Hot bath to calibrate thermocouples and RTDs.
- Vacuum packing system to seal materials up to 1 cubic feet in rough vacuum.

These facilities are routinely being used to help different experimental groups of IPR, ITER- India and FCIPT to achieve their desired vacuum parameters.

Members of the VESD team (Front L-R): Gattu Ramesh Babu, D.C. Raval, Kalpesh Dhanani, Pratibha Jakhmola, Prashant Thankey, Arun Prakash (Back L-R) Firozkhan S. Pathan and Siju George

Top Four Reviewers (for IPR Internal Publications)

We are happy to recognize the efforts of the reviewers of our internal publications (RR/TR). The following are the Top four reviewers of internal publications based on the number of publications reviewed in the last three years (2018-21)

Congratulations!!

Dr. Paritosh Chaudhuri
Reviewed 23 publications

Dr. Mainak Bandyopadhyay
Reviewed 20 publications

Dr. Sivakumaran V.
Reviewed 13 publications

Dr. C. Balasubramanian
Reviewed 11 publications


2005


2021

The Rising Sun !

The Sun is rising;
Not at east nor to set at west,
From the lap of the earth,
From mother earth its rising!

And that sans songs of singing birds to greet,
Sans bouquets of blooming flowers to cheer,
Neither there the dews to shine in rays as diamonds,
Nor there the soft sweet cool breeze of Dawn!
(To lull the men, to deprive them of the scene of dawn!)

Just soft mummers as in honor;
But there the clangs and claps of metal,
The humming lathes and the beeping Vax,
Eyes glued on gauges and terminals,
And the minds that work out the pluses and minuses
(To Sort out the haves and have-nots, the wills and wonts !)

All buzzing like bees and excited as ants
For there it comes, the Aditya !
To fulfill their dreams;
The dreams they pinned on the days it would make!!

K . K. Mohandas , July 1987
(When Aditya, for the first time, started rising from its pit, part by part

चाँद को क्या मालूम, चाहता है उसे कोई चकोर

चाँद को क्या मालूम, चाहता है उसे कोई चकोर
आज भले ही रात हुई है, कभी तो होगी भोर
चाँद को क्या मालूम.......

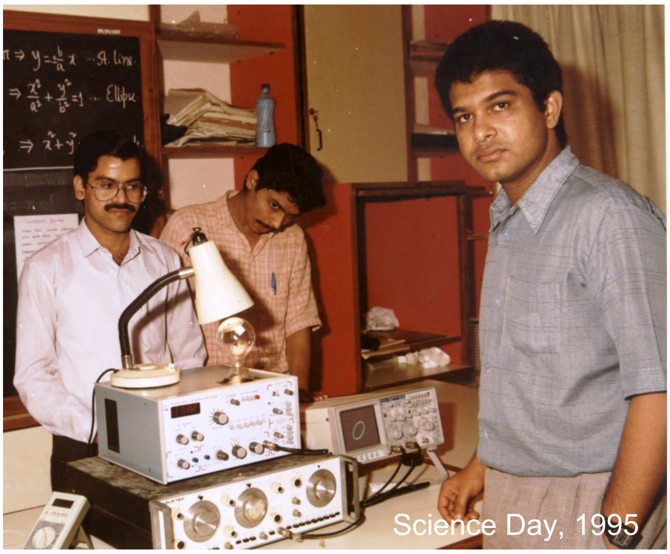
निकट तुम्हारे पहुच गये थे, आलिंगन बस बाकी था
इस पल देखो अपना मिलना, किस्मत को मंजूर नहीं था
मायूसी आज भले ही है, पर दिल में है एक शोर
चाँद को क्या मालूम.......

तुमसे खुद को टकरा के, अरमान सभी को जता दिये
यह परिचय है इस विक्रम का, सैलाब सभी को दिखा दिये
ऐ चाँद तेरे हम आशिक हैं, तू है मेरा चितचोर
चाँद को क्या मालूम.......

तू चाँद कभी है पूनम का, तो कभी अमावस आती है
पूरी होती है बात कभी, कभी आधी ही रह जाती है
कभी वेदना मिलती है, जो देती है झकझोर
चाँद को क्या मालूम.......

अनुरागी हैं हठधर्मी हैं, तेरे दिल पे दस्तक फिर देंगें
एक तूफां हमने पाला है, तेरे दर पे आके दम लेंगें
दीदार करेंगे हम तेरा, सौरभ होगा चहुंओर
चाँद को क्या मालूम.......

(चन्द्रयान की आंशिक सफलता के दिन लिखित कविता - मेरे इसरो के साथियों को समर्पित)
डा. ब्रज किशोर शुक्ला


Science Day, 1995


Annual Day, 1997

सी.सी.टी.वी. कैमरा आधारित निगरानी प्रणाली की कमीशनिंग

संस्थान में सुरक्षा एवं संरक्षा सुनिश्चित करने के लिए हाल ही में लगभग 120 आई. पी. कैमरों के साथ एक सी.सी.टी.वी. कैमरा आधारित वीडियो निगरानी प्रणाली को स्थापित कर सुचारु रूप से चालू किया गया है। चौबीसों घंटे निरंतर परिसर के विभिन्न इन-डोर और आउट-डोर स्थानों की निगरानी के लिए इस प्रणाली मे फुल एच-डी कैमरों की किस्में जैसे वैरि-फोकल बुलेट, डोम और उच्च रिज़ॉल्यूशन एवंम लंबी दूरी के पैन-टिल्ट-ज़ूम (पी.टी.जेड) आदि कैमरे लगाए गए हैं।

परिधि-सीमा और मेन गेट-एंट्री क्षेत्रों को विस्तृत फोकस रेंज वाले विशेष बुलेट कैमरों का उपयोग करके इस तरह स्थापित किया गया है कि विस्तृत और दूर की छवियों को स्पष्ट रूप से कवर किया जा सके। साथ-ही-साथ इन सभी कैमरों पर उपलब्ध इंफ्रारेड रेड तकनीक को प्रयोग मे लाकर, कम रोशनी या रात की स्थिति में भी छवियों की स्पष्टता को दिन के उजाले की स्थिति के समान ही देखा या रेकॉर्ड किया जा सकता है। कैमरे पर उपलब्ध ट्रिपवायर एज एनालिटिक्स (Tripwire Edge Analytics) फीचर को कॉन्फ़िगर किया गया है इस तकनीक के द्वारा संस्थान की चार दिवारी पर किसी भी घुसपैठ का पता चलने पर कंट्रोल रूम मे बैठे ऑपरेटर को अलार्म के द्वारा अलर्ट किया जा सकता है।

संस्थान की परिधि (चार-दिवारी) और उसके आस-पास के स्थानों को कवर करने के लिए परिसर के चारों-ओर लगभग 03 किलो-मीटर लंबाई का भूमिगत मल्टीकोर ऑप्टिकल फाइबर केबल नेटवर्क बिछाया गया है। कटीले तारों की बाड़ और चार-दिवारी पर स्पष्ट दृश्य प्राप्त करने के लिए, उपयुक्त ऊंचाई पर कैमरों को लगाना आवश्यक था, इसलिए परिधि सीमा पर विस्तारित हाथ (Extended Arm) वाले नए पोल का एक संपूर्ण सेट (लगभग 40 पोल) लगाया गया है।

सभी कैमरे PoE और PoE+ मानकों के अनुकूल हैं जो कैमरों को पावर फीड करने के लिए अलग से केबल बिछाने की मेहनत और खर्च को कम करने में मदद करते हैं। सीसीटीवी फाइबर नेटवर्क का विस्तार करने के लिए परिसर में और उसके आस-पास कई स्थानों पर औद्योगिक ग्रेड के नेटवर्क स्विच स्थापित किए गए हैं। कार्यान्वित समाधान पूरी तरह से मॉड्यूलर है और डिस्ट्रीब्यूटेड आर्किटैक्चर (distributed architecture) पर आधारित है, यह संस्थान में भविष्य में आने वाली कैमरों की किसी भी नई आवश्यकता को समायोजित करने में सक्षम है।

संस्थान मे पूरी तरह से एक आधुनिक एवम सुसज्जित सी.सी.टी.वी. नियंत्रण कक्ष भी स्थापित किया गया है, यहाँ सभी कैमरों के वीडियो (फीड) को (मैट्रिक्स-टाइल दृश्य /Matrix-Tile view में) बड़े डिस्प्ले पैनलों पर निरंतर रेमोटली (remotely) देखा एवम रेकॉर्ड किया जाता है।

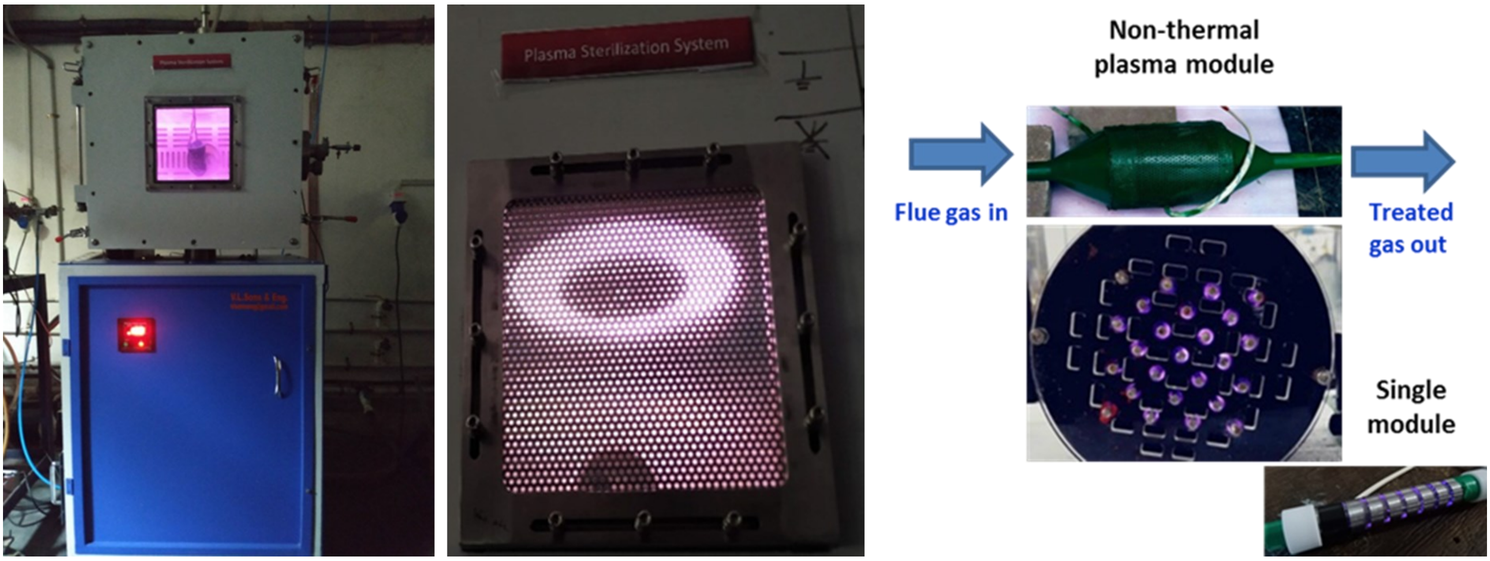
सीसीटीवी सिस्टम की स्थापना और कमीशनिंग का कार्य, संस्थान की परिसर सुरक्षा समिति (CSC) की दी गई आवश्यकता के अनुरूप, DACD डिवीजन द्वारा स्थापित एवं चालित किया गया है।

आई. पी. आर. में कमीशन किया गया सी.सी.टी.वी कंट्रोल रूम।

Activities of Atmospheric Plasma Division

The Atmospheric Plasma Division of IPR is involved in research and development of plasma based technologies for societal and industrial benefit. These technologies include plasma pyrolysis and gasification, plasma sterilization of medical tools and devices, nano-materials development, plasma for textile treatment, plasma activated water, plasma for coatings and so on. Some of the recent areas of R&D activities that the division is engaged in are described below.

Plasma Sterilization of Medical Tools and Devices : A plasma sterilization system has been developed that combines various physico-chemical properties of plasma like oxygen free radicals along with germicidal UV radiation at low pressure in order to achieve a novel method to kill deadly pathogens. Plasma has several advantages over the conventional techniques. Oxygen plasma produced in the plasma sterilization system produces UV radiation, large numbers of active oxygen species and radicals that are highly reactive and oxidize almost anything in contact, including viruses, bacteria, organic and inorganic compounds. These active species work as powerful disinfectants that disintegrate the outer cell wall of microorganism, leading directly/indirectly to the death of the cell. Several experiments in association with PERD Centre, Ahmedabad, were carried out successfully demonstrating killing of various micro-organisms. This involved in-vitro studies to disinfect and achieve 6-log reduction in many bacterial microorganisms such as *Staphylococcus Aureus*, *Escherichia Coli*, *Salmonella Abony* and *Pseudomonas Aeruginosa.* Scientists of have now embarked on an ambitious journey of the development of a compact user-friendly plasma sterilization system, with a view to achieve faster treatment, reduce footprint and minimize power. The focus is also on detailed understanding of the physical and biological processes involving rigorous trials using samples of micro-organisms. The new system will use plasma created by microwaves and has several advantages over the earlier one.



