वार्षिक प्रतिवेदन
2020-2021

ANNUAL REPORT
2020-2021

प्लाज़्मा अनुसंधान संस्थान
Institute for **Plasma Research**
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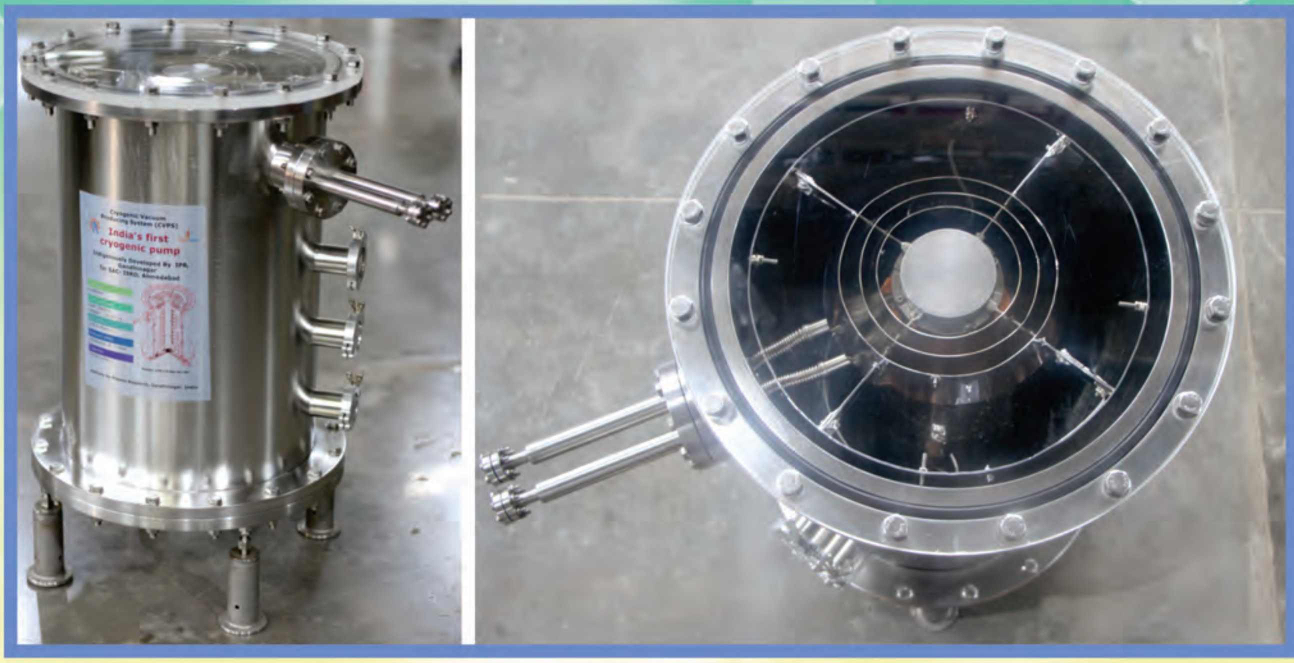

400 मिमी ओपनिंग के साथ आईपीआर में स्वदेशी रूप से विकसित क्रायो-पंप

Indigenously developed Cryo-Pump at IPR with 400 mm opening

स्वदेशी रूप से आईपीआर में विकसित हैंड-हेल्ड प्लाज़्मा स्टेरलाइज़र

Portable Hand-Held Plasma Sterilizer Indigenously developed at IPR

आवरण चित्र : डायवर्टर कॉयल ऑपरेशन के साथ आदित्य-अपग्रेड प्लाज़्मा डिस्चार्ज - स्ट्राइक पॉइंट दिखाते हुए

Cover Image: Aditya-Upgrade Plasma Discharge with divertor coil operation showing strike point

ANNUAL REPORT
2020-2021

प्लाज़्मा अनुसंधान संस्थान

Institute for Plasma Research

Bhat, Gandhinagar 382428

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EXECUTIVE SUMMARY

The Institute continued to make progress in three major areas, viz., (1) Societal and industrial applications of Plasma Science & Technology, (2) Fusion research and ITER deliveries, (3) Basic studies in the science of plasmas. The pace of progress was sustained despite disruption caused by the pandemic and delays in deliveries from suppliers.

IPR continued to develop & improve indigenous technologies with applications in sectors covering waste disposal, health, space, defence, industry, textiles and agriculture. The highlights include: (a) creating a bacteria-resistant catheter surface by plasma treatment; (b) development & testing of a portable hand-held plasma sterilizer and a glow discharge based plasma sterilizer for action against a range of microbes; (c) development of nano anti-microbial coatings for application to face masks and personal protective equipment; (d) development & testing of a system for producing plasma-activated water for healthcare and agricultural applications. IPR's High Performance Computing facility ANTYA, which achieved 11th position in a list of top supercomputers in India, saw a steadily growing user base and was used for running a variety of in-house as well as commercial software, including MHD, PIC, molecular dynamics as well as AI-based applications. One of the AI-tools identifies humans in CCTV images even in cluttered environments. Plasma antennas as well as steerable antenna arrays were developed. A Technology Incubation Centre was inaugurated at IPR, as part of DAE's thrust towards rapid deployment of societally-relevant technologies. An active Outreach programme was continued online, covering a large number of schools and colleges, despite the restrictions imposed due to Covid-19.

Remarkable progress was achieved in Aditya-U and SST-1 operations. Aditya-U achieved a peak current of 212 kA (85% of the design value) as well as repeatable discharges at the 200 kA level, a maximum shot duration of 400 ms (30% higher than the design value) and operation of the toroidal electromagnets at the full design value of 1.5 Tesla. Deuterium plasmas were created in Aditya-U for the first time. Progress on SST-1 was marked with the first-time energizing of the PF3 upper and lower coil pairs to 600 A/turn for a flat top duration of 7 sec. An indigenous vacuum barrier was developed & tested to meet a challenging set of requirements (electrical, cryogenic, vacuum, mechanical and gas-breakdown) for feeding current to the superconducting coils of SST-1. High-pressure tests (25 bar) at elevated temperatures were successfully completed for indigenously-developed components having 1 mm electro-deposited copper layer – this will be useful for similar components on neutral beam systems and plasma facing components in tokamaks. A 27 keV, 14 A H^+ ion beam was obtained for 3 seconds on a positive ion source-based SST1-neutral beam test stand. Indigenously-developed cryopumps and a sophisticated fiber-optic based imaging system were supplied for other Indian programmes. As part of technology development for tritium handling, coatings of Erbia (Er_2O_3) were produced on stainless steel using a high temperature reactive magnetron sputter coating process. The coating has been found to produce a 100-fold reduction in the hydrogen permeation rate through stainless steel.

ITER-India continued deliveries of in-kind commitments as the manufacturing work progressed. Nearly 100% deliveries from 4 out of the 9 packages have been completed and a significant number have also been successfully installed at the ITER site. Major achievements included completion of fabrication of the cryostat and in-wall neutron shielding blocks. The last batch of the cryostat top lid segments was shipped to ITER. along with 99% deliveries of components related to cooling water systems. Machine assembly started at ITER France with the base section of the cryostat being installed in the tokamak pit as the first major component. Close to five kilometres of cryolines and "warm lines" and a total of 16 circuits of Group Y cryolines and 48 circuits of warmlines have been successfully pressure tested in the cryoplant area of ITER. The pressure tests have been conducted with good quality in compliance with the technical specifications given by ITER Organization, and are now ready for operation with the Cryo-liquefaction plants.

Some of the major developments in basic plasma science are: (a) excitation and studies of whistler modes for the first time in a large laboratory device in India, (b) improving the control over electron energy distribution function, (c) increased pulse-length of pure electron plasmas to world-record levels, (d) creation of almost turbulence-free plasmas in a multi-cusp device, (e) experimental demonstration of dusty-plasma monolayer crystal and first order phase transition, and (f) innovative experiments on creation of negative ions using helicon waves; (g) Molecular Dynamics simulations for a strongly-coupled plasma have, for the first time, identified a transition from incompressible to compressible fluid.

DIRECTOR,
IPR.

ANNUAL REPORT

APRIL 2020 TO MARCH 2021

Since 1986 the institute has been involved in plasma physics research with fast growing facilities, trained man power and many fruitful national and international collaborations. Starting with small tokamak experiments and basic plasma experiments, the institute has been acquiring expertise in most of the relevant scientific and technological requirements for controlled thermonuclear fusion. Through the participation of the country in the ITER project, technologies related to fusion are being developed in the institute which are also being tested in the international arena. Also the technologies thus developed are being made available and being applied to many other societal problems benefiting the country. The estalishment of High Perfomance Computing (HPC) with 1 petaflop (1 PF) has increased the computing facilties also tremendously.

CHAPTERS

CHAPTER A

SUMMARY OF SCIENTIFIC & TECHNOLOGICAL PROGRAMMES

A.1 Plasma Based Technologies & Applications

IPR has a long-standing, focused programme for developing plasma technologies for a variety of societal applications, such as waste management, medical/health, agriculture, textile, industrial, space and defence. These are time-bound projects with clear deliverables involving partnerships with a variety of end-users including industry. Technology has also been transferred to industry in several areas. Progress in these areas is described in the following section.

A.1.1 Plasma Surface Engineering Applications

Antifouling Properties on Silicone Catheter Surface by Plasma Treatment: Catheter-related infections (CRIs) are one of the most common Hospital-Acquired Infections (HAI), caused by microbial colonization known as 'biofilm'. This can lead to increasing morbidity and mortality of patients. Researchers around the world are working on development of promising strategies based on material science and surface engineering to address these limitations. IPR's study, based on an anti-fouling approach, involves modification in surface properties such that bacterial cells are not able to adhere and grow further. Preliminary results reveal that a plasma-treated catheter surface has considerably altered surface chemistry and morphology. Microbiological test results have shown significantly less (~ 90%) bacterial adhesion on plasma treated silicone catheter surface as compared to the bare surface. Figure A.1.1 show the untreated (a,b & c) and treated (d,e & f) bare silicone catheter surface which shows the absence of colonies after the treatment.

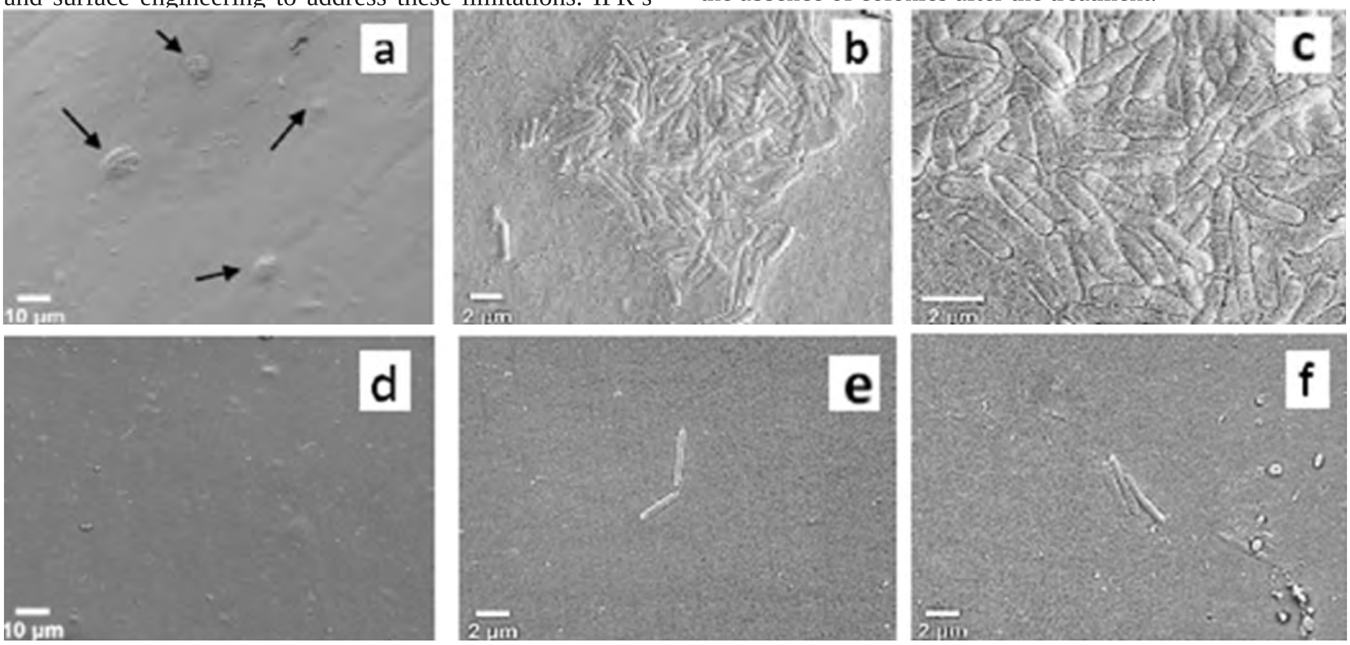

Figure A.1.1 Figures (a, b and c) are SEM (Scanning Electron Microscopy) images of bare silicone catheter surface at different magnifications, in which microbial colonies can be seen. Figures (d, e and f) are images of plasma treated surface in which no such colonies are found

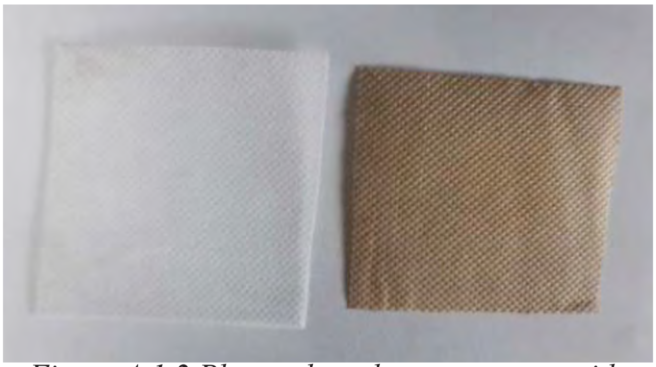

Figure A.1.2 Plasma-based nano-copper oxide coating made on polypropylene Fabric

***Nano Anti-microbial coatings*:** Nano-silver coatings on fabric as well as yarn, which offer anti-microbial properties, are normally expensive. Plasma-based nano-copper oxide (CuO) coating can also offer anti-microbial properties. Using a device called a magnetron, 100 nm thick layers of CuO have been made on polypropylene Fabric. Presently these coatings are being examined for their anti-microbial properties. Such coatings can be useful for making face masks, personal protective equipment, etc.