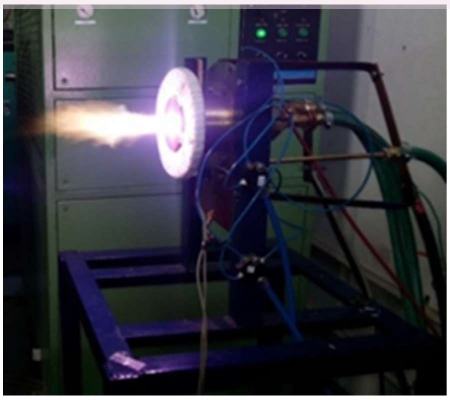
Plasma sterilization using (L) pulsed DC plasma (M) microwave plasma. (R) Treatment of exhaust gases using plasma

Treatment of Exhaust Gas using Non-Thermal Plasma : Increased environmental pollution is a major concern, especially in India due to rapid industrial growth. Environmental norms are getting stricter; many techniques to reduce pollution involving innovative engine design concepts, new fuels, catalysts, particulate filters etc. have been tried and almost all have reached design saturation. Major polluters are automotive, oil & gas, power generation industry and small-to-medium scale diesel generators. The diesel exhaust gas is a major pollutant and contains a complex mixture of particulate matter and gases. After-treatment of diesel exhaust gas is still an open technology. Non-Thermal Plasma (NTP) technique will offer a unique, novel, disruptive solution for post-treatment of diesel exhaust gas with simultaneous reduction in major pollutants. An exciting project is on its way to develop a retrofit non-thermal plasma module that can be fitted directly onto the exhaust of a diesel generator. The module is expected to cut the particulate matter (PM) and NOx emissions to up to 50%. The project is multi-pronged and involves several tasks such as detailed calculations for estimation of plasma parameters and plasma chemistry for treatment of the diesel exhaust gas, design and development of plasma modules, exhaust gas analysis for PM, NOx and SOx levels and flow rates, optimization of the parameter space and eventually design the retro-fit module. The demonstration will be carried out on a standard 10 kVA diesel generator. A state-of-the-art lab comprising of a diesel generator, electronic load bank, emission monitoring system, remotely controlled valves to control the gas flow and exhaust lines, is being set up for the project.

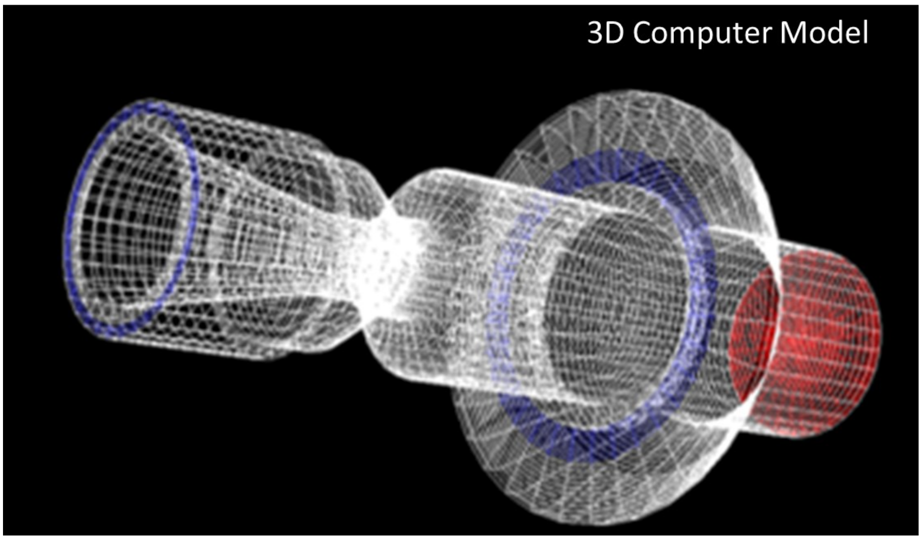
Very Low Pressure Plasma Spray System : Plasma spray processing is a major technique in materials engineering because it offers affordable and effective thin film and coating technology. However, demands of the rapid advances made in sectors like electronics, automotive, aerospace, biomedical etc. cannot be met by current technologies. The objective of the project is to develop a Very Low Pressure Plasma Spray System (VLPPS) for thermal spraying of specialized coatings. The technique that is being adopted offers to bridge the gap between PVD and atmospheric plasma spray by combining high deposition rates and cost-efficiency of thermal spraying and feature of PVD to deposit wide spectrum of columnar structured coatings. The technique will also offer the unique capability to deposit coatings on non-line-of-sight areas of substrates with complex geometries. The project involves design and development of high power (~ 100 kW) plasma torch for operation at very low pressures of 1–10 mbar, setting up of experimental facility including large volume vacuum chamber, power supplies, heat exchanger, control system and feedstock introduction mechanism. The experiments revolve around identification of the appropriate parameter regime, achieve a stable plasma plume, optimize feedstock introduction into the plasma, control the rate of vaporization and characterization of the coatings.

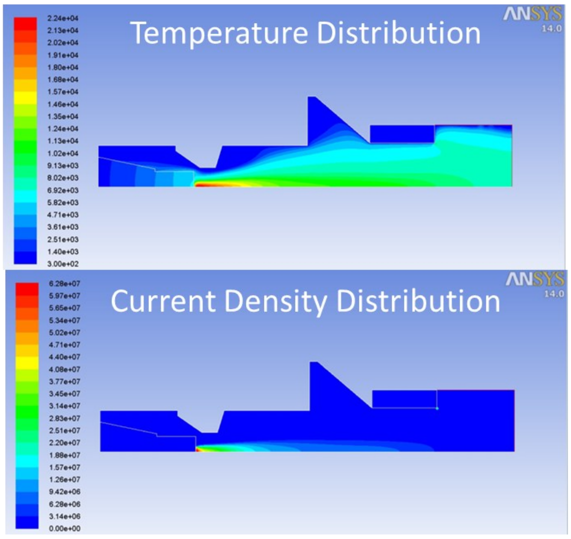
Activities of Atmospheric Plasma Division

This program was conceptualized based on the expertise on plasma torches developed at the Atmospheric Plasma Division, IPR over the span of a decade. The plasma torch activities over the years involved the understanding of dynamics of thermal plasma torches, the workhorse of any thermal plasma system that harnesses its unique properties. This involved the development of semi-empirical formulations, three dimensional computer models as well as fundamental studies. Understanding of the plasma dynamics was carried out using a clever combination of several diagnostics such as electrical and magnetic techniques, fast imaging and spectroscopy. High power (~ 100 kW) torches and enthalpy probes were also developed.




(L) 85 kW plasma torch in operation (R) Supersonic plasma plume





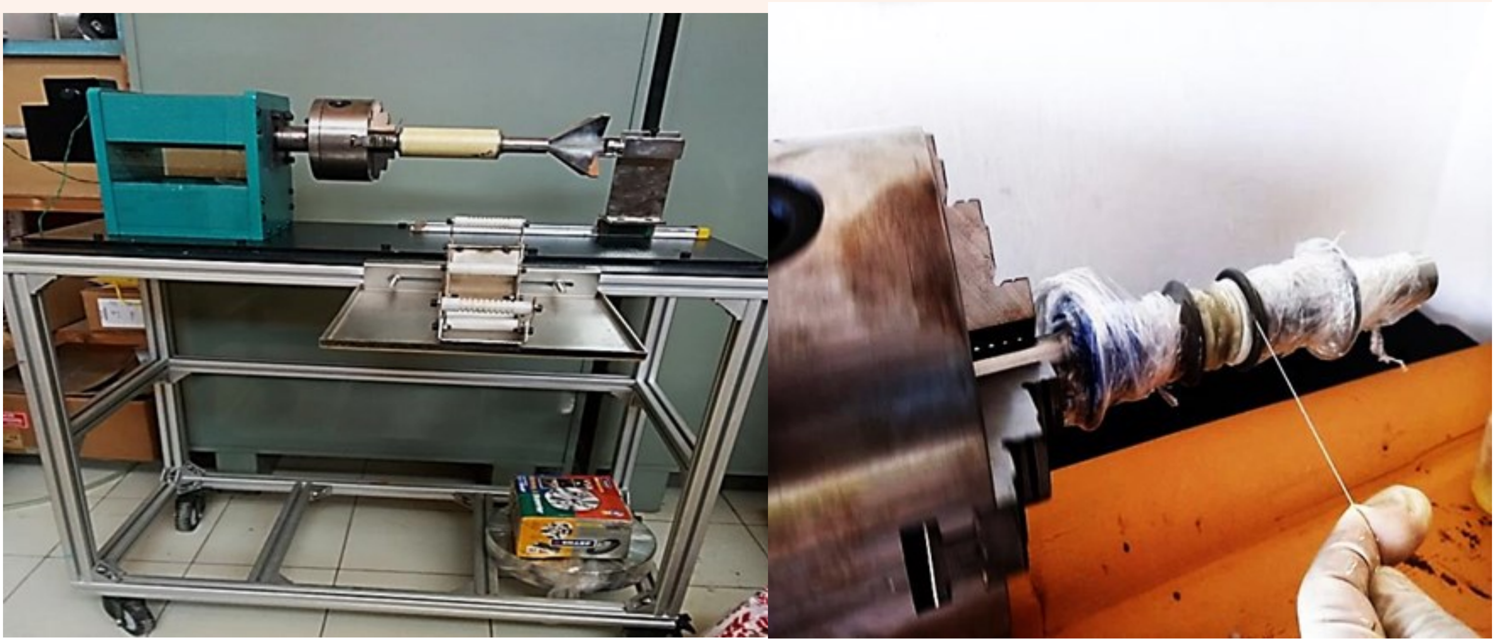
Computer modeling of plasma torch

Members of the APD group (L-R) Chirayu Patil, G. Ravi, S. K. Nema, Kushagra Nigam, Ram Krushna Mohanta Abhijit Boruah and Tejal Barkhade.

In-House Development of Filament Winding Machine

The cryogenic components as electrical insulation breaks, vacuum barrier is a dissimilar material joints which are used for electrical isolation and supply of cryogenic fluid in superconducting fusion magnet Tokamak. The components fabrication to round shape using wet filament winding process is done at vendor site. In house facility, infrastructure development and installation of filament winding machine has been done at IPR MEL cryogenic division. This facility eliminates the failure aspect of 1st stage dissimilar material joint of Stainless steel and GFRP of cryo component by controlled reduction of fibre speed. The developed installed machine facilitates to make dissimilar material joints and filament winding to form a round shape items. The salient feature of developed machine is:

- Wet type filament winding , Controlled adjustable RPM: up to 30 RPM by DC motor and gear box assembly mechanism, Easy movable
- Cylindrical/ Round job span: 10-100 mm dia and winding length: 0-300 mm, Fiber speed: < 6 mm/sec
- Manufactured by local Indian industry
- Machine cost significantly less (5 to 6 times) than of similar capacity machine



(L) Indigenously developed filament winding machine (R) Winding of filament using the machine

Activities of Accounts Section

Accounts section in order to achieve the dream of Digital India took initiative to have its processes digitized and hence minimized usage of paper. As part of this initiative the annual Form 16 is now being distributed to IPR staff digitally. IPR Accounts section successfully integrated *Jeevan Praman* Biometric enabled digital service for Pensioners. Every year, pensioners need to provide life certificates to ensure the credit of pension in their account. Biometric enabled digital services removes the requirement of personally being present in front of the disbursing agency and instead digitizing the whole process of securing the life certificate. From July 2021, The Public Financial Management System (PFMS) was made compulsory by the Controller General of Accounts (CGA), Department of Expenditure, Ministry of Finance, Government of India for all

Members of the accounts division of IPR

Activities of Accounts Section

financial transactions for IPR. Accounts section not only successfully transitioned to new system for all the financial activities but also ensured that necessary payments such as staff salary is carried out without any delay. Pension Fund Regulatory and Development authority (PFRDA) has recognized IPR as the 'Best Central Autonomous body for FY 2018-19' for successful implementation of National pension system by the accounts section.

For successful implementation of usage of Hindi Language in the official work Accounts section was awarded Rajbhasha Shield for the period of July to December-2018. With the help of Tally software team accounts section has successfully integrated Hindi language in all the Tally vouchers being printed so It captures the all necessary details not only in English but in Hindi as well. During the lockdown period of the covid-19 pandemic, the accounts section's personnel ensured that essential duties are not being affected during the lockdown. Staff Salary was executed on time and necessary payments were carried out in timely manner.

Accounts section was awarded Rajbhasha Shield for the period of July to December-2018.

Activities Under "*Azadi Ka Amrut Mahotsav*"

The ***Azadi Ka Amrut Mahotsav*** *On-line* Colloquium series began in Sept, 2021. This series of popular science lectures aimed at students is proposed to continue till August 2022.

The 3rd talk I this series entitled "Harnessing Plasma for Societal Applications" was delivered by ***Dr. Mukesh Ranjan*** *of FCIPT, IPR on 1-Oct-2021*

The 4th talk in this series, entitled "C.V. Raman: The Man, The Scientist" was delivered by ***Prof. Reji Phillip,*** *Head, Light and Matter Physics Department of the Raman Research Institute (RRI), Bangalore on 18-Oct, 2021*

Dr. Mukesh Ranjan

Prof. Reji Phillip

Congratulations !

Ms. Sukiriti Hans (PhD Scholar) was awarded the best Flash Oral presentation Award for her presentation entitled "Formation of triangular features superimposed by nanoripples by low energy ion beam" under student category in the 6th International Virtual Conference on Nanostructuring by Ion Beams (ICNIB-2021, 5-8/10/2021) jointly organized by IOP, Bhubaneswar and IUAC, New Delhi.

Ms. Hiral B. Joshi was awarded 1st prize for her poster entitled "*Effect of enclosure geometries on the performance of plasma-based microwave absorber*" at the National Conference on Advances in Materials science: Challenges and Opportunities (AMSCO – 2021), held at Maharaja Krishnakumarsinhji Bhavnagar University on 21st Sept. 2021.