A.1.2 Atmospheric Plasma Applications

Portable Hand Held Plasma Sterilizer: A portable hand held plasma sterilizer, indigenously developed by IPR, consists of a plasma unit with multiple jets (~100 numbers) along with power supply (230 V, 50 Hz). The portable sterilizer has been developed for disinfection of surfaces contaminated by microbes like bacteria and viruses. The device uses air at atmospheric pressure as the operating gas. The plasma generated from this device has a maximum temperature of 30^{o}C, making it particularly useful for sterilizing heat-sensitive materials. Preliminary test results on disinfection of bacteria (C. albicans, P. auruginosa and E.coli) revealed that a 180 second treatment led to near complete wipe out of all the bacterial colonies. The sterilizer was also tested on SARS-CoV2 and it was found that 79% viral reduction was obtained after treating for 300 seconds. The results are promising and indicate that this device can be used in hospitals and has a potential to sterilize surfaces that cannot be moved like bedside tables, bed mattresses, privacy curtains, slings for patient lifting, table tops, wooden furniture in patient’s room, wall blinds and medical equipments. Further testing and development is in progress. Figure A.1.3 show the portable hand-held plasma sterilizer and a mask being tested.

Figure A.1.3 (left)Portable hand sterilizer (top) Testing of mask using this portable plasma sterilizer

Plasma Activated Water (PAW) in Healthcare, Agriculture and Food Sector: Plasma activated water (PAW) has great potential to be used as a chemical-free alternative for disinfection against bacteria, fungi, viruses, etc. IPR has developed a compact, low-cost facility to produce PAW using non-thermal pencil plasma jet (PPJ). The interaction of the PPJ with water leads to formation of various reactive oxygen-nitrogen species (RONS). A detailed study shows that the reactivity and electrical conductivity of PAW can be controlled by optimizing process parameters. PAW with higher reactivity (ORP) has been found to inhibit the growth of bacteria and fungi, while PAW with low ORP value helps in improving seed germination and plant growth. A 6 Log reduction takes place when PAW interacts with P. aeruginosa (Figure A.1.2.2) and S. aureus even with few seconds of exposure, and this bactericidal efficacy is retained in long-term. Morphological analysis and fluorescence microscopy shows that PAW exposure with bacteria and fungi damages the outer membrane, due to which intra-cellular material leaks out, resulting in their inactivation.

Plasma Activated Water (PAW) work for milk industry: Water does not normally contain any reactive radicals. Hence, for disinfection of milk cans, detergents are commonly used to produce radicals with water. Later, to remove the extra detergent from the cans, a lot of water has to be used. Plasma Activated Water (PAW) is produced by exposing distilled water to atmospheric plasma, leading to formation of radicals like NO_2^- ions, H_2O_2, gaseous O_3, NO_3^- ions, dissolved O_3 etc. A study has been done to determine the suitability of PAW in disinfection of milk cans. Microbial reduction

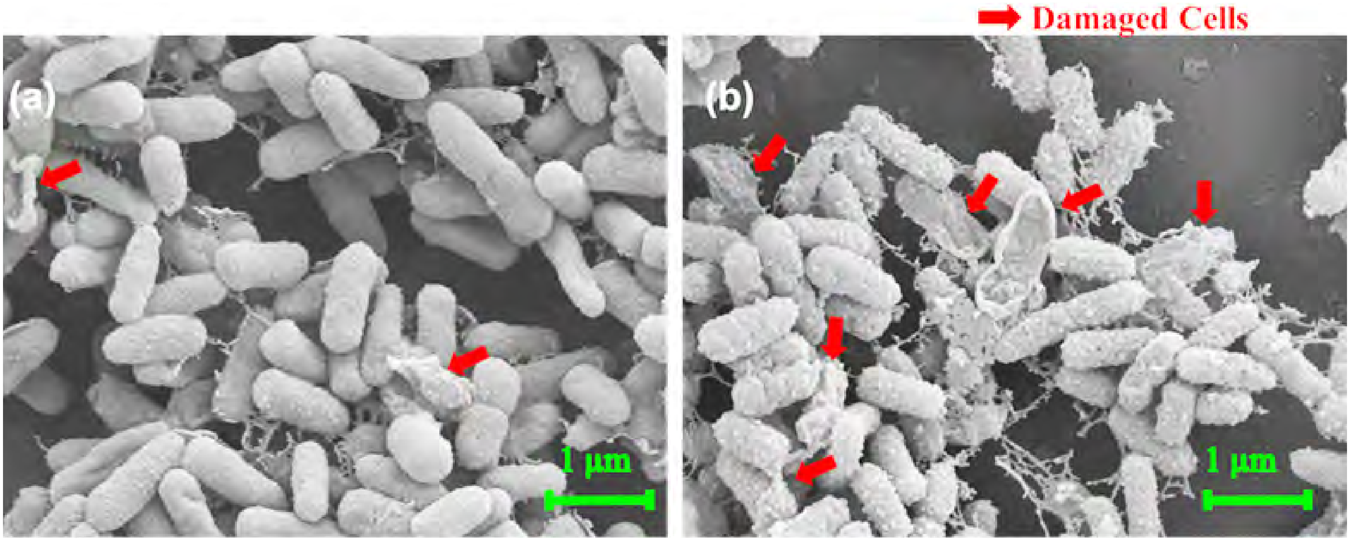

Figure A.1.4 Morphology of P. aeruginosa cells after treatment with (a) control and (b) PAW

is found to be 71% for 10 seconds exposure for cans made of different materials like glass, low density polyethylene, polypropylene, stainless steel and aluminium. More detailed studies are in progress.

Study on fungicidal properties of PAW on lemons: Lemons stored in cold storages beyond 2-3 months, depending upon the storage conditions, are often found to decay due to fungal growth. Since plasma activated water (PAW) has active radicals, it can be used as a fungicide. For a feasibility study, fungi from stored lemons were isolated and wetted with PAW for about 15 minutes. It was found that there is a 100% fungus reduction. Further studies are in progress to optimize the procedure and develop a system that can be used for industry.

Glow discharge based Plasma Sterilizer: An earlier version of such a system has been tested at B.V. Patel Pharmaceutical Education and Research Development (PERD) Centre, Ahmedabad, and found to work against different kinds of bacteria. That system was too large to use inside a BSL-3 facility, which is essential for testing against dangerous viruses like Covid-19. A compact version has now been developed and will shortly be sent for testing. Figure A.1.5 shows the developed plasma sterilizer in action (fig. a) and the setup (fig b)

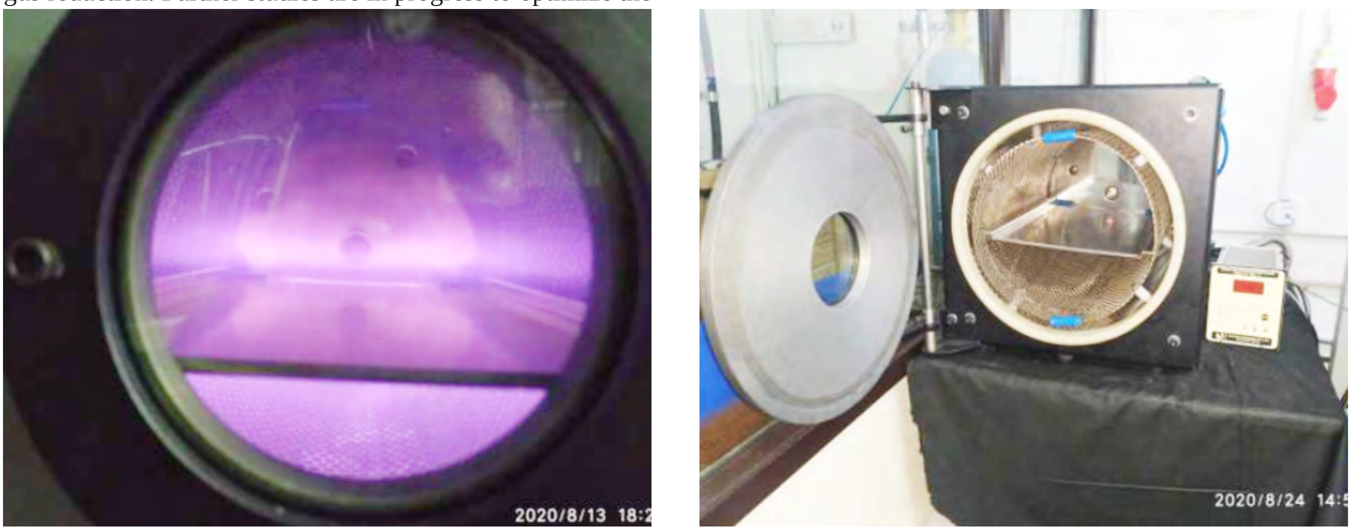

Figure A.1.5 Compact, glow-discharge based plasma sterilizer.

A.1.3 Other Technologies

Delivery of First indigenously-developed Cryopump to Space Applications Centre, ISRO: IPR and SAC-ISRO Ahmedabad signed an MOU in 2017, covering the indigenous development & delivery of three cryopumps by IPR to SAC. The first prototype cryopump (figure A.1.6) of 400 mm opening, with cryo cooling provided by a cylindrical bath at its center with cryopanels attached to it, has been delivered to SAC. This provides a pumping speed of 5000 litres/s for Air/Nitrogen and a pumping capacity of 6000 mbar-l/sec. The Cryogenic Vacuum Producing System (CVPS) was tested at IPR and is now installed on a Cryo-Vac chamber at SAC Ahmedabad and is working as per specifications. This is a 100% Made in India Product, including Cryo-adhesive, Sorbents, coating, panels etc. The facility for making such panels is under one roof at IPR, along with in-house characterization and pumping performance evaluation. The gases that can be pumped with liquid Nitrogen coolant include Nitrogen, Argon, Water vapor & hydrocarbons, while pumping of Helium, Hydrogen, Xenon and other gases can be done using liquid helium.

Figure A.1.6 CVPS -400 mm –opening Liquid nitrogen based cryopump

Development and supply of fiber-optic based viewing system for Waste Management Division (WMD), BARC: A viewing facility is required in the waste management facility of nuclear establishments for remote handling of components and waste immobilization needs. Conventionally, this is done by using a CCD camera-based viewing system. The environment being highly radioactive, direct viewing leads to fast decay/damage of the CCD camera, sometimes within 1-2 days. This not only requires a change of the CCD camera but also adds to radioactive waste inventory and also a significant recurring cost. In order to address this problem, IPR developed a fiber optics based imaging system wherein the CCD camera is placed behind the shield room, with a radiation-resistant optical fiber conveying the optical signal to the camera. This is a spinoff from indigenous development of optical diagnostics for tokamak plasmas. The imaging system has been recently supplied and installed successfully at WMD, BARC. Image processing software based on AI was also developed at IPR and supplied for improving the clarity of the captured images. This is a significant contribution to nuclear waste management practice and know-how in India.

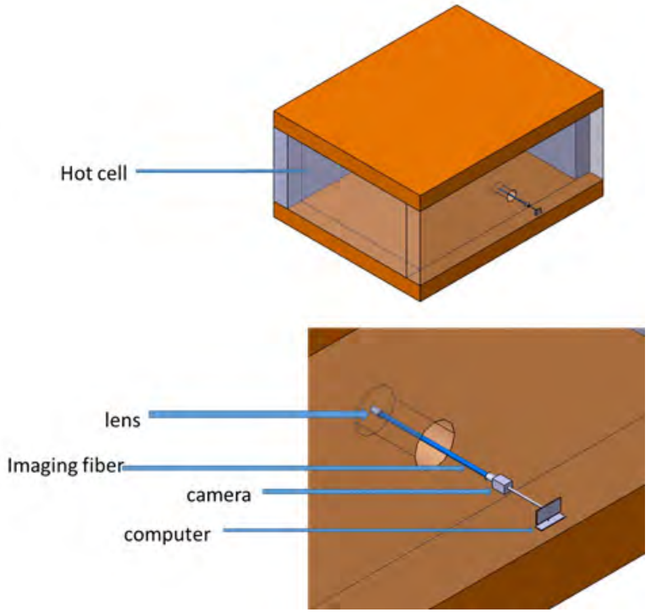

Figure A.1.7 CAD images showing the arrangement of CCD camera in the fiber optics based imaging system supplied to WMD, BARC

A.1.4 External Projects

A table with brief details about the external projects has been given below:

A) Projects Completed

Sr. no	Organisation	Description	Deliverables	Status
01	BARC-WMD	Optical Imaging system for waste management	Optical Imaging system with AI based software.	System installed in January 2021
02	Natural Storage Solutions Private Limited (NSSPL), Gujarat	Feasibility study of application of Plasma activated water & plasma jet for removal of fungus from lemon surface	Feasibility study report	Experiments with Plasma activated water and plasma jet were conducted. Initial results found promising.
03	SAC, ISRO	Development and installation of liquid nitrogen cooled cryopumps	03 nos. LN2 cooled Cryropumps	All 3 cryopumps installed at SAC, ISRO campus. First prototype installed in July 2020 and balance 2 nos installed in Feb 2021.
04	CIPET Ahmedabad	Development of a 3 layer geomembrane using plasma technology for adverse environment applications	Atmospheric pressure DBD plasma treatment system (01 no.)	Plasma System developed by IPR is installed and in use at CIPET Ahmedabad.
05	ARMREB, DRDO	Numerical simulation of electrical railgun	Software simulation report.	Completed in January 2021

B) Projects Started

Sr. no	Organisation	Description	Deliverables	Status
01	Uniexcel Agencies Pvt. Ltd.	Characterization of FeAl powders	Characterization report	Ongoing
02	IGCAR Kalapakkam	Upgradation of pulsed DC power supply for plasma nitriding unit	Pulsed DC power supply and demonstration of plasma nitriding system at IGCAR	Ongoing
03	ICMR-NIRT, Chennai	Development of artificial intelligence tool for screening/detection of pulmonary TB using chest X-Rays.	AI software tool capable for screening and diagnosis of TB using chest X-Rays.	Ongoing
04	Indian Space Research Organization	Synthesis and characterization of Boron Nitride nanostructures	1.Boron Nitride nano powder (~500 gm) to VSSC-ISRO 2. Report on synthesis and characterization of Boron Nitride nano powder	Boron Nitride nano powder (~500 gm) to VSSC-ISRO

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A.2 Fundamental Plasma Physics

Plasma is being created and characterized in various conditions so as to explore its fundamental properties which can be later used for applications. Here it is being studied in very small scale laboratory experiments as well as in moderately bigger size like Large Volume Plasma Device

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A.2.1 Basic Experiments

A.2.1 Basic Experiments

Large Volume Plasma Device (LVPD)

Controlled experiments on mitigation of energetic electrons by Whistlers: Experiments are underway to understand the role of whistler turbulence in the mitigation of high energy particles. In LVPD, oblique whistler waves are excited by reflected electrons from a magnetic mirror and they are seen interacting with the energetic electrons emanating out from the filamentary plasma source. Controlled experiments were performed using multi-filamentary plasma source producing plasma of density 10^{17} particles per cubic meter towards relating the energy of the electrons to the behavior of whistler wave turbulence. Systematic variation of the the discharge potential between 50V to 90V resulted in shifting and narrowing of the whistler mode frequency towards low-frequency side thus helping in mitigating the energetic electrons.

Large Area High Density Plasma Source: The LVPD machine is been being upgraded to produce more uniform and high density plasma with a Large Area Multi-filamentary Plasma Source [LAMPS] designed for ~ 10^{12}/cc plasma density and also for 50 ms duration of plasma discharges. The circular shaped LAMPS will consist of 162 numbers of W- filaments, each of dimension (ϕ= 0.5mm and L=180 mm). These filaments are powered through high current capacity Molybdenum current feedthroughs with water cooled ETP copper make cassettes. The total weight added by the plasma source assembly to LVPD-U system is approximately 400 Kg. A typical photograph of plasma source under development at IPR site is shown figure A.2.1. The new plasma source will also be supplemented by augmenting the new discharge power supply (DPS, 1000A at 150V for 50ms pulse) and solenoid power supply (SPS, 2500A at 175V for a pulse width of ~55ms). These power supplies are capable of producing plasma for 50 ms, an increase of approximately five times to the existing discharge pulse duration (~ 10ms).

Automated Status monitoring system & Web based electronic experiments logging facility: An automated status logging and monitoring system has been implemented using open source framework based on Syslog (RFC-3164) and web based data analytics on Graylog for the upgraded LVPD. The framework is interfaced with LabVIEW based SCADA system of LVPD using an in-house developed application in LabVIEW. The system has been applied successfully to the operation of radial probe positioning system and it will further be extended to the operation of all systems in the machine A application software platform for electronically logging experimental information has been developed for record keeping activities of LVPD plasma operations namely, 1) information on plasma pulses (shots), 2) parametric configurations, 3) noting of regular and maintenance activities, 4) scientific data and documents, and 5) raw data and processed data visualization facilities. The automated archival and backup scripts have also been developed..

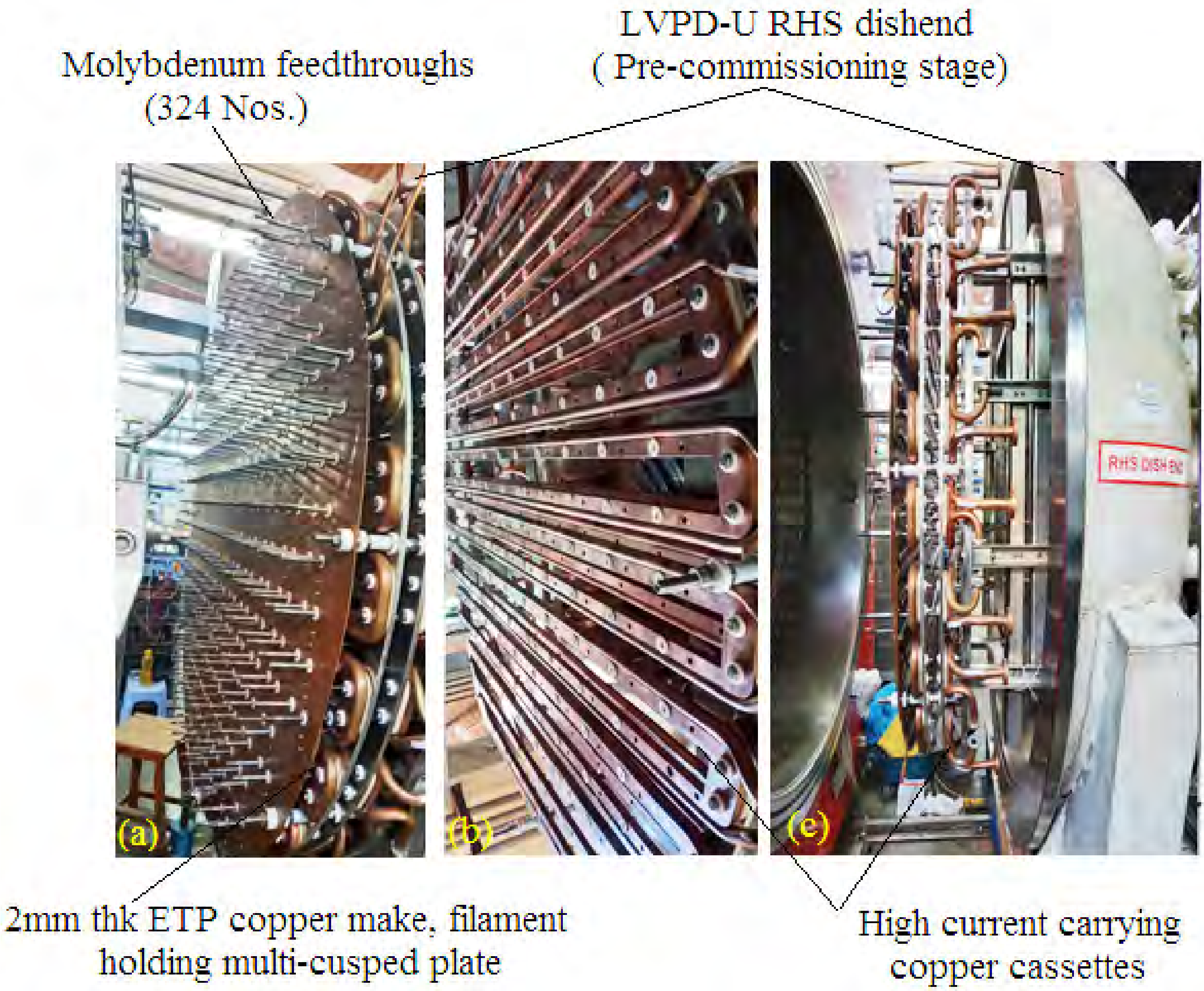

Figure A.2.1.The front and rear side view of pre-assembly stage of the new large area (~ 1.8 mm diameter) multi-filamentary plasma source is shown in figure (a) and (b) respectively. The pre-assembly of water cooled copper cassettes are shown augmented with the RHS dish end of LVPD.

Double Plasma Device

Radial Control of Electron Temperature Gradient with Optimized Operational Configuration of Double Plasma Device: A double plasma device (DPD) is tested for different operational configurations to identify suitable control for plasma parameters in a weakly ionized, unmagnetized plasma discharge. A separation grid is installed between the two chambers of DPD, which allows filtering of plasma from the first to the second chamber. Investigations are carried out to control the plasma parameters, especially the electron temperature by exploring the role of the grid. The grid bias is varied between −25–0 V and 0–30 V to reflect cooling and heating of plasma. The electron heating and cooling is prominent for the maximum ratio of n_source / n_target. The electron energy distribution function (EEDF) is obtained to describe the role of grid biasing in controlling the electron temperature in the second chamber. We have demonstrated control on the radial profile of electron temperature by charging different radial cross-sections of plasma differently by using a multi-grid assembly system (MGAS). We have also identified the suitable operational regime for DPD where exercising a radial control on electron temperature is possible. Such plasmas can facilitate investigations on electron temperature control for applications in plasma processing, cold–plasma material interaction, etc where low energy electrons are desired.

Non-Neutral Plasma Device

Small Aspect Ratio Toroidal Electron plasma eXperiment in 'C' shaped torus (SMARTEX-C): A new copper bus-bar based toroidal field magnet for SMARTEX-C has been designed to generate B-field of 1 kGauss at minor axis with the help of DC Power Supply of 3kA at 20V. It is air-cooled and designed such that it can be operated for 15-20 seconds at maximum B-field. The magnet system consists of 24 turns made of copper bus-bars uniformly placed with 150 toroidal angular separation. Our design makes optimal use of the limited space in the inner bore and therefore meets the challenge of accommodating the maximum number of turns of requisite dimensions in the small bore. It allows the flexibility to dis-assemble the TF coil from radial or top for easy access of radial or top ports during minor or major openings. The force on the toroidally wound conductors carrying a current of 3 kA will be high and can generate significant stresses detrimental to the coil especially the joints. In order to estimate the forces and resultant stresses, the conceived design has been modeled and the magnetic field and magnetic forces have been computed using a finite element software Comsol Multiphysics. To ensure reliable operation, a detail engineering analyses (electrical, magnetic, structural and thermal; both steady sate & transient) of the magnet design is carried out. Analyses have been carried out at normal magnetic field of 200 G and at high field of 1 kGauss. These analyses suggest that the present TF coils design can be operated in steady-state (for more than 600 s) with normal operating parameters (with I ~ 563 A) and for ~ 15-20 s at high magnetic fields of ~ 1 kG (with I ~ 3kA) with maximum temperature of TF coil not exceeding 70°C due to Joule heating. Toroidal magnetic field ripple has been less than 0.1% at minor axis and <1% even at the edge of the vacuum vessel, hence it is not poised to deteriorate the confinement of electron plasmas resulting due to any B-field ripple induced transport.

Figure A.2.2 A new copper bus-bar based toroidal field magnets fabricated for SMARTEX-C

Multi-Cusp Plasma Device

Role of Multi-Cusp Magnetic Field on Plasma Containment: Two magnetic configurations of Multi-cusp Plasma Device (MPD) have been explored to obtain high quiescence level, large uniform plasma region with nearly flat mean density and temperature profiles. In particular, properties of plasma in a Six Pole Six Magnet (SPSM) and Twelve Pole Six Magnet (TPSM) cusp configurations are rigorously compared and verified with old published results elsewhere. It is found that more uniform plasma with nearly flat profile (figure A.2.4)is

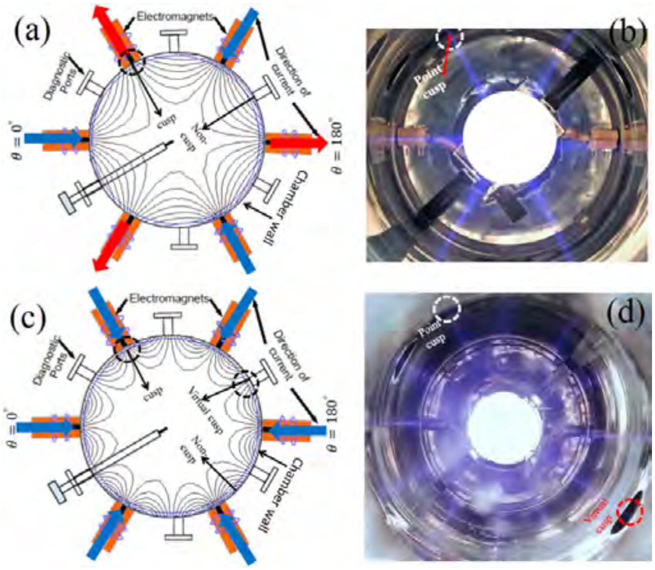

Figure A.2.3 (a) and (c) Simulated field lines of Six Pole Six Magnets (SPSM) and Twelve Pole Six Magnets (TPSM) , while (b) and (d) show the pictures of confined plasma

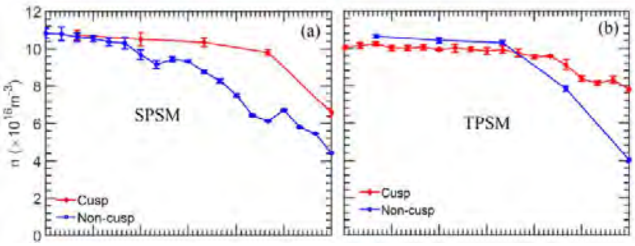

Figure A.2.4 Density profiles of both SPSM and TPSM configurations of the Multi-Cusp Device

found in TPSM along with increased quiescence level. Figure A.2.3 (a) and (c) Simulated field lines of Six Pole Six Magnets (SPSM) and Twelve Pole Six Magnets (TPSM) in the same experimental setup, while (b) and (d) show the pictures of plasma confined in SPSM and TPSM observed through the viewport from one end of the device, the center region of bright glow of filaments has been shadowed to record the feeble light from the wings or the cusp regions Findings are experimentally verified across various magnetic field strengths for both configurations.

<u>Excitation of Ion Acoustic Soliton in Multi-Cusp Plasma Device</u>: Ion Acoustic Solitons have been excited in the Multi-Cusp Plasma Device (MPD). MPD is a unique device in which different multi-pole cusp magnetic field configurations can be achieved. The excitation grid, a solid plate of molybdenum with a diameter of 50mm and thickness of 0.5mm, is placed inside the plasma at the center of the device at R=0 and Z=75 cm.. To excite the soliton a sinusoidal voltage of ~50vpp at 90 kHz frequency is applied to the grid. With this increase in the amplitude of perturbation signal, the excited waves show non-linear characteristics as Ion Acoustic Solitons.

Dusty Plasma Experiment Device

<u>Experimental Observation of a First-Order Phase Transition in a Complex Plasma Monolayer Crystal</u>: The formation and melting of a mono-layered charged dust particle crystal in a direct current (DC) glow discharge argon plasma is studied. The nature of the melting or formation process is established as a first-order phase transition from the variations in the Coulomb coupling parameter, the dust temperature, the structural order parameter, and from the existence of a hysteresis behavior. The experimental results are distinctly different from existing theoretical predictions for two dimensional crystals based on the Kosterlitz-Thouless-Halperin-Nelson-Young mechanism or the grain boundary induced melting and indicate a mechanism that is akin to a fluctuation induced first-order phase transition in complex plasmas.

<u>Excitation of Dust Acoustic Shock Waves in an Inhomogeneous Dusty Plasma</u>: An experimental investigation of the propagation characteristics of shock waves in an inhomogeneous dusty plasma is carried out in the dusty plasma experimental device. A homogeneous dusty plasma, made up of poly-dispersive kaolin particles, is initially formed in a direct current glow discharge argon plasma by maintaining a dynamic equilibrium of the pumping speed and the gas feeding rate. Later, an equilibrium density inhomogeneity in the dust fluid is created by introducing an imbalance in the original dynamic equilibrium. Non-linear wave structures are then excited in this inhomogeneous dusty plasma by a sudden compression in the dust fluid. These structures are identified as shock waves, and their amplitude and width profiles are measured spatially. Figure A.2.5 shows the image odf teh density crests and the intensity profile of the high amplitude crests. The amplitude of a shock structure is seen to increase, whereas the width broadens as it propagates down a decreasing dust density profile. A modified-Korteweg–de Vries–Burger equation is derived and used to provide a theoretical explanation of the results, including the power law scaling of the changes in the amplitude and width as a function of the background density.