प्लाज़्मा अनुसंधान संस्थान में राजभाषा संबंधी गतिविधियाँ

संस्थान में राजभाषा नीति के सुचारू कार्यान्वयन हेतु निरंतर प्रयास किये जा रहे हैं। प्रतिवर्ष संस्थान में विभिन्न गतिविधियाँ आयोजित की जा रही है, जिससे हिंदी के प्रचार-प्रसार में काफ़ी प्रगति हुई है। संस्थान में राजभाषा कार्यान्वयन हेतु निदेशक की अध्यक्षता में राजभाषा कार्यान्वयन समिति गठित की गई है, जिसके 12 सदस्य है: डॉ. शशांक चतुर्वेदी, अध्यक्ष, श्री राजसिंह, वैज्ञानिक अधिकारी – एच, श्री प्रवीण कुमार आत्रेय, डीन आर एंड डी, डॉ. सूर्यकान्त गुप्ता, वैज्ञानिक अधिकारी – जी, श्री निरंजन वैष्णव, मुख्य प्रशासनिक अधिकारी, श्री रमेश डी, क्रय अधिकारी – ।।, सुश्री प्रतिभा गुप्ता, वैज्ञानिक अधिकारी – एफ, श्रीमती फाल्गुनी शाह, लेखा अधिकारी – ।, श्री प्रशांत कुमार, वैज्ञानिक अधिकारी – डी, श्री सरोज दास, वैज्ञानिक अधिकारी – डी, श्री आनंद मिश्रा, प्रशासनिक अधिकारी एवं डॉ. संध्या पी. दवे, हिन्दी अधिकारी।

संस्थान में आयोजित होनेवाली हिंदी गतिविधियाँ का सार:

हिंदी सेमिनार: वैज्ञानिक/तकनीकी एवं प्रशासनिक विषय पर हिंदी सेमिनार का आयोजन प्रतिवर्ष किया जाता है जिसमें संस्थान के विभिन्न तकनीकी/गैर तकनीकी अनुभाग अनुसंधान एवं प्रयोगात्मक कार्यों से संबंधित विषय पर सरल हिंदी भाषा में पावर पॉइंट के माध्यम से प्रस्तुतिकरण किया जाता है।

हिंदी पखवाड़ा/माह समारोह: 14 सितंबर हिंदी दिवस के उपलक्ष्य में कई वर्षों से आयोजित होने वाले हिंदी पखवाड़ा समारोह ने इस वर्ष हिंदी माह का रूप ले लिया है। इस अवसर पर आयोजित विभिन्न प्रतियोगिताओं जैसे, निबंध लेखन, नारा लेखन, प्रश्नोत्तरी, आशुभाषण, समाचार वाचन, टिप्पण एवं आलेखन, कंप्यूटर पर हिंदी टाइपिंग, हिंदी पोस्टर, चित्र देखो-कहानी लिखो, कविता पाठ आदि प्रतियोगिताओं में प्रतिभागी उत्साहपूर्वक भाग लेते आ रहे हैं। इस अवसर पर पुस्तकालय अनुभाग द्वारा हिंदी पुस्तकों की प्रदर्शिनी का भी आयोजन किया जाता है।

अंतर अनुभागीय चल राजभाषा शील्ड योजना एवं राजभाषा पुरस्कार योजना - संस्थान में हिंदी में उत्कृष्ट कार्य करनेवाले अनुभाग को प्रोत्साहित करने के उद्देश्य से अंतर-अनुभागीय चल राजभाषा शील्ड योजना लागू की गई है और इस योजना के अंतर्गत प्रतिवर्ष हिंदी दिवस के अवसर पर संस्थान में हिंदी में उत्कृष्ट कार्य करनेवाले अनुभाग को इस शील्ड से सम्मानित किया जाता है। साथ ही हिंदी में उत्कृष्ट कार्य के लिए प्रति वर्ष तकनीकी या प्रशासनिक वर्ग के एक कर्मचारी को राजभाषा पुरस्कार प्रदान किया जाता है।

गृह पत्रिका "प्लाज़्मा ज्योति" का प्रकाशन: संस्थान की गृह पत्रिका "प्लाज़्मा ज्योति" का प्रति छमाही में प्रकाशन किया जाता है। इस पत्रिका में संस्थान की तकनीकी/वैज्ञानिक गतिविधियों एवं प्रशासनिक गतिविधियों के अलावा संस्थान की उपलब्धियों एवं कर्मचारियों द्वारा सामान्य विषय पर लिखे गये आलेखों को सम्मिलित किया जाता है। इस पत्रिका में संस्थान के परिवार के सदस्यों की रचनाओं को भी सम्मिलित किया जाता है। परमाणु ऊर्जा विभाग द्वारा पिछले 8 वर्षों से परमाणु ऊर्जा विभाग के सहायता प्राप्त संस्थानों की श्रेणी के अंतर्गत 'प्लाज़्मा ज्योति' को श्रेष्ठ गृह पत्रिका पुरस्कार प्राप्त हुए हैं।

हिंदी में कार्य करने हेतु प्रोत्साहन योजना: संस्थान में परमाणु ऊर्जा विभाग की "परमाणु ऊर्जा राजभाषा कार्यान्वयन योजना" के अंतर्गत सरकारी कार्य हिंदी में करने हेतु कर्मचारी/अधिकारी काफी उत्सुकता से भाग ले रहे हैं एवं नकद पुरस्कार प्राप्त कर रहे हैं।

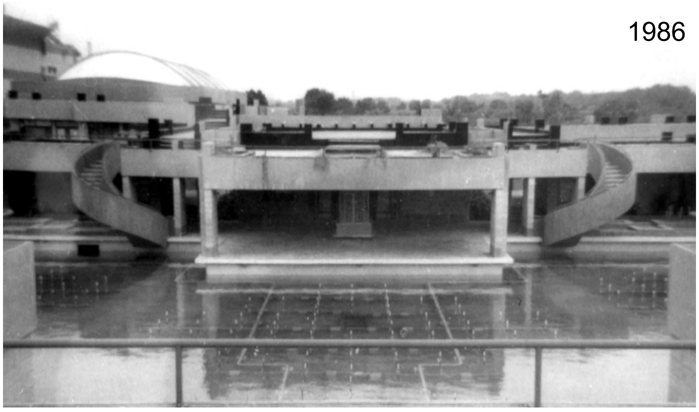
राष्ट्रीय विज्ञान दिवस का आयोजन: हर वर्ष आयोजित होने वाले दो दिवसीय राष्ट्रीय विज्ञान दिवस समारोह में राज्य भर की स्कूलों के छात्रों के लिए विभिन्न प्रतियोगिताओं का आयोजन, जिसमें स्कूली छात्रों के लिए प्रश्नोत्तरी, निबंध लेखन, पोस्टर, भाषण, नाटक आदि प्रतियोगिताएँ हिंदी व अंग्रेजी भाषा के साथ स्थानीय भाषा गुजराती में भी आयोजित की जाती है। इस वर्ष फरवरी 2021 में ऑनलाइन माध्यम से राष्ट्रीय विज्ञान दिवस पर उपरोक्त गतिविधियों का आयोजन किया गया ।

नराकास, गांधीनगर की गतिविधियों में प्रतिभागिता: नराकास, गांधीनगर स्तर पर आयोजित गतिविधियों में संस्थान के सदस्य सक्रिय रूप से भाग ले रहे हैं। आईपीआर द्वारा नराकास, गांधीनगर स्तर पर दिसंबर 2020 में निबंध प्रतियोगिता एवं अगस्त 2021 में हिंदी कार्यशाला का आयोजन किया गया। राजभाषा के क्षेत्र में श्रेष्ठ कार्यनिष्पादन हेतु नराकास, गांधीनगर स्तर पर आईपीआर को पिछले 5 वर्षों से शील्ड प्राप्त हो रही है।

संस्थान को राजभाषा के क्षेत्र में उत्कृष्ट कार्य हेतु परमाणु ऊर्जा विभाग के सहायता प्राप्त संस्थान श्रेणी के अंतर्गत पिछले सात वर्षों से राजभाषा शील्ड प्राप्त हो रही है।

डॉ. सूर्यकान्त गुप्ता, सुश्री प्रतिभा गुप्ता, श्री सुनिल मिसाल, डॉ. प्रवीण कुमार आत्रेय एवं श्री हरीश चन्द्र खण्डूरी को राजभाषा हिंदी के प्रचार-प्रसार में रचनात्मक एवं उत्कृष्ट योगदान देने के लिए परमाणु ऊर्जा विभाग द्वारा हिंदी सेवी सम्मान पुरस्कार प्राप्त हो चुका है। श्री राज सिंह को राजभाषा हिंदी के प्रचार-प्रसार में रचनात्मक एवं उत्कृष्ट योगदान देने के लिए परमाणु ऊर्जा विभाग द्वारा राजभाषा भूषण पुरस्कार से सम्मानित किया गया है।

Memories

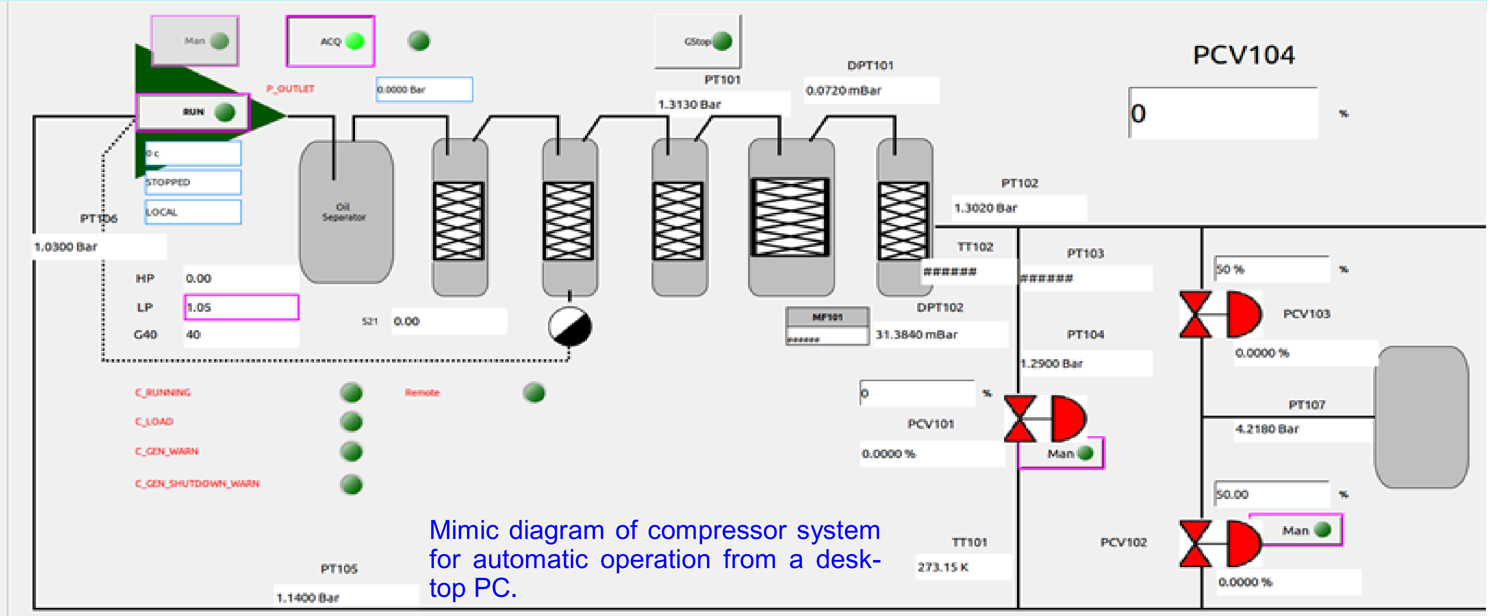


Activities of the Large Cryogenic Plant & Cryosystem Division

Development of Indigenous Helium refrigerator/liquefier : The indigenous development works for such plant for lower capacity ~200 W refrigeration power at liquid helium temperature, has been taken up by the LCPC division at IPR. Majority of the cryogenic components of this system have been developed in-house and for qualifying thee components for helium refrigerator/liquefier plant, appropriate test facilities have also been developed. The cool-down of the whole plant (without helium passing through the turbines), down to 80 K, have been successfully carried out using indigenously developed helium compressor in closed loop and the system is now ready for the next stage, *i.e.,* operation of the helium turbines.

View of the helium cold-box (L) Top view (R) Side view

Development of Helium Compressor Automation System : The automation system required for the operation of the indigenously built helium compressor system in closed loop was developed by LCPC & DAC divisions. Since various sequential operation of various valves are required during the start and end of the process, this automation system has made the compressor operation relatively easy and safe.



Mimic diagram of compressor system for automatic operation from a desktop PC.