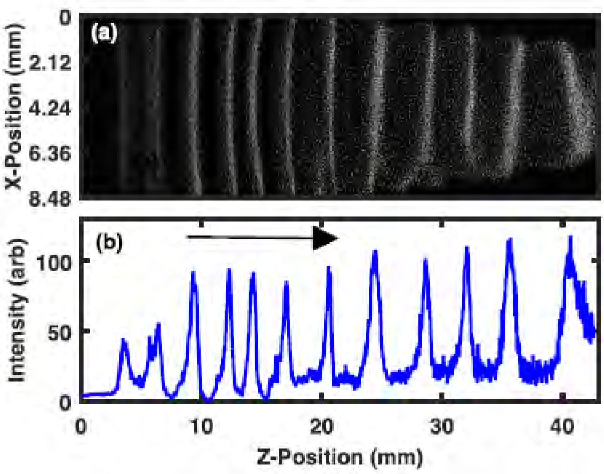

Figure A.2.5(a) Image of density crests in an inhomogeneous dust cloud.(b) Intensity profile of high amplitude density crests extracted from (a). The arrow represents the direction of propagation of the shock fronts.

Experimental Observation of Pinned Solitons in a Flowing Dusty Plasma: Pinned solitons are a special class of nonlinear solutions created by a supersonically moving object in a fluid. They move with the same velocity as the moving object and thereby remain pinned to the object. This well-known hydro-dynamical phenomenon has been shown to exist in numerical simulation studies but to date it has not been observed experimentally in a plasma. An experimental excitation of pinned solitons in a dusty (complex) plasma flowing over a charged obstacle has been observed for the first time and reported. The experiments are performed in a π shaped dusty plasma experimental (DPEx) device in which a dusty plasma is created in the background of a DC glow discharge Argon plasma using micron sized kaolin dust particles. A biased copper wire creates a potential structure that acts as a stationary charged object over which the dust fluid is made to flow at a highly supersonic speed. Under appropriate conditions, nonlinear stationary structures are observed in the laboratory frame that correspond to pinned structures moving with the speed of the obstacle in the frame of the moving fluid. A systematic study is made of the propagation characteristics of these solitons by carefully tuning the flow velocity of the dust fluid by changing the height of the potential structure. It is found that the nature of the pinned solitons changes from a single-humped one to a multi-humped one and their amplitudes increase with an increase of the flow velocity of the dust fluid. The experimental findings are then qualitatively compared with the numerical solutions of a model forced Korteweg de Vries (fKdV) equation.

Experiments for Negative Ion sources

Study on Negative Ion Production by Electronegative Gases in a Helicon Source: A helicon plasma source (HeliPS) experimental set-up is developed to perform experiments in electronegative gases. The schmetic of the HeliPS is shown in the figure A.2.6. The characterization of HeliPS is done in argon and oxygen discharge by varying the working pressure, magnetic field strength as well as radio frequency power at 13.56 MHz thereby identifying the optimum parameters for its operation. After characterization, experiments have been performed in electronegative gases such as oxygen and hydrogen to understand the effect of electron affinity in producing negative ions in such plasmas. To enhance the negative ion production, both magnetic filter and magnetic cage, used innovatively in such a system, shows interesting results on their influence in electronegative plasma production.

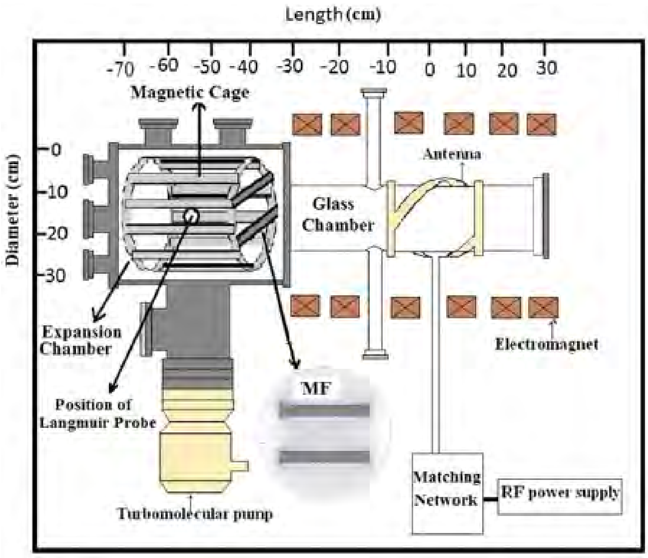

Figure A.2.6 Sketch of the helicon plasma source (HeliPS) experimental set-up.

Effect of Argon and Oxygen Gas Concentration on Mode Transition and Negative Ion Production in Helicon Discharge: The effect of mixing of argon and oxygen gas on the mode transition and negative ion production in the helicon discharge is investigated. In the source chamber of the experimental setup, argon–oxygen gas mixture plasma is produced by applying RF power from 100 W to 2000 W at an applied magnetic field of 0.03 T. In this experiment, the total flow rate is kept at 200 SCCM, corresponding to the working pressure of 4–5 × 10^{-1} Pa. The mode transition to helicon discharge is investigated by varying the concentration of these two gases. It is observed that an increase in the concentration of oxygen gas in the discharge shifts mode transition toward higher RF power values, indicating the influence of the nature of the working gas on the transition to the inductive as well as to the helicon mode. The variation of the electron density and temperature is explained in terms of particle and power balance equation. In the source and in the downstream expansion chamber, the effect of the concentration of argon gas on the negative ion production in oxygen discharge is also studied, and the results are explained in terms of various reactions involved in the production and loss of negative ions.

Prediction of Axial Variation of Plasma Potential in Helicon Plasma Source Using Linear Regression Techniques: Analytical expressions are used frequently for the determination and analysis of plasma parameters. Instead of relying on analytical expressions, the proposed method uses regression techniques supplemented with experimental data for the selected parameters (plasma potential). In the machine learning domain, this is equivalent to the creation of the training data set, building and training the model, and authenticating the result over a range of desired physical parameters. An experimental dataset is built using two axially movable Triple Langmuir Probe (TLPs) which measure the electron temperature, electron density, and electric potential of a plasma. The presented work is a first step towards developing an inclusive model with detailed kinetic simulations capable of characterizing the HELicon Experiment for Negative ion source (HELEN-I) with a single driver. Plasma potential is measured at different axial locations (z) by keeping pressure fixed at 6 mTorr.

<u>*Monte Carlo Simulation, Analytical and Experimental Studies on the Nozzle Structure of a Cs Vapour Delivery System for Negative Ion Sources*</u>: Experimental, analytical and Monte Carlo (MC) based study has been performed to investigate the nozzle structure of the cesium (Cs) vapour delivery tube of a Cs oven to ensure uniform Cs distribution with low Cs consumption rate (~2 mg/hr or less), suitable for fusion grade negative ion source application. The investigation suggests that Cs angular distribution and consumption rate is mainly governed by the nozzle aperture size at a constant oven reservoir temperature. The MC simulation results are compared with analytical calculations and benchmarked with the experimental results using one of the most suitable nozzle geometry, designed by calculations. Moreover, Cs spatial distribution from the nozzle head is correlated with the optimum Cs coverage duration on a plasma grid-like surface temperature condition, monitored by using infrared (IR) imaging technique. Infrared thermography is also used to diagnose time-dependent Cs coverage evolution on a surface both in situ and real-time under vacuum. Figure A.2.7 shows the infra-red image of the hair pin tungsten filament during the experiment. In ion source

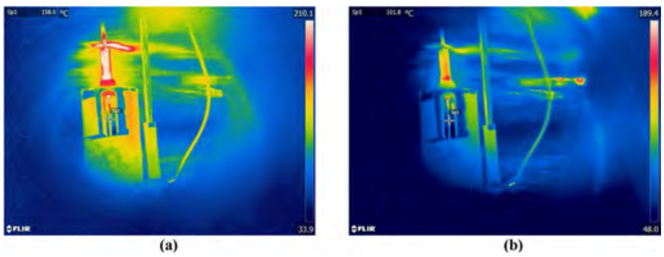

Figure A.2.7 (a) IR image of hair pin tungsten filament without Cs coverage at filament current~3 A and surface temperature~160 °C, (b) with Cs coverage atfilament current~3A and surface temperature~100 °C

application, Cs condition on the surface can be controlled by controlling the Cs oven temperature based on IR camera monitoring data in a feedback loop.

Inertial Electrostatic Confinement Fusion (IECF) Device

<u>*Kinetic Characteristics of Ions in an Inertial Electrostatic Confinement Device*</u>: The kinetic analyses are quite important when it comes to understanding the particle behavior in any device as they start to deviate from a continuum nature. In the present study, kinetic simulations are performed using the particle-in-cell method to analyze the behavior of ions inside a cylindrical inertial electrostatic confinement fusion (IECF) device which is being developed as a tabletop neutron source. Here, the lighter ions, like deuterium, are accelerated by applying an electrostatic field between the chamber wall (anode) and the cathode (cylindrical gridded wire), placed at the center of the device. The plasma potential profiles obtained from the simulated results indicate the formation of multiple potential well structures inside the cathode grid depending upon the applied cathode potential (from−1 to−5 kV). The ion density at the core region of the device is found to be of the order of 10^{16} m^{-3}, which closely resembles the experimental observations. Spatial variation of ion energy distribution function has been measured in order to observe the characteristics of ions at different cathode voltages. Finally, the simulated results are compared and found to be in good agreement with the experimental profiles (figure A.2.8). The present analysis can serve as a reference guide to optimize the technological parameters of the discharge process in IECF devices.

Laser blow-Off Experiments

<u>*Effect of Magnetic Field on the Lateral Interaction of Plasma Plumes*</u>: Lateral interaction between two geometrically modified plasma plumes in the presence of a transverse

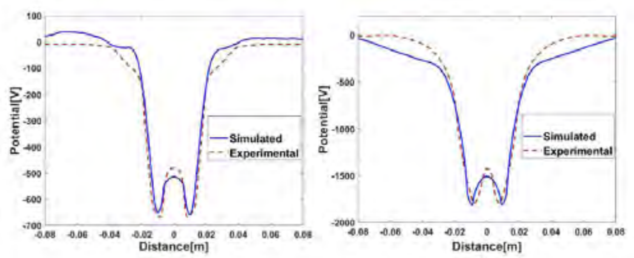

Figure A.2.8 Simulated potential profiles (blue lines) compared with the experimental ones (dashed red lines) during (a)−1kV,(b)−2kV magnetic field has been investigated. Characteristic behavior of both seed plumes and the interaction region in the presence of the field is compared with those for the field free case. Contrary to the field free case, no sharp interaction zone is observed; rather large enhancement in emission intensities in both seed and interaction regions is observed in the case of a magnetic field. The observed results could be explained on the basis of atomic analysis of the spectral lines from the interaction region of the interacting plumes. The physical processes responsible for higher electron temperature and increased ionic line emission from singly as well as doubly ionized aluminum have also been shortlisted.

Observation of Ion Acceleration in Nanosecond Laser Generated Plasma on a Nickel Thin Film under Rear Ablation Geometry: Acceleration has been observed for the ions produced in a 50-nm-thick nickel film coated on a quartz substrate, under nanosecond laser ablation, in the rear ablation geometry. A detailed study with varying background pressure and laser energy is done. Spectroscopic study including spectroscopic time of flight (STOF) measurements of ionic and other neutral transitions from the plasma has been undertaken. The STOF spectra recorded for ionic transition clearly show an enhancement in the velocity of the slow component as the background pressure increases. In addition, a large asymmetric spectral broadening in the 712.22-nm neutral line is observed, which increases with background pressure. While these observations have similarity to some of the reported studies on the acceleration of ionic species through double-layer formation, the electric fields calculated from the measured acceleration appear to be anomalously higher, and a double-layer concept seems to be inadequate. Moreover, the large asymmetry observed in the neutral line profile is indicative of microelectric fields present inside the laser produced plasma plume, which may play a role in the continuous acceleration of the ions. Interestingly, this asymmetry in spectral broadening exhibits temporal and spatial dependence, which indicates that significant electric field is present in the plasma plume even for longer duration and larger distance from the target. These spectroscopic observations of acceleration have also been complemented by triple Langmuir probe measurements.

Time-of-Flight Mass Spectrometry of Aluminium Plasma: Investigation of Multiply Charged Ions and Clusters: Ionic species in laser-produced plasma plume are generally analyzed by the time-of-flight method using a charge collector placed near to the target surface. One of the shortcomings of this method is the sacrifice of important information about large mass cluster ions and the different charge states of atomic ions. A modified Wiley–McLaren type time-of-flight mass spectrometer (TOFMS) has been designed, developed and optimized for the diagnostics of ions and cluster distribution in laser produced plasma (LPP) plume. Second harmonic (532 nm) from a pulsed Nd:YAG laser is used to ablate aluminium disk in a vacuum chamber evacuated to base pressure of 7×10^{-8} mbar. The mass spectrometric results of aluminium (Al) plasma are studied in detail. To minimize the degradation in detection and mass resolution of spectrometer due to the wide angular and energy spared of the ions in the plasma plume, optimization of the TOF spectrometer in different configurations, single as well as a double field, has also been done. Cluster ions as large as Al^{32+} and multiply charged ions (MCI) up to Al^{11+} are observed in the mass spectra. The possible pathways for the production of MCI and cluster ions could be explained on the basis of the Coulomb explosion mechanism

Other Experiments

Expansion Dynamics of Atmospheric Pressure Helium Plasma Jet in Ambient Air: The expansion dynamics of a helium plasma jet in ambient air is examined. By using a fast imaging technique, the expansion of plasma jet from glass nozzle to air is captured which is in the form of plasma bullet propagating into the air. To understand the plasma bullet travel path from glass nozzle to plasma jet tip a drag force model is used. Moreover, the spatial variation of plasma density along the plasma jet length is estimated using drift velocity, plasma jet current and the cross-sectional area of the plasma jet. It is observed that the slight increase in plasma density is due to the combined effect of reduction of drift velocity, plasma jet current, and jet cross-sectional area. The obtained plasma density from glass nozzle to jet tip is in the range of $(0.069\text{-}5.96) \times 10^{12}$ cm^{-3}. The above parameters can be of the essence in biological and industrial applications.

In-plane Optical Anisotropy and SERS Detection Efficiency of Self-Organized Gold Nanoparticles on Silicon Nanoripples: Substrate morphology-mediated plasmonic anisotropy and surface-enhanced Raman scattering-based molecular detection efficacy were studied on gold nanoparticles (Au-NPs). These nanoparticles were oblique angle grown and self-organized on ultralow energy ion-beam fabricated nanoscale rippled-Si (R-Si) substrates. To study the effect on plasmonic field coupling, the shape of Au-NPs is tuned from elongated to spherical ones by varying the growth angle leading to a change in the inter particle gap. Following this, post growth annealing of Au-NP arrays is carried out to change the shape and size of Au-NPs via Ostwald ripening process. The optical anisotropy is measured using generalized ellipsometry, while dielectric functions of Au-NP arrays are calculated using a biaxial layer model by fitting the Jones matrix elements. A stronger plasmonic field coupling becomes evident from the imaginary part of dielectric functions along x- and y-axes which is further supported by finite-difference time-domain (FDTD) simulations. Enormous near-field enhancement between Au-NPs leads to surface-enhanced Raman scattering (SERS)-based detection of an ultralow concentration (10 μM) of crystal violet dye. Further, FDTD simulation reveals that hotspot formation takes place between Au-NPs due to lesser interparticle gaps along the Au-NP arrays compared to the ones between two adjacent arrays. Thus, Au-NP arrays exhibit in-plane anisotropic optical response. The improved SERS-based detection efficacy of complex molecules is attributed to their enhanced Raman scattering cross-section in the vicinity of these hotspots. This study demonstrates that self-organized Au-NP arrays on nanoscale rippled-Si substrates can work as an efficient and longevous SERS sensor due to the prolonged stability of Au in environmental conditions. This study will pave the way to fabricate plasmonic devices and SERS-based sensing of complex molecules having low Raman scattering cross-sections.

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A.3 Tokamak Plasma Experiments

Experiments on the two tokamaks, ADITYA-U and SST-1, continued to make steady progress. The highlights of experiments on ADITYA-U include realization of plasma parameters close to the design values, deployment of a novel electromagnetic high-speed pellet injectors for the first time, experimental studies related to runaway electron generation and losses, toroidal rotation studies and modulation of drift tearing MHD modes. Continued technology improvements on SST-1 yielded, for the first time, a record 15 days of plasma operation with maximum ohmic pulse current durations of 650 ms, a good 200 ms improvement over the one obtained last year. The following sub-sections of this section provide details of the above.

A.3.1 Aditya Tokamak

Experiments in Aditya-Upgrade Tokamak

<u>Aditya-Upgrade Tokamak operated at full design value of magnetic field:</u> The Aditya-Upgrade tokamak has been operated at the full design value of 1.5 Tesla for the main (toroidal) magnetic field, combined with a long plasma duration of 360 milliseconds, which is 20% higher than the design value., as shown in the figure A.3.1.1.

<u>Deuterium Plasma Operation in Aditya-Upgrade Tokamak:</u> The Aditya-Upgrade tokamak has successfully demonstrated full Deuterium plasma operation for the first time in India. The long discharges (~ 300 ms) having ~140 kA of plasma current with deuterium as fuel gas (pre-fill as well as the gas-puffs: all deuterium) have been obtained at a main (toroidal)

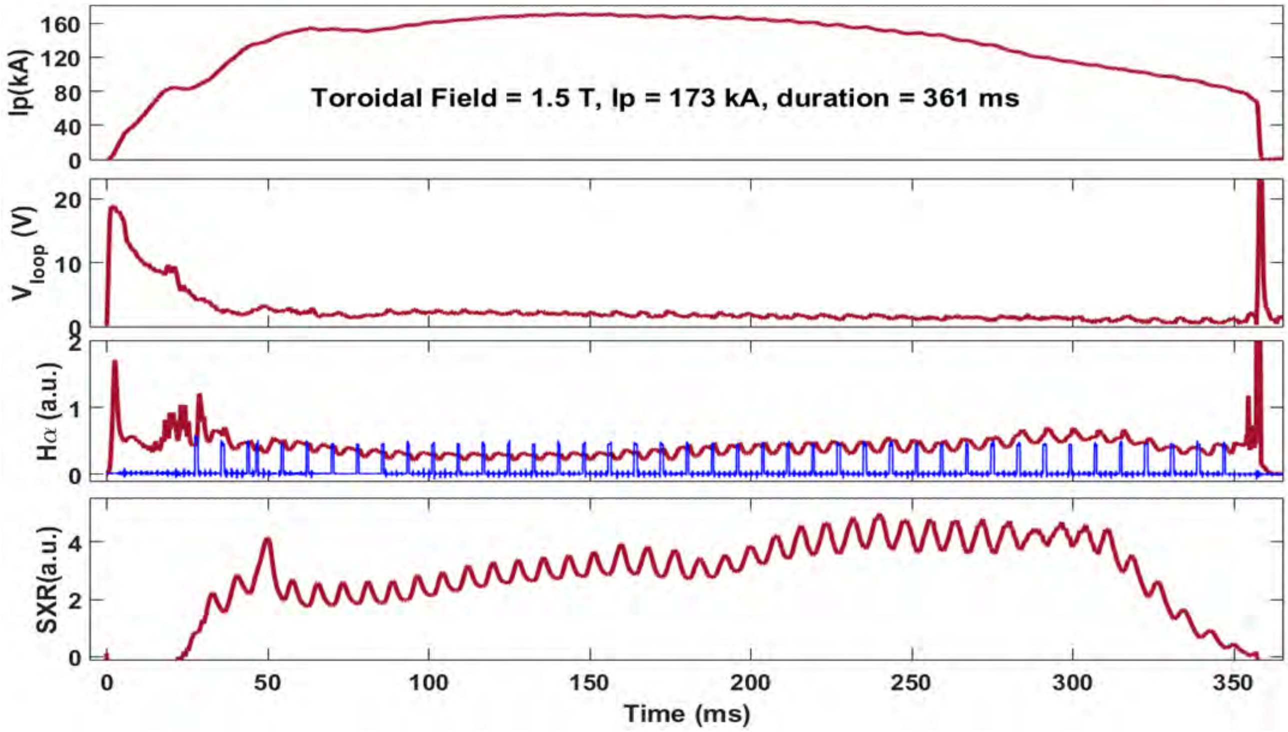

Figure A.3.1.1. Time evolution of Aditya-Upgrade shot (#34167), demonstrating 1.5 T toroidal field operation.

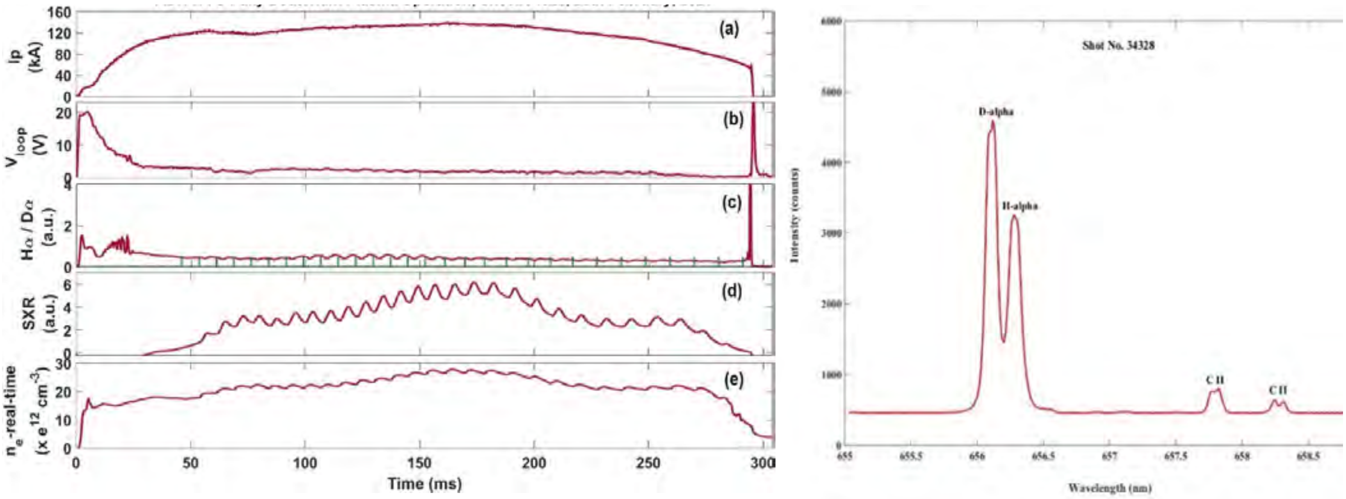

Figure A.3.1.2. (Left) The time evolution of fully Deuterium assisted Aditya-Upgrade plasma discharge (Shot #34328) represents the plasma parameters (a) Plasma current (kA)(b) Loop voltage (V) (c) Hα / Dα intensity (a.u.) and D2 gas pulses (d) Soft X-rays intensity (a.u.) and chord average real-time density (ne).

(Right). The D-alpha emission line measured using spectroscopic diagnostic for shot # 34328.

magnetic field of ~1.3 Tesla, and demonstrating an electron density of 3 x10^{19} m^{-3}. Spectroscopic measurements of D-alpha line intensity along with H-alpha line intensity (due to wall recycling as wall is loaded with hydrogen from previous discharges and also from discharge cleaning in hydrogen) is shown in the figures A.3.1.2.

Initial results of divertor strike point observations: Recent experimental campaigns in Aditya-Upgrade tokamak have demonstrated high-current, long-duration plasma discharges. While a peak current of 212 kA has been obtained (85% of the design value), repeatable discharges with current values over 200 kA have also been obtained. The maximum duration of 385 ms (28% higher than the design value) has been obtained recently. These achievements became possible because of sustained efforts put in to improve wall conditioning. For the first time in Aditya-Ugrade, plasma shaping has been attempted by energizing the newly-installed divertor coils, demonstrating the formation of a strike point on the lower side. The position of the strike point matches that predicted by the indigenously-developed plasma equilibrium code IPREQ.

Characterization of the Plasma Current Quench during Disruptions in Aditya Tokamak: The rate of plasma current-quench during tokamak plasma disruptions determines the electromagnetic forces on the in-vessel components/vacuum vessel. Also halo currents and rapid changes of poloidal field due to the plasma vertical displacement contribute to loads on vessel and in-vessel components and hence needs to be

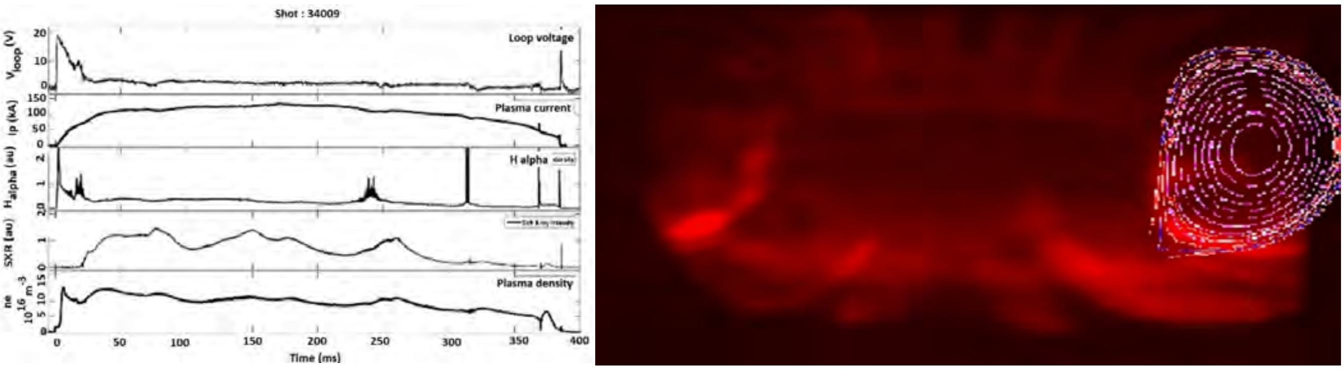

Figure A.3.1.3. (left)The plasma discharge with long duration of ~385 ms in the Aditya-Upgrade Tokamak . (right) The image of Aditya-Upgrade plasma discharge with divertor coil operation showing strike points on the bottom side studied thoroughly to safeguard these tokamak peripherals. The plasma current quench occurrence during the spontaneous major disruption has been investigated for a set of Aditya tokamak disrupted discharges and average plasma current quench and instantaneous current quench rates have been estimated. The fastest area-normalized plasma current (IP) quench time is observed to be~5 ms m^{-2}. The estimated post disruption plasma electron temperatures (PDET) are observed to be~15–35 eV and proportional to area-normalized plasma current quench time. Further analysis of several disruptive discharges of Aditya tokamak reveal that the current quench time is inversely proportional to the pre-disruptive values of edge safety factor, qa, and the current quench properties are strongly correlated with the prevailing pre-disruptive plasma magneto-hydro-dynamic (MHD) activities. For larger values of pre-disruptive qa, the larger island widths of m = 2 and m = 3 MHD modes leads to a significant overlap of these islands. Such an overlap along with the deeper locations of the islands inside the plasma column, as compared to discharges having smaller values of pre-disruptive qa, seems to facilitate the faster current quench.

Runaway Electron Mitigation with Supersonic Molecular Beam Injection (SMBI): The generation and subsequent loss of runaway electrons (REs) during the operation sequence in a tokamak is a potent threat to the plasma-facing components and the interface of actively cooled parts. Control and mitigation of REs are of prime importance to the safe operation and machine health of a fusion device. A supersonic molecular beam injection (SMBI) system has been installed in the Aditya-Upgrade tokamak to explore the effects of the high Mach number molecular beam on the REs and ways to mitigate the REs. In the majority of discharges in which SMBI has been injected, a burst in hard x-rays has been observed accompanying the SMBI pulse, indicating significant RE loss. This is followed by a long RE-mitigated phase in the discharge. The most plausible explanation of the mitigation of REs is minor disruption caused by SMBI. This in turn triggers field line stochastization and subsequent rapid RE loss. Finally, this leads to reorganization of the flux surfaces, resulting in bigger islands with the potential of trapping any surviving RE fraction.