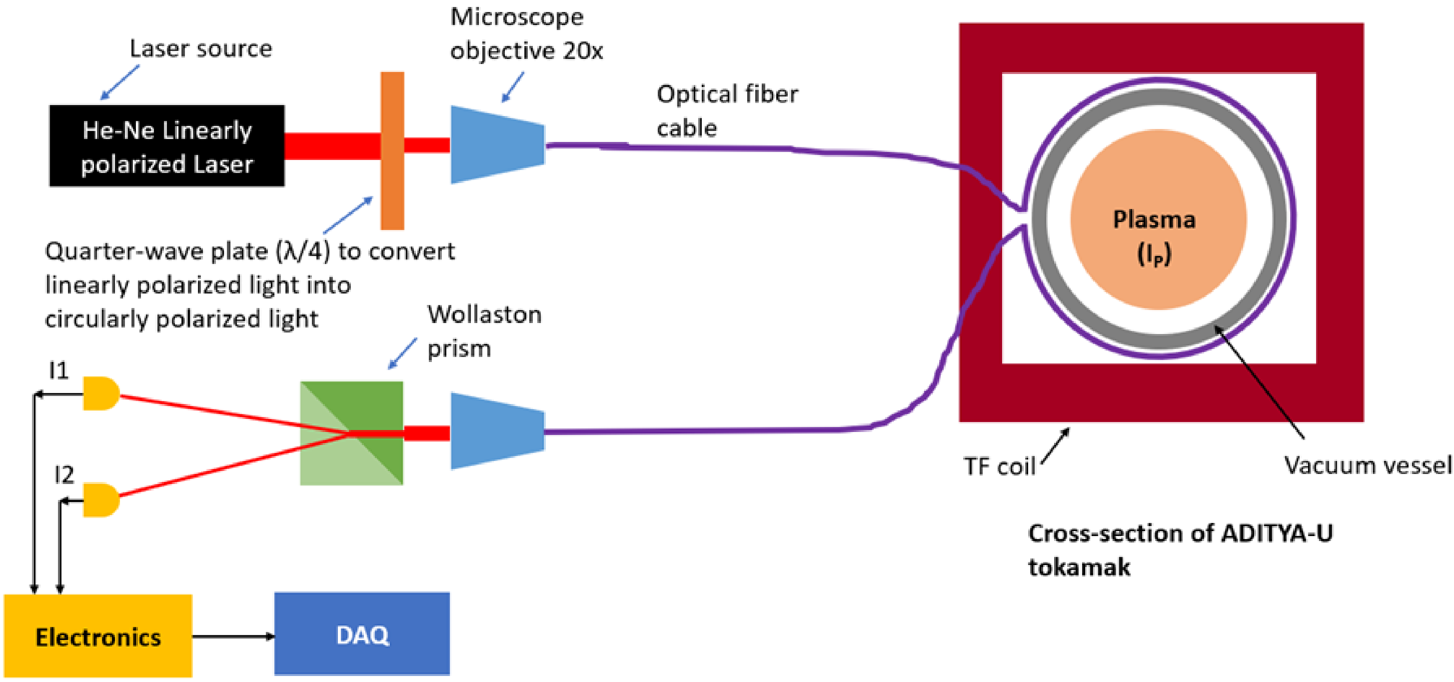
Members of the LCPC Division : Front row L-R : Omkar Chandratre, A. K. Sahu and Rajnikant Bhatasana. Back row L-R: Nawratan Kumar, Prashant Singh, Haresh J Dave, Hitesh Kavad and Priyanka Brahmbhatt.

Development of Magneto-Optic Current Sensor

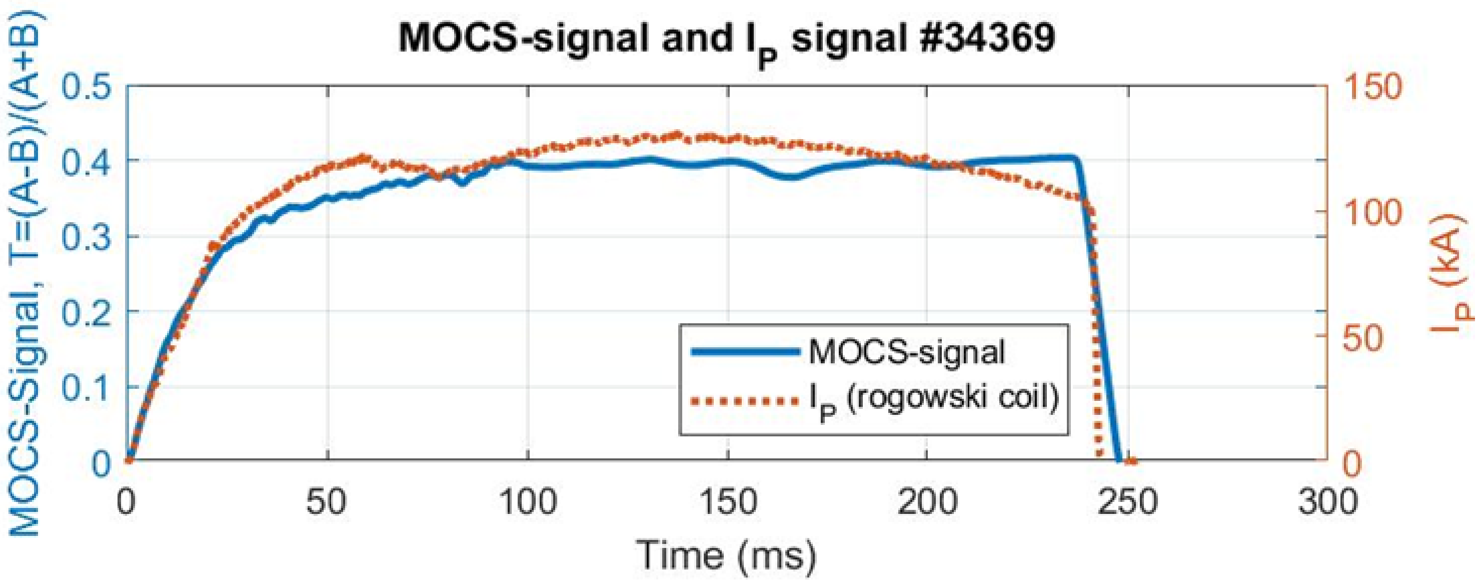
Conventionally, the plasma-current measurement is performed by inductive sensors such as Rogowski coil or array of pick-up coils, Hall-effect sensor can also be utilized for the magnetic field / current measurements. However, in case of the future fusion devices such as ITER, DEMO, and long-duration discharges in present-day steady-state tokamaks, there are a few problems associated with the drift of integrator that is utilized in the conventional plasma current measurement diagnostic techniques. Hence these sensors have an inherent weakness. In addition, a nuclear-radiation induced environment also introduces noise in the conventional plasma-current measurement system. Redundant diagnostic measurements will also be useful for cross-comparison and validation of results.

This demands an alternate and reliable technique that can measure the plasma current directly. Magneto-optic Current Sensor (MOCS) *or* Fiber Optic Current Sensor (FOCS) based on the principle of Faraday effect can be utilized for this purpose. In MOCS, the plasma current is directly estimated by measuring the rotation angle of the linearly-polarized light passing through the optical fiber loop nearly enclosing the plasma current channel. The MOCS diagnostic system is being designed, developed for ADITYA-U tokamak and subsequently will be developed for the SST-1 tokamak.

A prototype MOCS diagnostic has recently been developed for ADITYA-U tokamak and installed on the tokamak. The prototype MOCS system has been characterized in a Lab setup environment and also the first results of plasma current estimation up to ~150 kA were obtained for plasma discharges. The preliminary results show a reasonable and consistent agreement with the Rogowski coil.



Schematic of the first phase MOCS diagnostic setup installed on the ADUTYA-U tokamak for plasma current measurement



First results from the MOCS diagnostic installed on the ADITYA-U tokamak and comparison of MOCS-signal with Rogowski-coil signal during long pulse plasma discharges.

Activities of Large Volume Plasma Device Section

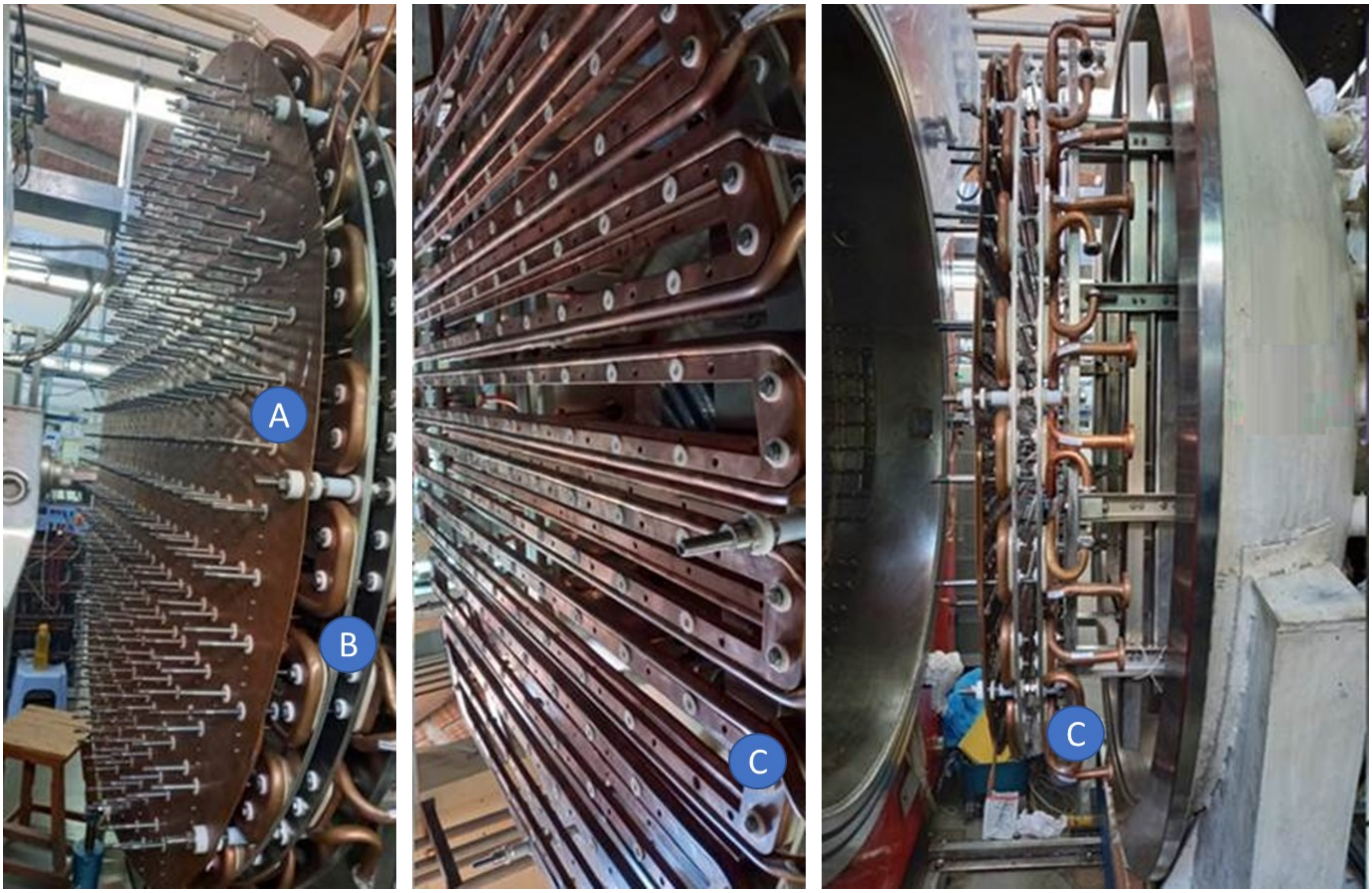
The Large Volume Plasma Device-Upgrade (LVPD-U) is a cylindrical, double walled, water cooled, linear plasma machine of diameter 2m and length 3m. It has been recently commissioned for producing plasma of discharge duration 50ms. In pursuit of raising the plasma density, plasma uniformity and exerting better control on plasma investigations for unfolding various physical phenomena, the machine gets augmented with few new subsystems namely, 1) Large area multi-filamentary plasma source (LAMPS), 2) Electron Energy Filter (EEF) and 3)High current Power Supply System (PSS). The LAMPS is a 400kg circular shaped plasma source, containing 162 numbers of tungsten filaments for electron emission.

The most critical element of the LAMPS is its anode plate. It is a water cooled, 2mm thick, 1.8m diameter, ETG grade copper plate. It is reinforced by a continuous line cusp which is made up of Samarium Cobalt magnets, each providing surface magnetic field of 4kG. An X-Y matrix of 15 K- type thermocouples is mounted on the cathode plate to monitor remotely the temperature distribution of the plate. Figure 1 shows different developmental stages of LAMPS. The device has been successfully tested for the leak rate of ~1 x 10^{-8} mbar-liter/sec The ultimate vacuum obtained for the safe operation of the LAMPS in LVPD-U is ~ 1×10^{-6}mbar.

The second major subsystem is the Electron Energy Filter (EEF). It is installed inside the machine and it divides its plasma into three regions of Source, EEF and Target plasmas. It makes target plasma devoid of energetic electrons which is a very significant contribution for making clean measurement of electron temperature by probes. Here, source region is defined as the volume between plasma source and EEF whereas target region covers the space between the EEF and the end plate mounted on the LHS dish end plate.

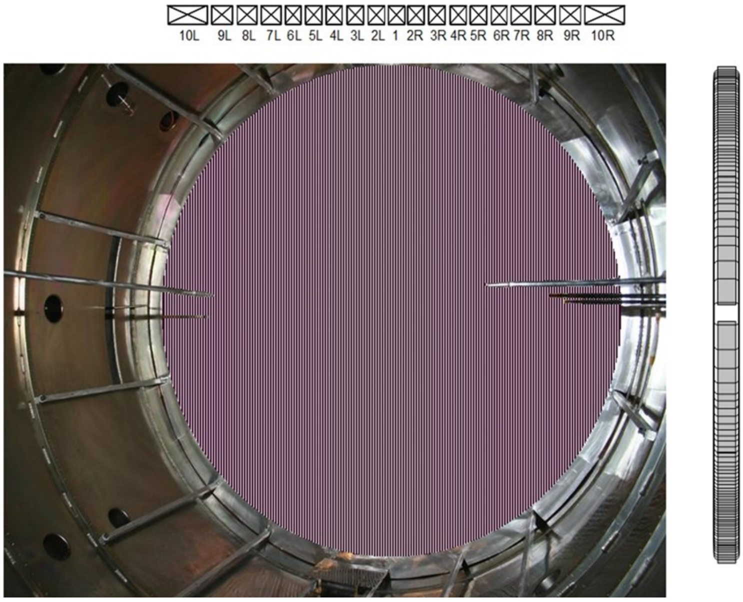
The third major subsystem is Power Supply System (PSS). It comprises of three high current power supplies named as discharge power supply (DPS), solenoid power supply (SPS) and filament power supply (FPS), with respective current delivery ratings of 1kA, 2.5kA and 10kA respectively. These supplies are tested for 55ms pulse operation across the dummy and plasma load in local and remote mode of operations.