Aditya-Upgrade Diagnostics

Experimental Results of Core Ion Temperature and Neutral Density Measurements on Using Four Channels Neutral Particle Analyzer: Core-ion temperature measurements are based on resolving the energy components and the analysis of fast neutrals coming out of the magnetic confinement of plasma. Aditya-Upgrade tokamak uses Neutral Particle Analyzer (NPA) based charge exchange diagnostic system for measurement of the core ion-temperature in the range of 100–300 eV of Aditya-Upgrade plasma. Several ohmic plasma discharges are investigated for the Aditya tokamak, which provides an estimate of core ion-temperature (Ti0) evaluation with time and its comparison with the core electron-temperature (T_{e0}). The analysis shows the ratio of Ti0/Te0 is typically in the rage of 30%–40%. Attempts have been made to estimate the neutral hydrogen (nH) density in the core regime and its evolution with time using a simple approach. The core neutral densities estimated in the order of 10^8 –10^9 cm^{-3} for ohmic discharges in Aditya-upgrade tokamak. Effect of the ion cyclotron radio frequency heating (ICRH) on the experimental charge-exchange spectrum is also observed, which shows a typical increase of the perpendicular ion temperature (Ti) by 50 eV.

Lanthanum Bromide (LaBr3 (Ce)) Based Hard X-Ray Spectroscopic Diagnostic for the Study of Runaway Electrons: Study of hard X-ray (HX) spectrum is an important tool to understand the runaway electrons (RE) behavior present in the tokamak plasma as these energetic electrons, especially those generated during disruption, represent a major threat to tokamak plasma devices in terms of melting and damaging the plasma-facing component (PFC) and thereby reduced the lifetime of the first wall. A LaBr3 (Ce) detector based spectroscopic diagnostic has been set up on the Aditya-Upgrade tokamak to measure the HX spectrum. This diagnostic consists of a photomultiplier tube and multi-channel analyzer along with the detector, viewing the whole plasma tangentially along a line of sight terminating on the limiter. The spectrum has been observed in the energy range of around ~ 75 keV to 3 MeV and is continuum in nature. The spectrum is having the peaks within ~ 85–150 keV and the estimated RE temperatures have been found to be in the range of 100–600 keV for the analyzed discharges. This temperature decreases with the increase of the thermal electron temperature of the discharges. The ratios of the estimated confinement time of runaway electron and energy confinement time of thermal particles are mostly inversely proportional to the plasma electron density.

Design & Development of 140 GHz D-Band Phase Locked Heterodyne Interferometer System for Real-Time Density Measurement: A 140 GHz phase-locked heterodyne interferometer system has been designed, developed and installed at Aditya-Upgrade Tokamak for real time density measurement. The interferometer uses a novel approach of zero-cross detection using in-phase and quadrature (IQ) signals with a single balanced mixer. The transmitter and receiver systems are phase locked by a 100 MHz crystal oscillator and the output signals are mixed in a single balanced mixer which produces highly stabilized intermediate frequency (IF) frequency of 2.0 GHz. This signal is further amplified by low noise amplifier (LNA) and power amplifier with built-in automatic gain control (AGC) of response time 5 ms. The AGC keeps the IF signal amplitude stable for 20–70 dB attenuation. This IF signal is further down converted to 100 KHz IQ signals using a synthesizer which is phase locked by the same 100 MHz crystal oscillator used for phase locking the transmitter and receiver oscillators. The 100 KHz IQ signals are digitized by built-in 12 bits ADCs and processed though FPGA programming for real time phase-density calculations. The developed system has minimum phase sensitivity of 0.07 radian and a time resolution of 5 μs with 10 KHz resolution for real time density measurement. The density evolution of plasma discharge and effect of gas puff on density built up is successfully measured in real time.

Phase Detection System Based on Digital Signal Processing in Millimeter Wave Interferometer for Fusion Plasma Diagnostics: The design and development of a processing unit for the microwave interferometer is proposed here. The Microwave interferometer is well known for its use in several applications, and one of them is to measure the electron density of fusion plasma. An indigenous effort has been made to build a phase detection system that can be used to calculate fusion plasma electron density for millimeter-wave interferometer. It consists of oven controlled crystal oscillator (OCXO), frequency synthesizer, IQ mixer, analog to digital converter (ADC), field programmable gate array (FPGA) for processing the task and other proximity electronics. The phase-detection algorithm is derived using MATLAB. Testing and hardware realization is achieved by implementing it on an FPGA-based system. All the relevant system development requirements are attained with more than 95 percent accuracy. The device will be used in Aditya-Upgrade tokamak for calculating electron plasma density.

A.3.2 Steadystate Superconducting Tokamak - 1 (SST-1)

Arc Detection system for Current Feeder System (CFS) PF ducts in SST-1 Cryogenics system: It is very crucial to detect arcs occur either due to Paschen discharges or any electrical faults inside the current feeders system (CFS) in SST-1. It is therefore, a novel technique using optical fibres has been to detect and alert the operators so that necessary action may be taken to mitigate any potential damages inside the CFS. This arc detection system would not only detect the vacuum arcs but also any reflected light from the cold surfaces (such as ~ 77 K surfaces of cryostat duct inside CFS in which superconducting (SC) magnet bus bars are connected with SC current feeders or current leads). Optical fibres are mounted inside the vacuum chamber using the vacuum compatible optical feedthroughs onto the PF ducts of Cryostat inside CFS and routed in vacuum through optical window. In this system, a photo transistor detects any light coming from flash / arcs in the visible spectrum and guides it through the vacuum compatible multimode aluminium coated pure silica optical fibres. The electronics card which is used to convert the light intensity to a voltage signal, is designed and developed indigenously. The work is in progress. Test experiments have been carried out to detect flash /arc created inside a vacuum chamber.

Development, testing and integration of new vacuum barrier with PF#3 coil bus-bars: The vacuum isolator/barrier is a crucial electrical component for superconducting (SC) magnets for Tokamaks operating at Cryo temperature, high current and high voltage. The SC magnets' cold terminal ends are housed in the current feeders system (CFS) and the warm terminal ends are connected to the room temperature (RT) electrical bus-bars of power supply. During the Ohmic transformer operation, huge voltage (up to a kV) may be induced on the poloidal field (PF) magnet coils that may cause damages either on the coil insulation or at the current leads or associated instrumentation feedthroughs via a Paschen discharge. It may also severely damage the magnet winding packs and therefore, to avoid such incidents, a vacuum isolation between cryostat and current leads vacuum chamber is required. Therefore, a vacuum barrier (VB) made out of dissimilar material has been indigenously developed which would help in isolating the SST-1 cryostat and the CFS. Further, it would also provide electrical barrier to avoid the propagation of Paschen discharge from CFS to the SST-1 cryostat so as to protect any damages of magnet winding packs. In

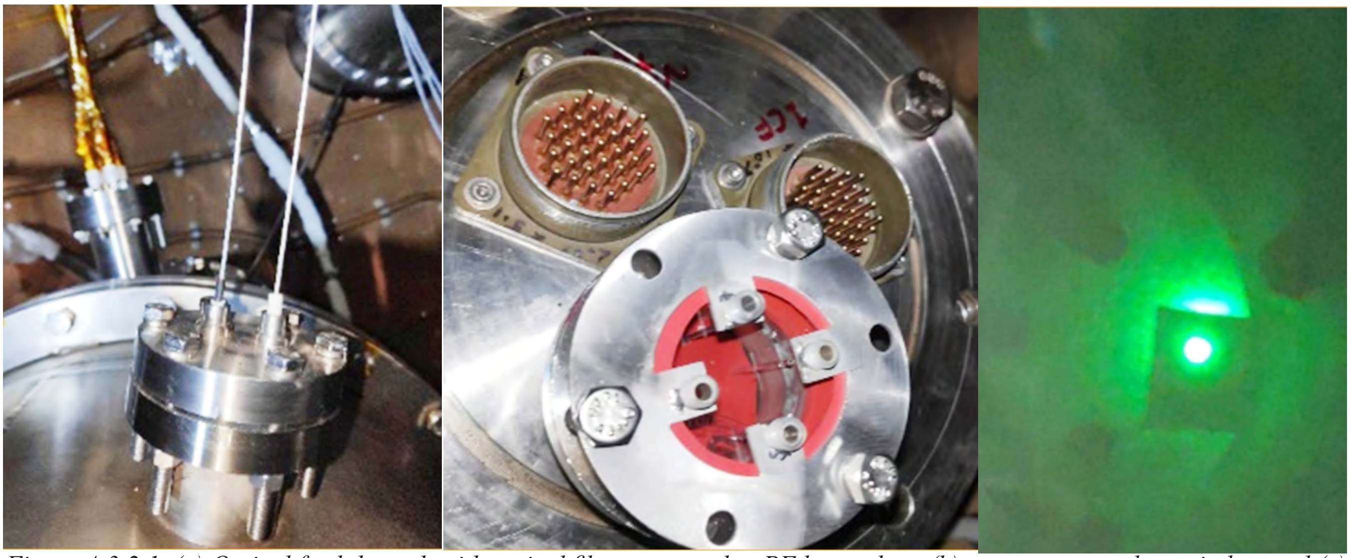

Figure A.3.2.1. (a) Optical feed through with optical fibres mounted at PF lower duct (b) outer vacuum glass window and (c) the fibre alignment using Laser light

the laboratory, dissimilar material joint based axial and radial barrier VBs are developed and tested for the Paschen condition at room temperature and 77 K.

Specific Features of developed VBs:

(i) Material and Type : Dissimilar materials joint of metal SS 316 + S-glass fibre insulation + In-house developed cryo epoxy resin system)

(ii) Helium leak tightness at 300 K and after 5 thermal cycles at 77 K, 5 bar Helium gas pressure : < 1.2 x 10^{-6}mbar-/s,

Figure A.3.2.2 The radial, axial with compensating bellow and the integrated assembly with PF-3 coil bus-bars

Electrical DC voltage test from 100 V to 5 kV range, at 5 kV insulation resistance: ≥ 100 GΩ, Leakage current : 5x10^{-8} amp.

The radial, axial with compensating bellow and the integrated assembly with PF-3 coil bus-bars are shown in figure A.3.2.2

Thermo-Structural Analysis of SST-1 Cryopump: A liquid nitrogen-based cryopump for Steady State Superconducting Tokamak (SST-1) is designed for pumping of water vapour from vacuum vessel during baking and under heavy gas load conditions. During baking, the load of the water vapour molecules increases while the resultant speed of available Turbo-Molecular Pumps is less for water vapour which increases the pressure of the vacuum vessel. Cryopump with the same opening area as of TMPs has more pumping speed for water vapour molecules. Hence, the said cryopump will pump water vapour molecules with higher pumping speed. In principle, water vapour molecules get condensed at a surface temperature of < 120 K which corresponds to the saturation pressure of < 10^{-10} mbar. The pump is based on the cryosorption principle where nitrogen gas and water vapour get adsorbed on to the cryo-surfaces at a temperature of < 80 K. The amount of gas pumped and accumulated on cryosurfaces depends on many factors such as the temperature of a gas, microscopic surface roughness of cryosurface, its temperature and thermal conductivity, etc.. Various components of this cryopump are thermal shield, cryopanels coated with suitable sorbent, baffles and vacuum chamber. For reliable and long duration operation of this pump, detailed thermal analysis is done to study the temperature distribution and thermal stresses generated for the efficient operation of the pump. Thermo-structural analysis of the developed pump is carried out for failure protection. The design by analysis method is followed to realize the concept of cryopump for SST-1 and the same has been documented in detail.

Lower Hybrid Current Drive (LHCD) System

Steady-State Operation of High CW Power Circulator: Challenges and Solutions through Simulation and Experiments: The lower hybrid current drive (LHCD) system of the steady-state superconducting tokamak-1 (SST-1) has been augmented with two more klystrons, each rated for 500-kW continuous wave (CW) power at 3.7 GHz to increase its power rating to 2-MW CW. To protect these klystrons at rated power, the existing 250-kW CW circulators, connected to each of the klystrons, are required to be upgraded to 500-kW CW rating. Simulation studies are carried out using COMSOL Multiphysics to ascertain the key parameters which limit its performance to the desired value. In this article, we present the simulation and experimental studies of the high power circulator, highlighting major challenges and its solutions. The effect of ferrite temperature on the RF performance of the circulator is analyzed with the help of multiphysics simulations. Accordingly, the configuration of the circulator is modified. A series of low power tests are carried out to characterize the circulator performance. High power tests, up to a few seconds, have been successfully carried out to ensure that no breakdown is observed at rated power. The results from the simulation studies and experiments have enabled us to conclude that the circulator can handle a forward power of 400-kW CW under matched load conditions.

Neutral Beam Injection Heating

Development of Technology for Fabrication of Prototype Ion Extraction Grid for Fusion Research: Steady-state Superconducting Tokamak (SST-1) has a provision for a positive hydrogen ion-based Neutral Beam Injection (NBI) system. This system has a capability of injection of neutral hydrogen beam power of 1.7 MW at 55 kV. This NBI system consists of a 3-grid accel-decel ion extractor system. Each grid has 774 apertures distributed in the area of 23 cm × 48 cm on the OFHC copper plate. During beam operation grid received maximum heat load of ~1.75 MW/m^2 which is removed by a dense network of 22 semi-circular (r = 1.1±0.05 mm) cooling channels embedded between the rows of shaped apertures. The water flow velocity inside the cooling channel is 13 m/s and the pressure drop is 9 bar. To maintain the high electric field (~7 kV/ mm) between grids, the required surface flatness of the OFHC copper plate is 100 μm. Another requirement is positional tolerance of aperture of ±60 μm. All these critical requirements imply that the fabrication of the ion extractor grid is very complex and several technologies are involved: (i) Friction Welding (FW) for joining of dissimilar metals of SS304 L rod to the specific location of OFHC copper plate for the fabrication of water manifold of the grid. This has been successfully developed and obtained FW joint strength of 264 MPa (ii) 2.5 mm thickness electro-deposition of OFHC copper for making embedded cooling channels (iii) Precision CNC grid machining. The development of these technologies for the manufacturing of the extractor grid has been documented in detail.

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A.4 Fusion & Related Technologies

Under the purview of continuous progress related to fusion science and technologies , many technologies are being developed. A brief about the technologies developed under various heads are given here.

A.4.1 High Temperature Technologies

Exposure of Indian RAFM under Variation of He+ Flux and Target Temperature in the CIMPLE-PSI Linear Device: The first investigations of the effect of low-temperature helium (He) plasma exposure on the India specific reduced activation ferritic martensitic (IN-RAFM) steel are done. Experiments are performed in the CIMPLE-PSI device, over the variation of ion-flux (~$3 \times 10^{22-23}$ m^{-2} s^{-1}) and target temperature (316 K−830 K), for ion-fluence up to 1.6×10^{26} m^{-2}. Strong morphology changes have been observed, in particular, fiber-form surface structures with nanometer-sized grain structures, pinholes, and hollow fibers. Surface enrichment of tungsten up to 2.3 atomic percentage was measured by energy dispersive x-ray spectroscopy (EDX), which was supported by Rutherford backscattering spectrometry (RBS) measurements. This had happened because iron and chromium were preferentially sputtered out by the He ions. It is demonstrated that the porous, micrometer-sized surface inhomogeneities, produced under high ion-flux (≥8.0×10^{22} m^{-2} s^{-1}) and high target temperature (≥518 K), critically influence the shape of the RBS spectrum, which necessitates a revision of the data analysis procedure. Through optical emission spectroscopic observations, we demonstrate that the sputtering yield of the steel decreases with exposure time, primarily because of

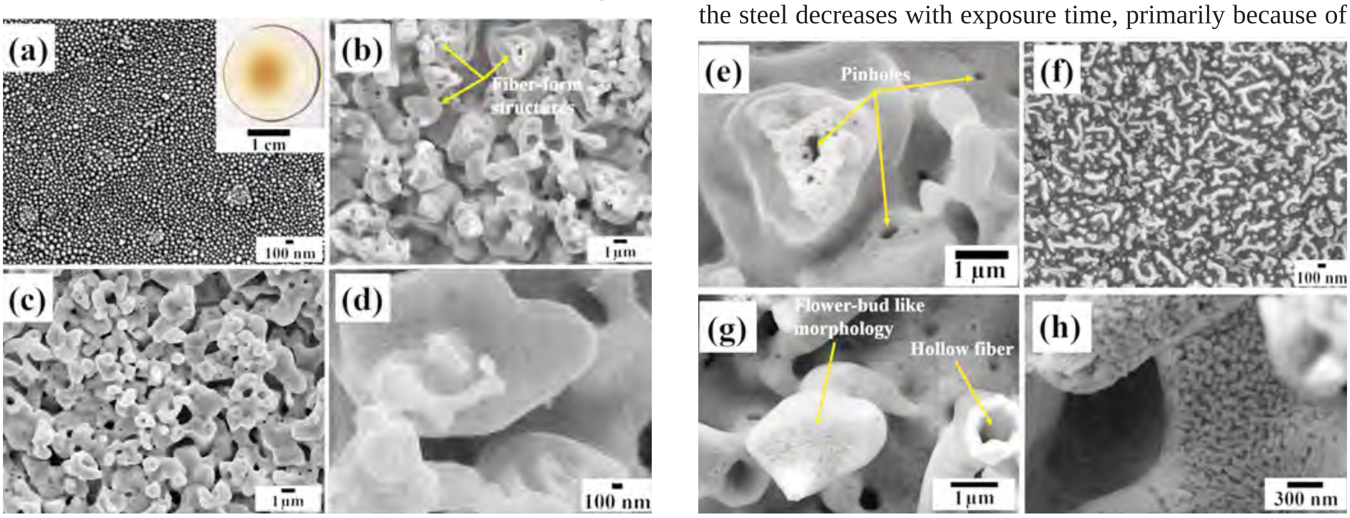

Figure A.4.1.1 Field Emission Scanning Electron Microscope Images of different Reduced activation ferritic martensitic (RAFM) steel samples which were exposed ((a) photograph of the exposed target in the inset) to different Helium ion flux and target temperatures the formation of the porous surface microstructures and also due to the surface enrichment of the exposed samples with tungsten atoms. It is concluded that the formation of bubbles underneath the surface of RAFM, and their subsequent distortion and rupturing leads to the formation of fiber-form structures under the relatively high target temperature, high ion-flux irradiation conditions.

A.4.2 Fusion Blanket Technologies

Indigenous Development of Tritium Permeation Barrier Coating: Nuclear fusion reactors make use of an artificial hydrogen isotope called tritium. Since this is expensive and highly radioactive, its leakage by permeation through metals must be substantially reduced. This requires coating of the reactor walls with Tritium Permeation Barrier (TPB). IPR has produced coatings of Erbia (Er_2O_3) on stainless steel using a high temperature reactive magnetron sputter coating process. A state of the art coating system has been developed in-house as shown in the figure A.4.2.1 while the figure A.4.2.2 shows the permeation flux of deuterium of the sample before and after the coating. The coating process has been optimized based on rigorous experiments, varying different parameters to obtain good performance and reproducible coatings. The coating has been found to produce a 100-fold reduction in the hydrogen permeation rate through stainless steel.

Figure A.4.2.1 High temperature reactive magnetron sputter coating system developed in-house.

Helium Cooled Dual Breeder Blanket-Preliminary Design Analyses of a Candidate Breeding Blanket Concept for Near Term Indian DEMO Fusion Reactor: Helium cooled dual breeder (HCDB) blanket concept is designed for future Indian DEMO fusion reactor and it is made of two tritium breeder materials PbLi and Li2TiO3. It has helium as a coolant and the India specific RAFMS as a structural material. High-pressure helium first cools the plasma facing first-wall and subsequently extracts heat from PbLi and ceramic breeder. Since PbLi is not used as a coolant, it therefore circulates with a low flow rate. It will overcome the corrosion and MHD issues associated with high temperature and high flow rate of PbLi. The idea behind the concept is to make a design which can be made using the existing blanket materials, extract high-grade heat from the reactor and also enhance the availability. In HCDB blanket the role of neutron multiplier is done by PbLi, an alternative to the beryllium and it eliminates the issue associated with high toxic beryllium handling. It can be a potential tritium breeding blanket concept along with lead lithium cooled ceramic breeder (LLCB) and helium cooled ceramic breeder (HCCB) for near term Indian demonstration nuclear fusion power plant. In order to realize the HCDB conceptual design, preliminary estimations of tritium production, nuclear heat density have been carried out. The thermal behaviors of the HCDB blanket in Indian DEMO conditions have been also assessed. The assessment establishes the proof of HCDB blanket concept and supports it to be a good alternate blanket candidate for the Indian DEMO. The HCDB concept has been documented along with analysis to verify the tritium self-sufficiency and materials temperature limits.

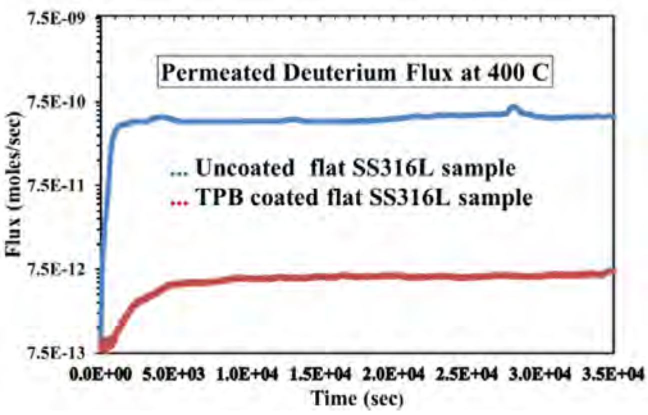

Figure A.4.2.2 Permeation flux of Deuterium at 400 °C for uncoated sample and TPB coated sample

Experimental Measurements of Gas Pressure Drop of Packed Pebble Beds: The nearly spherical shaped ceramic pebble beds in the breeder blanket of the future fusion reactor are purged with low-pressure gas to channelize the produced tritium fuel into the tritium extraction system. The required pumping power for the flowing gas in pebble beds can be estimated using the pressure drop across the pebble beds. The aim of this work is to measure the gas pressure drop experimentally across packed pebble beds as a function of pebble sizes, pebble shapes, pebble materials, and gas velocity. The pebble beds are packed in a cylindrical-shaped stainless steel container with an inner diameter of 24 mm and a length of 130 mm. Various experiments have been performed on stainless steel spheres (Diameter: 1 mm, 2 mm, 3 mm, and 4 mm), alumina pebbles (Mean diameter: 1 mm and 1.5 mm), and lithium meta-titanate pebbles (Mean diameter: 1 mm and 1.3 mm). The gas flow has been controlled and measured using a digital mass flow controller. The static differential pressure across the pebble beds has been monitored by a differential pressure transducer. The pressure drop significantly increases with a decrease in the diameter of pebbles/spheres and an increase in the packing fraction of the bed. The material type does not affect the results which are too obvious for the fixed pebble bed which is considered in these experiments. The obtained experimental results of gas pressure drop have been compared and found to agree well with the prediction of the Ergun's correlation.

Preliminary Performance Analysis and Optimization Based on 1D Neutronics Model for Indian DEMO HCCB Blanket: India, under its breeding blanket R&D program for DEMO, is focusing on the development of two tritium breeding blanket concepts; namely the lead-lithium-cooled ceramic breeder and the helium-cooled ceramic breeder (HCCB). A focused study has been done on the neutronic design analysis and optimization from the tritium breeding perspective of the HCCB blanket. The Indian concept has an edge-on configuration and is one of the variants of the helium-cooled solid breeder blanket concepts proposed by several partner countries in ITER. The Indian HCCB blanket having lithium titanate (Li_2TiO_3) as the tritium breeder and beryllium (Be) as the neutron multiplier with reduced-activation ferritic/martensitic steel structure aims at utilizing the low-energy neutrons at the rear part of the blanket. The aim of the optimization study is to minimize the radial blanket thickness while ensuring tritium self-sufficiency and provide data for further neutronic design and thermal-hydraulic layout of the HCCB blanket. It is found that inboard and outboard blanket thicknesses of 40 cm and 60 cm, respectively, can give a tritium breeding ratio (TBR) >1.3, with 60% 6 Li enrichment, which is assumed to be sufficient to cover potential tritium losses and associated uncertainties. The results also demonstrate that the Be packing fraction (PF) has a more profound impact on the TBR as compared to 6 Li enrichment and the PF of Li_2TiO_3.

Measurement of Effective Thermal Conductivity of Lithium Meta-titanate Pebble Bed by Transient Hot-Wire Technique: In future fusion reactor lithium metatitanate (Li_2TiO_3) as a functional material in the form of packed pebble beds have been selected in breeding blanket concepts to generate and release tritium. The effective thermal conductivity (k_{eff}) of Li_2TiO_3 pebble beds are needed to be well characterized for the design and analysis of breeding blankets under fusion relevant conditions. The transient hot-wire technique based experimental system has been fabricated, tested and installed for keff measurement of Li_2TiO_3 pebble beds. Finite element method (FEM) simulations have been performed to optimize the dimension of an experimental setup with the intention of minimizing the uncertainty in keff measurements. The experiments have been performed on 1 ± 0.15 mm diameter Li_2TiO_3 pebble bed with a packing fraction of 63 %. The influences of temperature (35–800 °C), gas environment (helium and air) and gas pressure (0.105−0.4 MPa (abs.)) have been investigated on k_{eff} of Li_2TiO_3 pebble beds. Reduction in k_{eff} was found to decrease with helium gas pressure while it was insignificant for the decrease in air pressure. The measured effective thermal conductivity (k_{eff}) results of Li2TiO3 pebble beds have been compared and found to agree well with the literature experimental results. The empirical correlations are also proposed for keff of Li2TiO3 pebble beds in helium and in air environment at 0.105−0.4 MPa and as a function of temperature.

A.4.3 Neutral Beam Technologies

Hot helium leak test for high temperature components: In fusion machines, several precision-fabricated components, such as the plasma grids in Neutral Beam Injectors, are cooled using hot water at high temperature & pressure (150^{o}C & 25 bar). These must be subjected to qualification tests to establish the manufacturing process before use in the actual device. To our knowledge, for the first time, the plasma grid of the extractor and accelerator system of the neutral beam injector has been subjected to such a qualification test. The grid involves a 1.5 mm thick copper layer electrodeposited on Copper base plate with milled channels to allow flow of water. The tests have been performed inside a temperature controlled furnace and a global leak rate of < 10^{-9} mbar l/s has

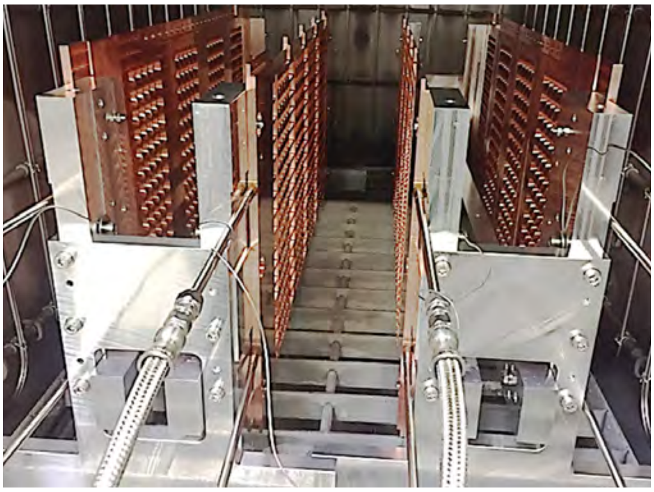

Figure A.4.5.1 Plasma grid segments inserted in a vacuum hot furnace in preparation for the hot helium leak test

been demonstrated. The process stands established for application in testing leak rates for components at their operational temperatures

Design and Analysis of TWIN Source Extraction System Grids with Indigenous Manufacturing Feasibility Assessment: A 3 grid extractor and accelerator system is to be coupled to the two driver RF negative ion source test bed to extract and accelerate H- ion beams up to 50 keV. One of the aims of the TWIN test bed is to characterize and benchmark the optics design of such an accelerator system (1:4 scale) which has been modelled for the 8 driver diagnostic neutral beam negative ion source. A cooling scheme based on analysis and indigenous manufacturing assessment has been selected. In order to enable indigenous manufacturing of embedded cooling channel of such an accelerator a route of vacuum brazing has been considered to close the water cooling channels of the 3 grid segments as against the conventional route of 1 mm thick electrodeposited layer of copper. This choice has been made considering the limited availability of copper electro-deposition thereby significantly reducing the manufacturing time and establishing an alternate route suitable for test beds. The optimal geometrical requirements for establishing brazing to close the water cooling channels have been successfully realized and validated experimentally by subjecting the developed prototype braze coupon under high heat flux facility at IPR. The selected cooling scheme choice has then been utilized on a strip model (Grid segment) to perform thermo-mechanical analysis under operating load conditions to study thermal profile, stresses, out of plane deformations and aperture displacements (misalignment).