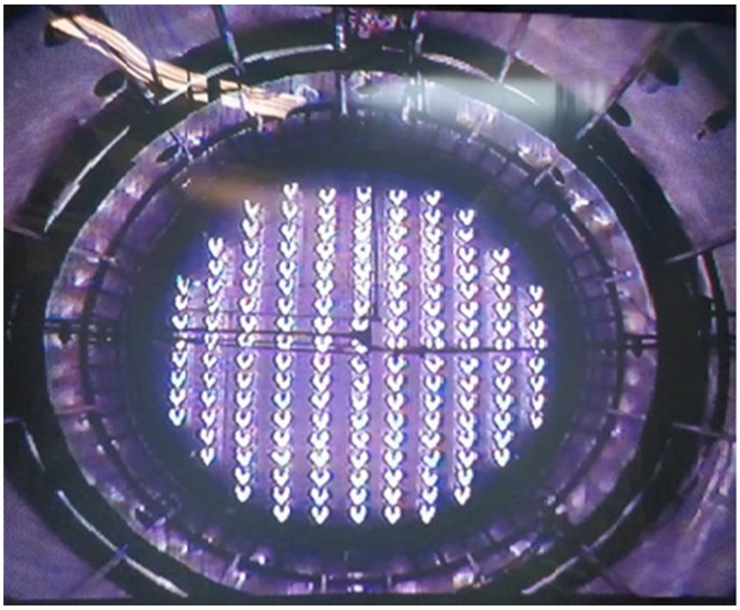
The LVPD- U is commissioned with first plasma discharge at feeding power of 46 kVA to LAMPS. The magnetized pulsed Argon plasma of 50ms duration and 1kA of discharge current has been successfully produced for discharge parameters (P_{Ar}~4×10^{-4} mbar, B_z ~ 6.2G, V_d~ -70V).This has produced a plasma density ~ 5×10^{11}/cc and electron temperature ~ 4eV in the source plasma. The plasma operations are controlled by the in- house developed Web based electronic experiments logging facility.



The front and rear side view of pre-assembly stage of the LAMPS is shown in (Left & Middle) respectively. (Right) The pre-assembly of water cooled copper cassettes is shown attached to the RHS dish end of LVPD-U. (A) Molybdenum feed-throughs (B) ETP copper filament holding multi-cusp plate (C) High current carrying copper cassettes

Development and Commissioning of Large Volume Plasma Device-Upgrade System





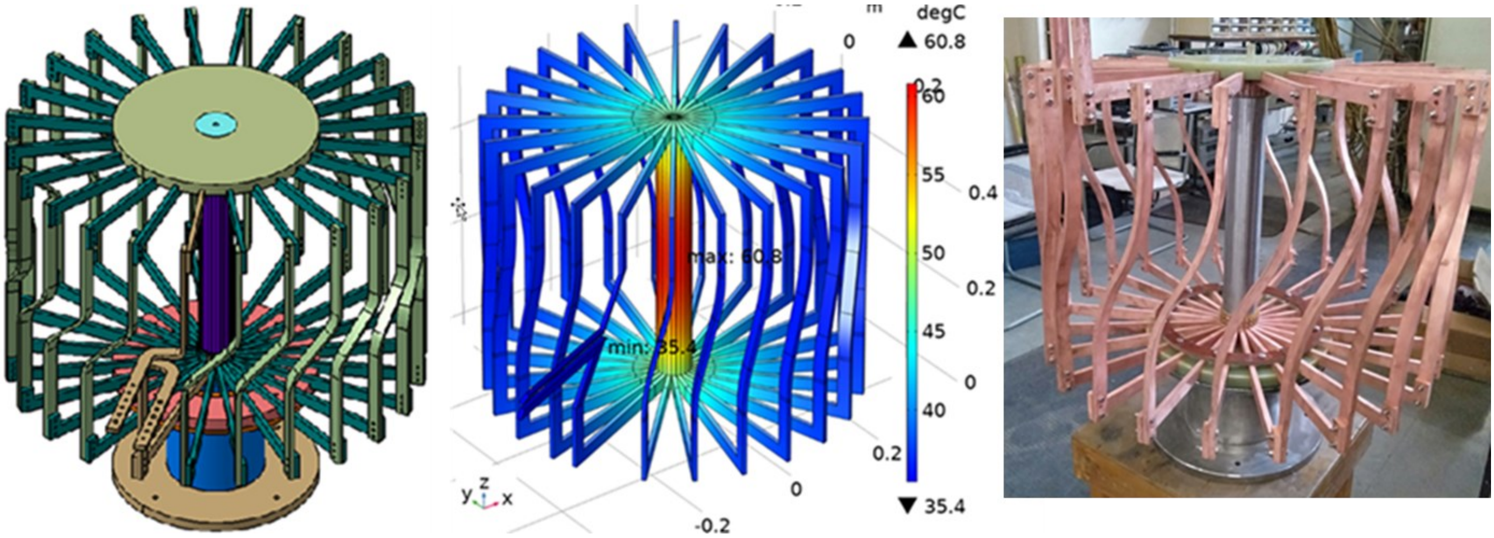
(L) Photograph of Electron Energy Filter (EEF) installed in LVPD-U. The EEF is made up of 19 solenoids (marked above the image) as (-10L to 10R). (R) photograph of heated LAMPS is shown.

Members of the LVPD Division (L-R) Ayan Adhikari, A. K. Sanyasi, Ritesh Sugandhi, L. M. Awasthi and P. K. Srivastava

Mechanical Engineering Services Division (MESD)

The MESD division has four sections namely Engineering Design & Analysis Section (EDAS), Drafting Section, Workshop Section and Inspection & Quality section (IQS). The activities undertaken by the division is conforming to full product cycle which includes concept to commissioning. The major tasks are design and analysis of the various experimental systems of various projects in IPR, preparation of the engineering drawings, fabrication/manufacturing, inspection, testing and commissioning of various systems. The division comprises of team of experienced mechanical engineers, physicist, draftsman and tradesman. The EDAS of MESD has been actively executing various tasks related to design, analysis, and technical specifications preparation for fabrication/manufacturing of various systems. The Drafting section of MESD is equipped with 6 licenses of CATIA-V5 R13 installed on work stations for 3D modelling and 2D drawing preparation and HP inkjet T2300 plotter. Section has been supporting the users for designing and preparation of engineering drawings for various systems of Aditya-Upgrade and SST1 Tokamaks, LVPD system and other experimental projects being executed at IPR, FCIPT and CPP.

The Workshop section of MESD is equipped with modern versatile machineries including machining and fabrication (shearing, rolling, TIG welding etc.) facilities catering for needs of IPR, FCIPT, ITER-India and CPP for the fabrication of a system/product required by users. Apart from conventional machines, Workshop also has 3-axis abrasive water-jet machining facility, which is useful for machining the intricate shapes of different materials at room temperature. It has also CNC machining centre with better than 10 micron accuracy. Workshop has manufactured the UHV/HV components on CNC machine and delivered to stores (which are otherwise stores stock items procured from outside). In this year workshop will be equipped with CNC Vertical Machining Centre of micron level accuracy. The Inspection & Quality section (IQS) has been supporting the inspection & testing of incoming stock items at Store. The section is supporting the inspection and quality control activities of SST1 and other installations at IPR.



(L) Toroidal Coil 3D view (M) Thermal analysis and (R) manufactured Cu bus-bar for SMARTEX-C

(Top) Some of the items designed and fabricated by MESD (Bottom) Members of MESD

Activities of the Magnet System Division

Magnet Test Facility : MSD is establishing the Magnet Test Facility (MTF) with the required sub-system suitable for test and validation of the large superconducting magnets of height up to 5 m and diameter up to 4 m at 5 K. The integration of all the sub-systems has been carried with cryostat along with its 80 K thermal shields. The performance test of the integrated cryostat and thermal shields to 80 K along with required control and DAQ system has been validated at 10^{-5} mbar. The first phase validation test of thermal shields of the cryostat up to 80 K at the operating pressure of 10^{-5} mbar completed successfully. In the second phase, the support structure for the magnet, current leads, cooling network for LHe, high current power supply, and protection system for testing of large superconducting magnets will be established in the future.

Members of the Magnet System Division in front of the Magnet Test Facility at IPR

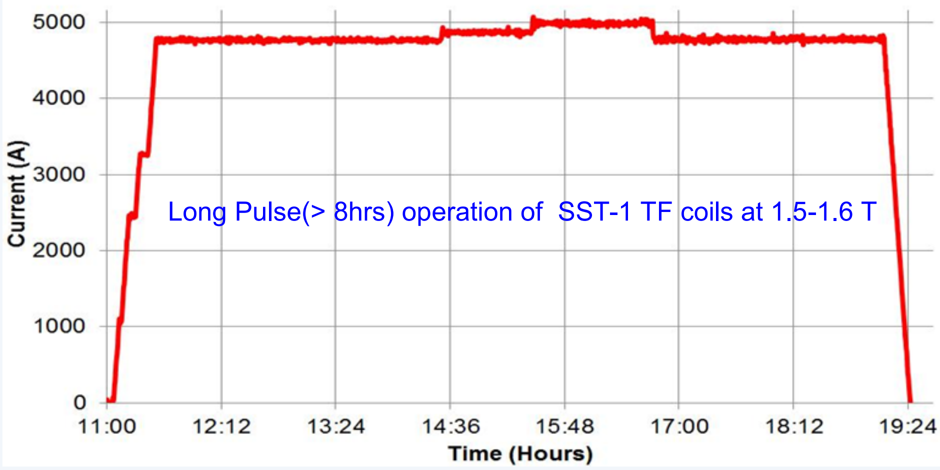
Sub-cooled Liquid Nitrogen (LN_2) system : Sub-cooled Liquid Nitrogen (LN2) system is of immense economic importance for cooling of high temperature superconducting cable and magnet for various applications. MSD has developed a system which can deliver sub-cooled LN2 at ~63 K using vacuum pumping of LN2 and 69.5 K helium gas temperature for experimental application using a heat exchanger. Room temperature helium gas was cooled using heat exchanger, submerged in sub-cooled LN2 bath at ~ 63 K. Minimum temperature achieved during solidification of nitrogen was 56 K. An external varying heat load of up to 1.5 kW was applied to measure effect of heat load on various operating parameters of system.

Fabrication and testing of high temperature superconducting magnets: The significant progress has been made for the development of high temperature superconductor (HTS) based 1 kA cable of cross-sectional area $29 mm^2$, nano-ohm class HTS-HTS tape joints and a 1.1 T compact solenoid coil of inner diameter 50 mm. Two double pancake based HTS coils have been fabricated with a low resistance joint of 47.5 nΩ. These coils have been charge up to 400 A @ 10K using pulse tube cryo-cooler.

Nb_3Sn CICC based Solenoid Magnet fabrication : Nb_3Sn Cable-in-Conduit Conductor (CICC) was fabricated by cabling of Nb_3Sn strands and the jacketing of the same inside a SS316 LN conduit. This CICC has been wound in solenoid form and heat treated at 650°C in the Argon gas environment under vacuum for Nb_3Sn phase formation. Nb_3Sn- NbTi hybrid joints fabricated with both the terminals of solenoid for electrical testing at low temperature. This was tested in a Nb_3Sn CICC based solenoid coil up to 10 kA, using liquid helium without any quench at a current ramp rate of 5-20 A/s up to 10 kA at ~ 6 K. This Nb_3Sn CICC based multi-turn solenoid can be used for high magnetic field (>10 T) generation for magnetic fusion and other applications.

L-R) Fabricated new TR#4 coil, New vacuum barrier, PF#3 coil current leads and power feedthrough for PF coils

Activities of the Magnet System Division

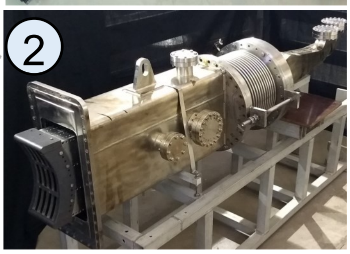


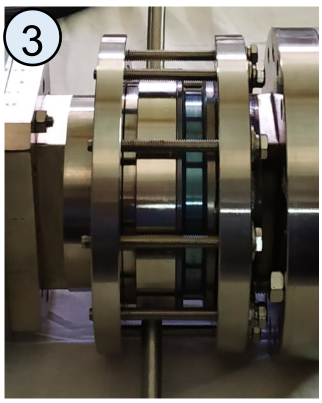
Upgradation of SST-1 Magnets & its Operation : The operating temperature of SST-1 SC coil is -268.5°C, current 10 kA and stored magnetic energy of toroidal field (TF) coils is 55 MJ. TF coils of SST-1 were operated up to 2.7 T, which was 90 % of the designed value at the major radius of 1.1 m of the SST-1. The requirement of better magnetic null is the prime requirement for the plasma initiation in SST-1. From simulation it was found that adding four more turns with the present single turn TR#4 coils would fulfil this requirement. Installation of additional four turns in TR#4 and TR4#B was seen to enhance the magnetic null evolution during Ohmic coil charging that lead to plasma pulse > 680 ms. The developed insulation was tested up to 22 kV. Similar insulation system was applied to the actual copper conductor used for additional turns of TR#4 coil winding, and these coils have been repeatedly operated up to 7 kA during the two SST-1 experimental campaigns. New PF#3 coil current leads with improved electrical insulation were also integrated with PF#3 coil bus-bars and these coils too were operated up to 6 kA/turns in superconducting state. New vacuum barriers to eliminate the Paschen discharge inside CFSC and high voltage and cryogenic compatible high current feedthrough were also integrated with the PF#3 coil bus-bars.

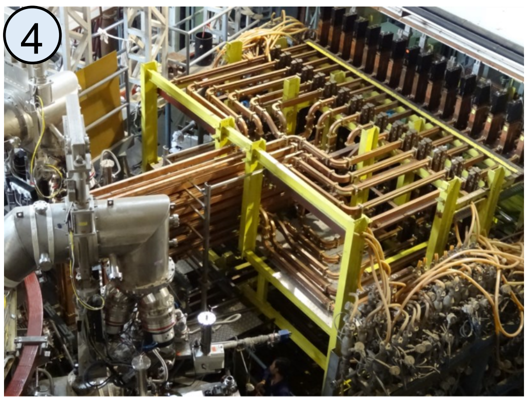
High Power LHCD Systems Division

High power lower hybrid current drive (LHCD) division provides RF power to ADITYA-U and SST1 tokamaks, to drive plasma current non-inductively by employing lower hybrid waves (LHW's). Four klystrons, each rated for 0.5MW-CW RF power, at 3.7GHz, are used to generate the RF power. These RF systems are very huge and includes complex sub-systems interfaced with thermal-managements/auxiliary power supplies/ controls/interlocks/safety mandates. Conventional grill antenna, designed to launch 1 MW-CW RF power and passive-active-multijunction (PAM) antenna, designed to launch 250kW-1s, is used for SST1 and ADITYA-U machine respectively and are developed indigenously. Several RF components like high power window, loads, in-vessel/out-vessel module, E/H-bend, impedance transformer, four-port circulator, reactor-grade oversized corrugated bend *etc.* has also been designed/developed indigenously. The longest plasma shot of ~650ms has been achieved on SST1 with LHCD with confirmation that the non-inductive current drive employing LHW's. Recently, two ECR systems, each sourced by 6kW-CW magnetron, at 2.45GHz, is being designed/developed for spherical tokamak.

LHCD members (L-R): ArvindKumar Thakur, Pramod Parmar, Chandra Sekhar Singh, Promod Kumar Sharma, Kirankumar Ambulkar, Chetan Virani and Saifali Sharma







(1) Oversized Corrugated bend – Converter Assembly for LH system .

(2) PAM Launcher for ADITYA-U

(3) 150kW-1sec, 3.7GHz Pill-box Vacuum Window for PAM

(4) LHCD System view from SST1 Tokamak side

हिंदी माह - पुरस्कार वितरण समारोह

16 अगस्त से 14 सितंबर 2021 तक आयोजित हिंदी माह समारोह की प्रतियोगिता के विजेताओं को पुरस्कार प्रदान करने हेतु दिनांक 17 सितंबर 2021 को पुरस्कार वितरण समारोह का आयोजन किया गया। इस अवसर पर डॉ. शशांक चतुर्वेदी, निदेशक, डॉ. प्रवीण कुमार आत्रेय, डीन आर एंड डी, श्री निरंजन वैष्णव, मुख्य प्रशासनिक अधिकारी एवं श्री राज सिंह, उपाध्यक्ष, राभाकास ने विभिन्न प्रतियोगिताओं के विजेताओं को पुरस्कार प्रदान किये। हिंदी में उत्कृष्ट कार्य करने हेतु वर्ष 2020-21 के लिए क्रय अनुभाग को राजभाषा शील्ड एवं डॉ. रितेश सुगंधी, वैज्ञानिक अधिकारी-एफ को राजभाषा पुरस्कार प्रदान किया गया। निदेशक महोदय ने संस्थान में हिंदी के व्यापक प्रचार-प्रसार हेतु किये जा रहे प्रयासों एवं नराकास स्तर पर प्राप्त उपलब्धियों की प्रशंसा की और आगे भी इसी उत्साह से राजभाषा को पूरी निष्ठा से प्रयोग में लाने का संदेश दिया। उन्होंने विभिन्न प्रतियोगिताओं के मूल्यांकन में निर्णायकों के महत्वपूर्ण योगदान की सराहना की और सभी विजेताओं को बधाई दी। श्री प्रवीण कुमार आत्रेय ने हर वर्ष संस्थान में आयोजित हिंदी कार्यक्रमों में प्रतिभागियों की बढ़ती संख्या पर प्रसन्नता व्यक्त करते हुए कहा की इसी प्रकार कर्मचारियों का उत्साह बढ़ता रहा तो निश्चित रूप से राजभाषा कार्यान्वयन में आसानी होगी। श्री राज सिंह ने अपने उद्बोधन में हिंदी को सहज रूप में सरलता के साथ अपनाने की सलाह दी और हिंदी के कठिन शब्दों का प्रयोग करने से बचने का सुझाव दिया। श्री निरंजन वैष्णव ने सभी प्रतिभागियों को हिंदी माह की गतिविधियों के सुचारू रूप से पूर्ण होने के लिए धन्यवाद दिया और वर्ष भर आयोजित होने वाली अन्य हिंदी गतिविधियों में भी भाग लेने के लिए सभी कर्मचारियों को प्रेरित किया। अंत में डॉ. संध्या दवे ने इस आयोजन को सफल बनाने हेतु हिंदी अनुभाग की ओर से राजभाषा कार्यान्वयन समिति एवं हिंदी प्रतियोगिता समिति के सभी सदस्यों को धन्यवाद दिया।

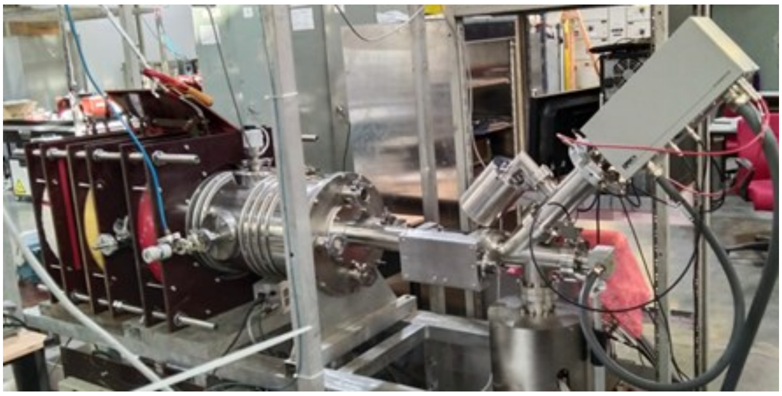
हिंदी माह समारोह की पुरस्कार वितरण समारोह की तस्वीरें

हिंदी माह - पुरस्कार वितरण समारोह

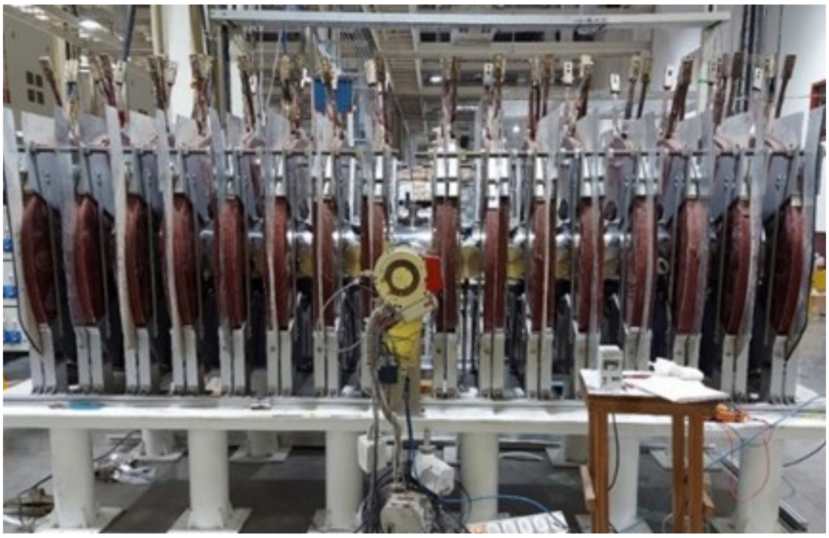
हिंदी माह समारोह की पुरस्कार वितरण समारोह की तस्वीरें

Magnetized Plasma Development Laboratory

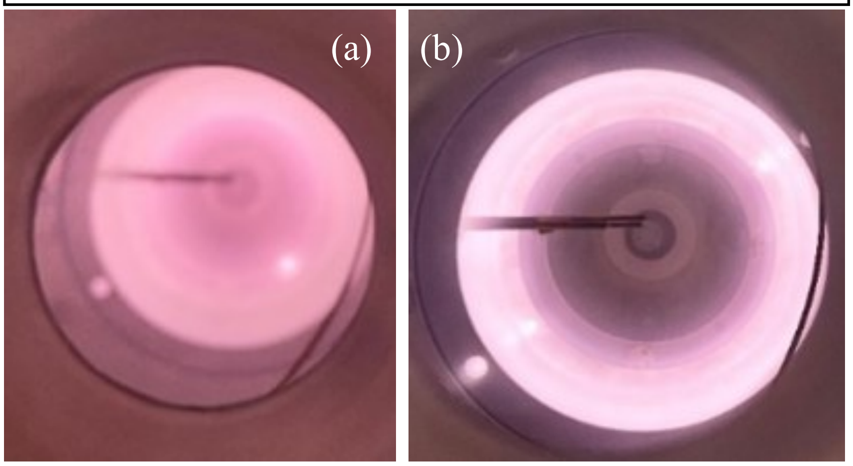
Magnetized Plasma Development laboratory was initiated in 2011, with a primary motivation to enable research and innovation in low temperature magnetized plasmas; *applied to fusion, industrial and space plasma technologies*. The experimental research spans from *negative ion plasma, to the development of alternate plasma & ion beam sources with advanced plasma diagnostic systems/ sensors*; vital for the characterization & controlling of a plasma system. The experiments helped to learn; how the global properties of a magnetized plasma column can be externally controlled, the underlying mechanism behind charge particles transport across magnetic fields in presence of obstacles, how magnetic field help to enhance negative ion production by creating inhomogeneous electron temperature inside the discharge, and the core behaviour of capacitive coupled radio-frequency discharges to create uniform plasma. For focussing on the above goals, specific experimental systems namely BEAM (*Basic experiments in Axially Magnetized Plasma*), the SPIN-eX (*Stimulated Phenomena in Negative Ion experiment*) and LAPS (*Large Area plasma Source*) have been developed through assiduous efforts by motivated research scholars and scientists. MPD also has exclusive and state-of-the-art plasma diagnostic instruments such as; EQP-300 Mass & Energy Analyzer system and dual pulse Nd:YAG laser for the diagnostics of negative ions. A number of innovative plasma sources based on magnetized hollow cathodes and cylindrical radio-frequency electrodes with axial magnetic field has been demonstrated. The ability to spatially control plasma density and temperature, are the key feature of these sources. Along this a range of plasma diagnostics based on microwave hairpin probe and RF compensated Langmuir probes have been developed in-house for the diagnostics of negative ions.



(L) The BEAM setup houses the EQP-300 diagnostic system, which provides direct measurement of ion energies ranging from 0.5 to 1000 eV for a wide range of species with mass range 1-300 a.m.u. The instrument is used for characterization of multi-component ionic species inside plasma and facilitate the in-house development of plasma based ion sources. (R) The SPIN-eX device is integrated with a 6 nanoseconds dual pulse Nd:YAG laser system, with an adjustable delay of 100 ns to several 100’s of microseconds. The 1064 nm (fundamental) wavelength is used for the detachment of negative hydrogen ions; and 532 nm (second harmonic) is suitable for photo-detachment of negative oxygen ions.



(L) The APPEL-device has a combination of 16 electromagnets producing 0.5 Tesla magnetic field in excess of 10 minutes over a length of 0.4 m and radial uniformity 40 cm. The experimental system will provide a test bed for conducting versatile experiments like hypervelocity beam-beam interaction with material targets inside magnetic field trap within the linear device.



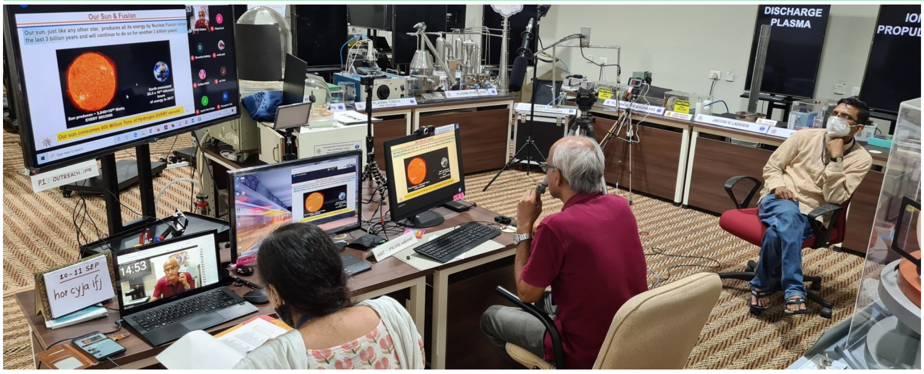
(Top) Members of the MPD Laboratory (L) (a) Photograph of plasma inside the cylindrical device (b) With application of magnetic field, the energetic electrons remain confined near the surface of the electrodes leaving cold electrons inside the central region.

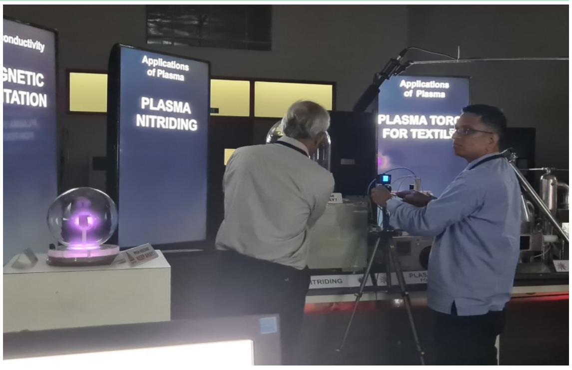
Activities of the Outreach Division

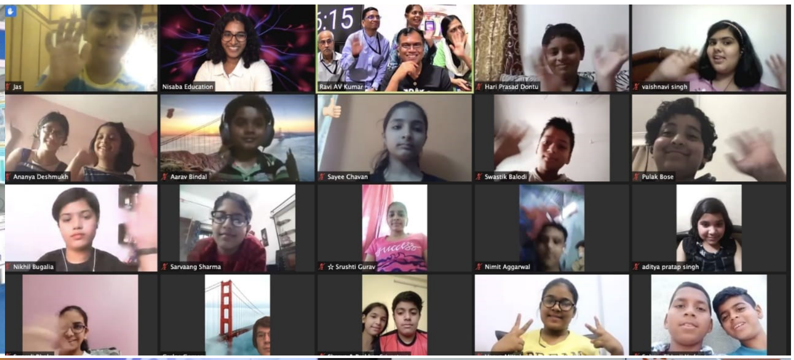
Since establishing the IPR Outreach Division (ORD) in Dec 2017, the group has carried out various outreach activities across the country. Some of the activities include ;

- Participation in science & technology exhibitions across India and showcasing technologies developed by IPR
- Conducting training programs on Plasma, its Applications and Nuclear Fusion for science teachers across the country
- Organizing the IPR National Science Day activities.
- Participation in various DAE organized outreach events
- Organizing webinars for a wide range of audiences ranging from primary, higher secondary, UG and PG students as well as teachers.
- Development of resource materials such as books, posters, science activity kit, DVD's, exhibits *etc.* for various outreach activities.
- Organizing academic visits to IPR
- Conducting science outreach programs in rural schools of Gujarat
- Generating video contents based on technologies developed by IPR

However, during the COVID-19 pandemic and its aftermath, all outreach activities outside the campus were stopped, so Outreach Division had to come up with alternate ways to continue outreach activities. The webinar program was thus designed and implemented in July 2020. With different levels of popular talks designed to cater to school students, UG/PG students, science teachers as well as general public, the USP of the program were the hands-on live exhibits of plasma and its applications. A set of 14 exhibits were designed and built and used for the webinars. During the period from July 2020 to September 2021, ORD conducted over 38 webinar training programs with a total of over 2150 participants.



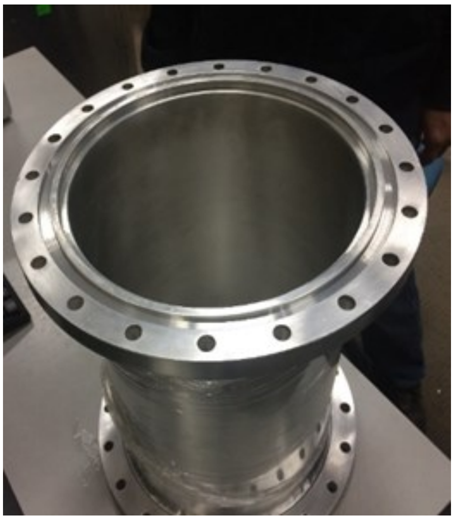




Members of the Outreach Division (L-R) Narendra Chauhan, K. K. Mohandas, Ravi A V Kumar, Chhaya Chavda and Harsha Machchhar

Development of High Power Aluminium Coaxial Transmission Line

A new, high power $9^{3/16}$ inch sized lightweight and low cost aluminium coaxial transmission line was designed and developed domestically using indigenous technology and with the help of domestic industries. High power RF transmission lines are required to be seamless and generally made by extrusion technique. Though a few domestic industries have recently extruded smaller diameter pipes, the requirement of larger diameter of 9 inch, straightness of < 2.1mm/m for over 3000mm length, stringent ovality constraint (< 3.2µ and thinner wall thickness (4mm) made the development challenging. The new line is fabricated, tested and compared with traditionally imported expensive copper transmission lines used in IPR till recently. The new Aluminium Transmission line is having 56% less weight, 500% cheaper, and can be quickly manufactured instead of dependence on importing copper pipes with long lead time. The new line is tested to withstand 40% higher breakdown voltage at DC. The Aluminium lines are very less prone to ovality during handling, easy for maintenance due to lightweight, no corrosion issue like copper. The new line is now successfully integrated with Aditya-U ICRH system and tested for high power RF.




(L) A section of the transmission line (R) The transmission line under testing

Ultra High Voltage System (UHVS) Division

The Ultra High Voltage Systems (UHVS) Division of IPR has set-up a UHVS Laboratory wherein they have indigenously designed and build two large High Voltage DC Power Supplies viz., 500 kV/100 mA up-gradable to 1000 kV/100 mA; and 250 kV/2 A upgradable to 500 kV/few tens of ampere. All the developmental efforts of UHVS division focuses on Make in India/ *Atma Nirbhar Bharat Abhiyan* of Govt. of India, and have developed these systems in close collaboration with Indian Micro, Small, Medium Enterprise (MSME). UHVS Division is also developing in-house small (upto 50 kW) rating AC and DC power supplies which are being used by other divisions of IPR. The UHVS laboratory is equipped with state-of-art measuring instruments, testing equipment's and infrastructure facilitating safe operation of Power Supply Systems.

The 500 kV/100 mA DC PS System along with the members of the UHVS division

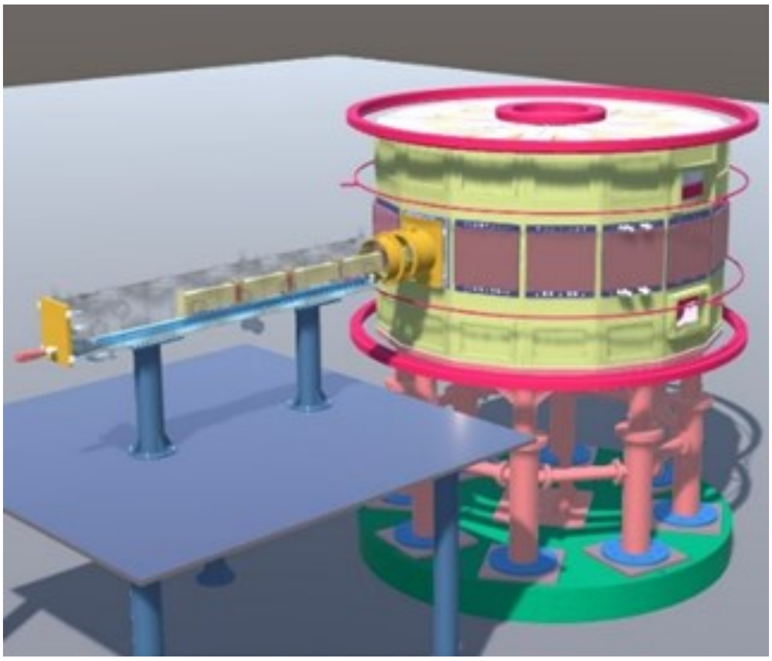
Remote Handling & Robotics Technology Development Division

The Remote Handling & Robotics Technology Development Division (RHRTD) has been actively involved in development of Remote Handling (RH) systems to cater the various inspection and maintenance requirements in challenging environments such as tokamaks. To minimize maintenance cycles and increase availability of machine for experiments, In-service inspection operations without breaking vacuum becomes necessary. The RHRTD division has successfully developed a vacuum and high temperature compatible In-Vessel Inspection System (IVIS) for In-service inspection of SST-1. IVIS is a 4m long 6 DOF articulated arm deployed toroidally carrying a camera inside the IVIS vacuum vessel without breaking the vacuum. The division has also established a 3 sided fully immersive CAVE VR facility at IPR. The VR facility is extremely useful in creating 3D virtual walkthroughs of the machine, accurate virtual prototyping eliminating need of physical prototypes, design reviews and analysis by integrating various CAD & simulation software, Real-time monitoring and control of remote handling operations and customized operator training by simulating multiple scenarios etc.

The RHRTD division under international task agreements successfully completed various tasks for International Thermonuclear Experimental Reactor (ITER). These tasks include service contract for engineering support to ITER RH control systems, concept design & system analysis of ITER Multi-Purpose Deployer (MPD), RH compatibility assessment of ITER Diagnostics, Kinematics and compatibility assessment for ITER MPD for decontamination, installation and removal of Blanket manifolds, and maintenance of the articulated joints. Also, the division has successfully delivered conceptual design of the RH compatible structure fort the ELM control coils for Joint European Torus (JET), UK.

The present developments include indigenous development of a hyper redundant inspection system which is a cable driven long reach arm, having dexterity similar to an elephant trunk deployable in narrow spaces & challenging environments, a dual arm manipulator which can perform human-like coordinated manipulation tasks and a 6- DOF Haptic force feedback master arm to be used by operators to have perception of the forces for fast, precise and accurate control of the slave robot.

RHRTD members (L-R) Jignesh Chauhan, Manoah Stephen, Ravi Ranjan Tiwari, Naveen Rastogi and K. K. Gotewal

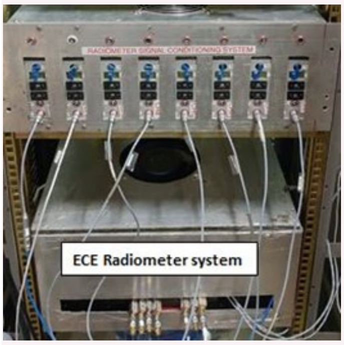


(L) VR “cave” facility at IPR (R) Computer visualization of integration of IVIS system in SST-1

Microwave & ECE Diagnostics Section

Microwave & ECE Diagnostics Section is involved in the Design, Development And Operation Of Plasma Diagnostics Systems using microwave / terahertz frequency spectrum techniques. At the same time, the group is involved in Millimetre / Sub-millimetre Domain Instrumentation and measurements which still remains a technological challenge yet to be devised and perfected. The Microwave & ECE Diagnostics group was established a decade ago to cater to these measurement challenges. With the passage of time, the group has evolved itself in the process of developing different techniques in these frontier areas. These include -

W/D Band (100/140 GHz) Heterodyne Interferometer System : Microwave interferometer system measures plasma line averaged density using millimeter wave frequency (30-300 GHz). The wavelength of the wave travelling through the plasma changes due to the refractive index of the plasma medium with respect to the wave passing through the free space. Interferometer measures this difference in the wavelength in terms of phase. This phase information gives the plasma density. 100 GHz six channel interferometer system,100 & 140 GHz single channel interferometer systems are operational at IPR.



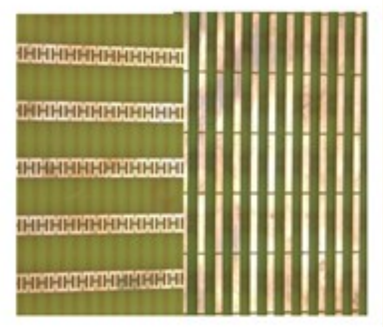
E-Band ECE Radiometer System : The electron cyclotron emission (ECE) Radiometer Diagnostic is a passive microwave receiver that provides local electron temperature measurements, spatially and temporally. A 16-ch. super-heterodyne Radiometer system at Aditya-U measures the second harmonic frequency range of 65-82 GHz with a spatial resolution of 1.2 cm and a temporal resolution of 10μs. Another 8-ch. heterodyne Radiometer at SST-1 provides the second harmonic measurements for a frequency range of 74-86 GHz with a spatial resolution of 0.6 cm and a temporal resolution of 10μs.

Michelson Interferometer System (70- 500 GHz) : Fourier transform Michelson interferometer diagnostic measures the spectral and temporal evolution of plasma electron temperature profile up to several harmonics by probing the full electron cyclotron emission (ECE) spectrum emitted by high-temperature plasmas in fusion experiments. The diagnostic measures the ECE spectrum in the spectral range 70–500 GHz and studies broadband plasma electron temperature profile and its dynamics in SST-1 tokamak. Michelson interferometer is absolutely calibrated with hot – cold technique and the sensitivity of the diagnostics is decided by these measurements.

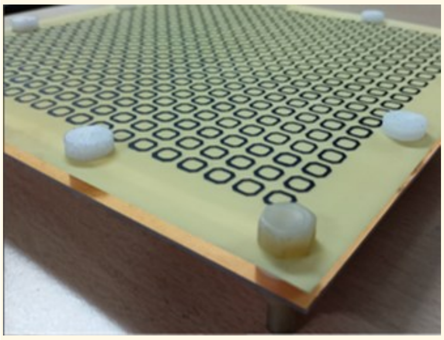
Ultrafast Super Heterodyne FMCW Ka-Band (26-40 GHz) Reflectometry System : Reflectometer is an ultra wide band and ultra fast radar like diagnostic which operates in 18-28 GHz and 26-40 GHz frequency ranges. It is capable of measuring radial density profile in 0.4-1.9 10^{19} m^{-3} ranges. It sweeps the complete frequency range in 5 microseconds which enable hundreds of profile measurements in a single plasma shot. Spatial resolution for the system is 1cm approx. This system has been completely developed in-house at IPR.

Members of the Microwave & ECE Diagnostics Section

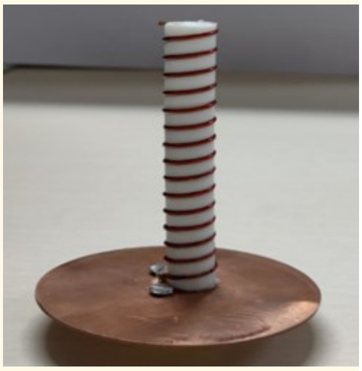
Microwave & ECE Diagnostics Section



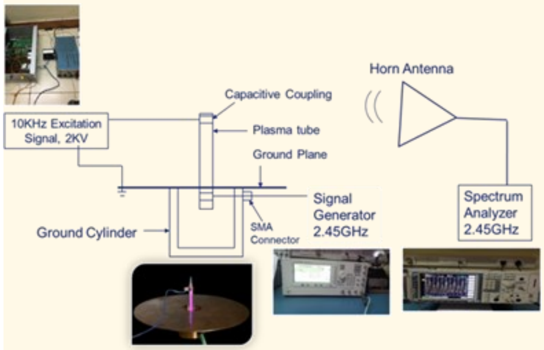
Meta-Material – Design, Development & Characterization : Meta-materials are used in stealth applications to hide materials / objects from the incoming radar signals for the desired frequency region. At IPR, we used CST microwave studio software to design the meta-materials. Experiments are carried out to verify the final results with respect to the simulated data. Vector network analyzer is used to investigate the reflection and transmission parameters and determine material's absorbing ability. High quality meta-materials can be designed having very good absorption coefficient.



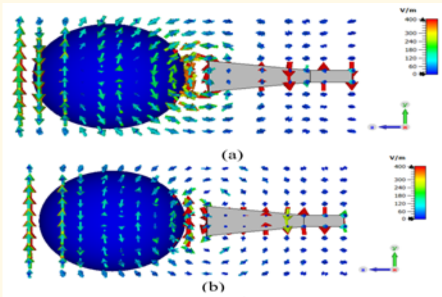
Wide Incidence and Polarization Insensitive Metasurface Absorbers : A wide incidence and polarization-insensitive Metasurface RADAR Absorber is designed using CST Microwave Studio, to achieve 99% absorptivity for X and Ku frequency spectrum (8-18 GHz) under the normal angle of incidence, and 90% absorptivity under the oblique angle of incidence up to 50º within X-Band to Ku-Band spectrum. The designed Metasurface absorber is fabricated and characterized, using ABmm Vector Network Analyzer (VNA) 8-220 GHz system and free space measurement method, for both normal and oblique angle of incidence, and it is observed that measured absorption characteristics are in good agreement with numerical findings.



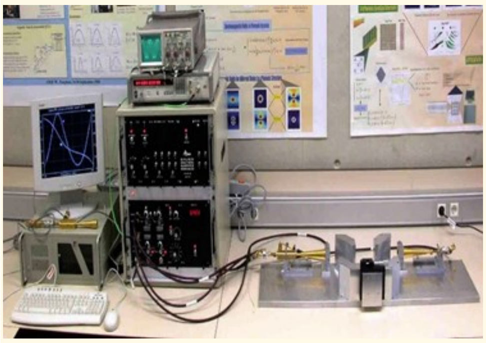
•Development of Helical Antenna: Antenna is a device used for radiating and receiving electromagnetic waves. In today communication system, there is huge demand of circularly polarized antennas. The main merit of circularly polarized antennas over linearly polarized antennas are that it avoids signal degradation due to polarization mismatch and multipath interference. In this work, a wideband circularly polarized two-layer concentric Cylindrical Dielectric Resonator Antenna is developed for C-band applications. The helix is used to excite the two orthogonal modes in quadrature phase which result in the circular polarization. This antenna covers impedance bandwidth of 50.46 % ranging from 3.60 GHz to 6.03 GHz and 3-dB axial ratio impedance bandwidth of 43.13% (4.20 GHz – 6.51 GHz) with measured peak gain of 10.9 dBi at 4.5 GHz.



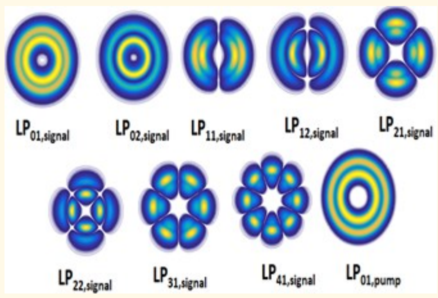
Computational and Experimental Analysis of Plasma Antenna : Design and development of Plasma antenna at 2.45 GHz, which is made up of a dielectric cylindrical glass tube, filled with a neutral gas such as Neon and Argon at low pressure. The effective axial length of the plasma generated inside the tube can be gradually increased or decreased as a function of input power, which, in turn, helps to tune/retune the resonant plasma antenna to the desired frequency. This type of antenna is useful for RADAR and military Wi-Fi communication systems where a continuous change in frequency could be required.



Simulation Study of Luneburg Lens on K-band Horn Antenna for FMCW Reflectometry Applications In FMCW Reflectometry diagnostic, antenna radiation beam plays a crucial role in measuring the electron density profile of tokamak plasmas. Reflectometry technique assumes that electromagnetic waves are reflected from the equatorial center of the tokamak plasma. For this assumption to be true we should be radiating a point beam & need a beam diameter which is as close to this size at a distance of few hundreds mm which is a typical tokamak parameter, the plasma center. In view of the above requirements the highest possible gain/directivity is required which will improve its sensitivity and precision. A Luneburg lens (LL) is a good solution for increasing the gain-directivity of a broadband low-gain antenna



Millimeter Wave Laboratory Test Facility at IPR (8-220 GHz) : The millimetre wave laboratory at Microwave & ECE Lab, IPR is equipped with state of the art measurement equipment ranging from few Hz to 220 GHz. These include – (i) Full 2 -Port VNA with frequency range: 8 to 224 GHz, (ii) Quasi Optical Material Testing Bench from 40 – 220 GHz (iii) Spectrum Analysers from 20 Hz – 220 GHz (iv) Signal Generator from 250 KHz – 170 GHz (v) Power Meters from 50 MHz – 220 GHz (vi) High end Functional Generators & Oscilloscopes.



EDFA for Space Division Multiplexing Based Optical Communication System : In order to increase the data carrying capacity beyond Shannon's Limit, it is necessary to develop "Few Mode Erbium Doped Fiber Amplifiers (FM-EDFA)" for Space Division Multiplexing based optical communication system. We have designed a FM-EDFA for C -Band frequency which could simultaneously amplify 8 modes groups as shown in the adjacent figure with almost equal amplification.

The Scientific Information Resource Centre (SIRC)

The Scientific Information Resource Centre (SIRC) at IPR is the hub of intellectual activities, connecting its community to the specialized curated scientific contents and facilitating the flow of knowledge resources. It supports the scientific and technical programmes of the Institute by providing physical and intellectual access to scholarly information. It also helps in generating new knowledge in the areas of institutional research. Library as part of the SIRC acts as a gateway to Plasma Physics and Fusion Science and Technology information, has a huge collection of resources, both in Print and Electronic formats and it aims to develop a comprehensive collection of documents/resources valuable to the user community. Modern technological tools are efficiently used towards managing services. Library collaborates with many National and International libraries and provides information services not only to the researches within the institute but also globally. SIRC team at IPR always endeavor to excel in the information organization and dissemination process.

Members of the SIRC (L-R) Neha, Kartik, Shilpa, Smita, Saroj, Shravan, Swarup and Payal

Memories

Past Events @ IPR

- ***Mr. Abhishek Saraswat,*** gave a talk on "*Development of a compact multivariable sensor probe for two-phase detection in high-temperature PbLi-Ar columns*" at International Conference on Diagnostics for Fusion Reactors (ICFRD2020), on 6th September 2021
- ***Dr. Shashank Chaturvedi,*** Director IPR, Gandhinagar, gave a special talk on "*Science-Based Development of Plasma and Fusion Technologies: Achievements and Challenges*" at Celebration of Engineer's Day 2021, Homi Bhabha National Institute, on 20th September 2021
- ***Mr. K. A. Jadeja,*** gave a talk on "*The Role of Wall Conditioning Procedures in Vacuum Vessel for ADITYA Upgrade Tokamak*" at National Conference on Advances in Materials Science: Challenges and Opportunities (AMSCO2021), M. K. B. University, Bhavnagar, on 21st September 2021
- ***Ms. Hiral B. Joshi,*** gave a talk on "*Effect of enclosure geometries on the performance of plasma-based microwave absorber*" at National Conference on Advances in materials science: Challenges and Opportunities (AMSCO – 2021), M. K. B. University, Bhavnagar, on 21st September 2021 (Awarded **1st prize for poster Presentation**)
- ***Dr. Arunsinh Zala,*** gave a talk on "*XRD & SEM techniques - an overview*" at "National Webinar Series on Processing and Characterization of Materials (PCM-21) at Metallurgy Department, Government Engineering College, Gandhinagar, on 21st September 2021
- ***Mr. Bharat Singh Rawat,*** gave a talk on "*Effects of axial magnetic field in a magnetic multipole line cusp ion source*" at International Conference on Ion Sources (ICIS-2021), on 23rd September 2021
- ***Talks presented at 5th Asia-Pacific Conference on Plasma Physics, Japan, 26 September-1 October 2021***
  - ***Ms. Snehlata Aggarwal,*** gave a talk on "*Time-of-flight low-energy analyzer for Aditya-U Tokamak*"
  - ***Dr. Nirmal Bisai,*** gave a talk on "*Blob Formation Mechanism from 3D Plasma Simulation in Scrape-off Layer Tokamak Plasmas*"
  - ***Dr. Ankita Gaur,*** gave a talk on "*Studies on electromagnetic properties of multilayer/ coaxial circular waveguide*"
  - ***Dr. Debasis Chandra,*** gave a talk on "*Synergistic influence of equilibrium toroidal flows on RMP control of ELMs*"
  - ***Ms. Swapnali Khamaru,*** gave a talk on "*Discovery of a quiescent toroidal nonneutral plasma state at small aspect ratios*"
  - ***Mr. Ayan Adhikari,*** gave a talk on "*Evolution of Plasma in the Influence of Varying Ratio of Transverse to Ambient Magnetic Field of LVPD-Upgrade*"
- ***Dr. Mukesh Ranjan,*** gave a talk on "*Harnessing Plasmas for Societal Applications*" on 1st October 2021 (**Colloquium #306)**
- ***Dr. Rohit Kumar Saini,*** IIT, Dhanbad, gave a talk on "*Design and Characterization of High Performance Circularly Polarized Planar Antennas for Wireless Communication*" on 1st October 2021
- ***Dr. Shruti Priya,*** IIT, Dhanbad, gave a talk on "*Self-Multiplexing Antennas using Substrate Integrated Waveguide*" on 8th October 2021
- ***Dr. Sayantan Mukherjee,*** KIIT, Bhubaneshwar, gave a talk on "*Thermo-physical properties of nanofluids*" on 14th October 2021
- ***Dr. Yogendra Kumar,*** gave a talk on "*Surface modifications study of Si substrate in Ar/O2 RF plasma for semiconductor device applications*" on 13th October 2021

Upcoming Events

- European Cryogenics Days 2021, 3-4 November 2021, https://www.cryoeurope.org/events/conferences/european-cryogenics-days-2021.html
- 63rd Annual Meeting of the APS Division of Plasma Physics, Pittsburgh, United States, 8-12 November 2021. https://engage.aps.org/dpp/meetings/annual-meeting
- 30th International Toki Conference on Plasma and Fusion Research (ITC 30), 16-19 November 2021. https://itc.nifs.ac.jp/
- 39th Annual IVS Conference, Conferences on Atomic and Plasma Physics (IVS-IPSTA), BarIlan University, Israel, 17 Nov 2021 https://www.ivs.org.il/IVS2016
- 3rd Research Coordination Meeting of the Neutral Beams CRP, IAEA, Vienna, Austria, 24-26 November 2021 on Data for Atomic Processes of Neutral Beams in Fusion Plasma. https://amdis.iaea.org/meetings/neutral-beams-rcm3/
- 4th IAEA Technical Meeting on Fusion Data Processing, Validation and Analysis, Southwestern Institute of Physics (SWIP) Chengdu, China, 30 November-03 December 2021. https://conferences.iaea.org/event/251/
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Know Your Colleague

Mr. Imran A. Mansuri joined IPR as an Engineer-SC in May 2006 with SST-1 Data Acquisition Division and contributed to the development of CAMAC system using LabVIEW/LabWindows CVI for SST-1 fast diagnostic channels. He was involved in the upgradation of SST-1 fast data acquisition to PXI Express based system. He developed Matlab GUI based SST-1 data analysis software SSTPLOT.

He also worked at CEA, France in 2014 under the IPR/IRFM collaboration for the Pulse supervision module development. He was chosen to be part of the newly formed DAC Division in 2017 due to his experience in DAQ. Since then he is mainly involved in the development and maintenance of various DAQ systems i.e. SST-1 DAQ system & PXI based DAQ for various diagnostic systems of IPR, Matlab as well as Python based Data analysis/Post processing software etc. Currently he is also involved in the enhancement of Aditya data acquisition system and its post processing software.

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