Evaluation of Heat Transfer Performance of Hypervapotron Elements in Two Phase Flow Devised in Indian test facility: Indian Test Facility (INTF) is a testbed to carry out neutral beam experiments where the beam diagnosis is envisaged using a calorimeter capable of handling 100 keV 20 A neutral hydrogen beams with peak power densities >10 MW/m^2. To survive such thermal fluxes, water-coooled Hypervapotron (HV) elements are used to design the calorimeters. The HV element has a finned surface inside and works in a subcooled nucleate boiling regime with water as a coolant. HV elements offer efficient heat transfer technologies made from high thermal conductive materials (CuCrZr – Copper alloy) and are capable of removing heat flux densities about 10‒30 MW/m^2 w.r.t various coolant flow conditions. Efforts have been made to evaluate heat transfer performance of these elements using three approaches – a) 3D FEA using Empirical correlations available in literature, b) 2D CFD in ANSYS CFX, c) Conducting high heat flux experiments on the HV element. The results from these approaches have been compared to establish the safe operating boundaries for INTF operation

Effect of Argon and Oxygen Gas Concentration on Mode Transition and Negative Ion Production in Helicon Discharge: In this study, the effect of mixing of argon and oxygen gas on the mode transition and negative ion production in the helicon discharge is investigated. In the source chamber of the experimental setup, argon–oxygen gas mixture plasma is produced by applying RF power from 100 W to 2000 W at an applied magnetic field of 0.03 T. In this experiment, the total flow rate is kept at 200 SCCM, corresponding to the working pressure of 4–5 × 10^{-1} Pa. The mode transition to helicon discharge is investigated by varying the concentration of these two gases. To the best of our knowledge, the literature survey indicates this to be the first study of the influence of the mixing of oxygen–argon gas on the mode transition from the inductive to the helicon mode. It is observed that an increase in the concentration of oxygen gas in the discharge shifts mode transition toward higher RF power values, indicating the influence of the nature of the working gas on the transition to the inductive as well as to the helicon mode. The variation of the electron density and temperature is explained in terms of particle and power balance equation. In the source and in the downstream expansion chamber, the effect of the concentration of argon gas on the negative ion production in oxygen discharge is also studied, and the results are explained in terms of various reactions involved in the production and loss of negative ions.

Conceptual Design of Doppler Shift Spectroscopy Diagnostics for INTF: INTF (Indian Test Facility) is a negative hydrogen ion source based neutral beam test facility to characterise 100 keV,60 A Diagnostic Neutral Beam (DNB), conceptualised for ITER. Several diagnostics are under development to monitor and characterise the performance of ion source and the beam properties. Doppler Shift Spectroscopy (DSS) diagnostics shall be used to estimate the beam divergence, beam inhomogeneity and the stripping losses of the extracted H^- ion beam. In this work, the conceptualisation of the DSS diagnostics and the performance evaluation of the proposed system has been considered. A forward model is developed to predict the signal strength and signal to noise ratio for various beam operation scenarios and for different optical setups. The model also estimates the expected error in the line width analysis carried for estimating the beam divergence. To reduce the error in the estimated beam divergence, a study on the error propagation was carried out by considering a range of viewing angles, different types of light collection systems and optical instruments. An optimum viewing angle, the light collection system and the instrumentation is chosen accordingly. An endoscopic design concept for each LOS has been adopted and the mechanical assembly of the same has been designed in accordance. This work also reports considering individual divergence of beamlets using conventional methods of line width analysis might lead to large errors in the beam divergence measurements obtained by DSS. A suitable algorithm has been developed to de-convlute such effects thereby improving the preciseness of the beam divergence estimation.

A.4.4 Cryopumps for SST-1 and Pellet Injectors

A Review of Pellet Injector Technology: Brief History and Recent Key Developments: For the last 15 to 20 years, substantial advancement has been achieved globally in the field of pellet injector technology (PIT). Nuclear fusion is a method for producing high-energy neutrons, alpha particles, and an enormous amount of energy with the help of thermonuclear reaction of hydrogen isotopes. The way of producing this huge energy source is similar to that of the sun's generated energy. This type of energy does not produce greenhouse gases or a high-level radioactive surplus. Solid hydrogen is used as a fuel in a fusion reactor in the form of pellets of different diameters and lengths. These pellets are produced by a pellet injector. In the sophisticated fueling system, these pellets are continuously produced with the help of a twin-screw extruder (TSE) and cooled by more than one cryocooler or liquid helium. Each pellet injection system has its pros and cons. We have identified different injection criteria for different types of injectors. Higher-density, continuous injection with high reliability is the major constraint of a future pellet injection system such as the Gifford-McMahon cryocooler-based TSE. In the past, limited innovative applications for PIT were established and used effectively in fusion experiments. At the present time, an innovative cryogenic-based extrusion system is being designed to meet the different injection criteria. In this regards a technical note has been prepared which presents the progress of eminent activities, discusses some of the best models available in the published literature. Gray areas such as non-Newtonian behavior of solid H2 has also been touched upon. The note also dicusses the associated challenges with recent key developments in the field of PIT.

Design and Analysis of Liquid Nitrogen Cooled Sorption Cryopump for SST-1 Tokamak: SST-1 is a Steady State Superconducting Tokamak for a proposed plasma discharge of long duration. This plasma device has two vacuum vessels, the cryostat and the vacuum vessel (VV). Cryostat houses the superconducting magnet systems (TF and PF coils), LN2 cooled thermal shields and hydraulics for these circuits and the plasma will be confined inside the VV [1]. To have plasma discharges, ultra-high vacuum (UHV) is required to be maintained in VV [2]. To attain a vacuum level of $\sim 1 \times 10^{-8}$ mbar in VV, 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 from the bulk of materials which are adsorbed/absorbed. In baking, the gas load of mainly water vapour and hydrogen gas is increased. The pumping system for vacuum vessel consists of six sets of turbomolecular pumps (each set consist of 3 TMP) and one cryopump which is sufficient to achieve a vacuum of $< 1 \times 10^{-7}$ mbar. But closed-cycle cryopumps of the machine has less cooling capacity for taking high radiation heat load during baking. So, custom made liquid nitrogen-based cryosorption cryopump of high cooling capacity will be added on the radial port of machine to enhance the pumping speed of mainly water vapour. This pump comprises of activated charcoal coated panels cooled down to 80 K, which also provide pumping speed for nitrogen, and oxygen by cryosorption. Further detailed thermal analysis of coated cryopanels and baffles have been preformed at a different baking temperature of the VV and structural analysis of components of cryopump for a robust design.

Development of CFD Model for the Analysis of a Cryogenics Twin-Screw Hydrogen Extruder System: A cryogenic twin-screw extruder for plasma fuelling is under development at Institute for Plasma Research (IPR), India. The fuel for Indian tokamaks SST-1 and Aditya-Upgrade is injected in the form of frozen hydrogen pellets; the current injector design has a pipe gun based concept, cooled by a GM-cryocooler. An advanced fuelling system will produce hydrogen pellets continuously using a twin-screw extruder, cooled by a GM-cryocooler. The viscous dissipation is one of the critical design parameters for the extruder system which determines the screw torque as well as the required cryocooler heat load. The performance of an extruder is assessed by measuring the pressure development for different throughput. In the current investigation, CFD model has been developed using ANSYS POLYFLOW under cryogenic temperature. A computational model for non-Newtonian isothermal solid hydrogen flow in the screw channel was developed and used to calculate extruder efficiency and viscous dissipation rate. The shear-rate-dependent viscosity law was applied in the present analysis for shear stress modelling of solid hydrogen in the temperature interval from 10 to 13 K. The effect of screw rotation speeds (5–20 rpm) on the viscous dissipation rate and pressure development at required throughput was also examined. As the screw rotation speed reduces, the viscous dissipation rate reduces. The results show that as temperature increases, the viscous dissipation rate and pressure development reduces. The analysis also revealed that the operating point of extruder-die system is highly sensitive to the screw rotation speed.

Nitrogen and Water Vapor Pumping Study on a 400 mm Opening LN2 Cooled Sorption Cryopump: To study the pumping speed of nitrogen and water vapor, 400 mm opening liquid nitrogen cooled sorption cryopump is developed in house and its applicability is studied. This pump has cryosorption panels made of copper and coated with granular activated charcoal using cryogenic adhesives. Pumping speed of the cryopump is measured using the American Vacuum Society (AVS) standards. Experimentally measured average pumping speed for nitrogen and water vapor are 2388 $l\ s^{-1}$ and 17542 $l\ s^{-1}$ respectively. Pumping performance is also simulated using Molflow + software developed by CERN. On comparing the experimental results with the Molflow+, it is found that, charcoal sticking co-efficient (ratio of number of molecules sticking to the surface compared to the total number of molecules impinged upon) for nitrogen at 82.5 K is 0.14 and at maximum experimental pumping speed it is 0.25. For water vapor, measured pumping speed is close to the simulated pumping speed when 0.8 sticking co-efficient is considered for the louvre baffle, radiation shield and front panel and their temperatures were below 95 K. Measurement of nitrogen pumping speed for different geometrical conditions is carried out to see the geometrical effect on pumping speed. Our findings agree for applicability of this pump for nitrogen and water vapor pumping and can be mounted in any orientation and is easy to regenerate.

A.4.5 Neutronics Studies

Development and Performance of a 14-Mev Neutron Generator: An accelerator-based 14-MeV neutron generator for fusion neutronics studies has been developed in Fusion Neutronics Laboratory (FNL) at the Institute. The generator is initially designed to produce a neutron yield of 10^{10} n/s and operated for 1.1×10^{9} n/s. It will be further upgraded to the neutron yield of 10^{12} n/s. The neutron generator consists of various components such as 2.45 GHz ECR ion source, 300 kV linear accelerator, beam diagnostic system, TMP based vacuum system, solid tritium target, and control system. Various direct and indirect neutron detection techniques are deployed to evaluate the performance of the neutron generator in terms of neutron emission. These techniques include foil activation, alpha particle diagnostic, and He-3 proportional counter. The reaction rates for the foil activation are estimated using the Monte Carlo technique. Results of all independent diagnostics are obtained and compared. The experimental setup and neutron diagnostics have been documented along with the performance of the 14-MeV neutron generator highlighting its stability under continuous operation.

Experimental Study of Neutron Irradiation Effect on Elementary Semiconductor Devices Using Am-Be Neutron Source: An experiment has been conducted to evaluate the lifetime, reliability and operational performance of elementary semiconductor devices in the neutron radiation environment which supports to reduce the fatal in measurements and plan the preventive actions in nuclear facilities. It will also support the enhancement of electronics for nuclear facilities. The elementary semiconductor devices used in the experiment are Diode (1n4007), Zener Diode (5.1v), Light Emitting Diode, Transistor (BC547, 2n3904), Voltage controlling IC (7805), Operational Amplifier (LM741) and Optocoupler (4n35). The selection of devices has been made by keeping in mind their application in transmitting devices (i.e. Temperature transmitter, pressure transmitter, flow transmitter, monitors and controllers) for Indian test blanket system in ITER. Such devices are also used in general nuclear electronics. The devices have been irradiated in the Am-Be neutron source environment. The maximum fluence has been given up to 10^{11} n/cm^2. The neutron source has energy range from low to high.

All semiconductor devices have been characterized before and after irradiations. The deviation of 5 - 10% is observed in diodes I-V characteristics whereas transistors show a bit higher deflection in basic functionality. Optocoupler shows more than 50% deviation in its basic characteristics whereas voltage-controlling IC is not even functioning after the irradiation of 10^{11} n/cm^2. The details of the experiment and the behavior of semiconductor devices after irradiation have been documented. The experiment supports the selection and further research of the Indian test blanket system instruments.

Occupational Radiation Exposure Control Analyses of 14 MeV Neutron Generator Facility: A Neutronic Assessment for the Biological and Local Shield Design: The 14 MeV neutron generator facility is being developed by the Institute to conduct the lab scale experiments related to Indian breeding blanket system for ITER and DEMO. It will also be utilized for material testing, shielding experiments and development of fusion diagnostics. Occupational radiation exposure control is necessary for the all kind of nuclear facilities to get the operational licensing from governing authorities and nuclear regulatory bodies. In the same way, the radiation exposure for the 14 MeV neutron generator facility at the occupational worker area and accessible zones for general workers should be under the permissible limit of AERB India. The generator is designed for the yield of 10^{12} n/s. The shielding assessment has been made to estimate the radiation dose during the operational time of the neutron generator. The facility has many utilities and constraints like ventilation ducts, accessible doors, accessibility of neutron generator components and to conduct the experiments which make the shielding assessment challenging to provide proper safety for occupational workers and the general public. The neutron and gamma dose rates have been estimated using the MCNP radiation transport code and ENDF eVII nuclear data libraries. The ICRP-74 fluence to dose conversion coefficients has been used for the assessment. The annual radiation exposure has been assessed by considering 500 h per year operational time. The provision of local shield near to neutron generator has been also evaluated to reduce the annual radiation doses. The comprehensive results of radiation shielding capability of neutron generator building and local shield design have been documented and detailed maps of radiation field have been generated.

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A.5 Theoretical, modeling and Computational Plasma Physics

The Institute has a vibrant programme involving theoretical analysis and computer simulations for plasma systems. This covers basic research as well as plasma applications. Continuing with its long-standing focus on high performnce computing facilities, IPR has now set up a 1 Petaflop HPC facility.:

A.5.1 High-Performance Computing (HPC, 1 Peta flops) System

ANTYA in India's Top Supercomputers List: IPR has established a High Performance Computing facility having a theoretical peak performance of 1 Petaflop. This HPC system named ANTYA (meaning 10^{15} in Sanskrit), has more than 10,000 cores that can perform 10^{15} Floating-point Operations Per Second (FLOPS). CDAC Bengaluru maintains and publishes a Top Supercomputers-India list (TopSC.in). IPR's ANTYA stands at 11th position in the July-2020 list (*http://topsc.cdacb.in/jsps/july2020/index.html*). ANTYA achieved an operational uptime of ~96% and there was only a single incident of 2-days complete shutdown during the chiller maintenance activity in DC. Table-1 gives a summary of the computational resources (CPU and GPU) of ANTYA.

Transitioning Users to Advanced Architectures: As more and more GPUs are now being used for scientific computing for performance enhancement, there was a need for Users to build proficiency in using GPUs to be able to use the 44 GPU cards in ANTYA. To help IPR HPC Users to reduce the barrier to run their codes on GPU nodes of ANTYA HPC Cluster, the IPR HPC Team partnered with NVIDIA and held its first GPU Bootcamp in IPR to get started and identifying the applications that can benefit from the GPU acceleration. Users primarily gained knowledge and expertise about GPU programming and applied that knowledge to port and accelerate their scientific codes on ANTYA GPU nodes. Towards

Table 5.1.1 Computational Resources Summary of 1 PetaFlop (1 PF) ANTYA HPC Cluster

Resource Name	*No. of Nodes*	*No. of CPU Cores*	*No. of GPU Cards*	*RAM/Node (in GB)*		*Remarks*
				CPU Node	*GPU Card*	
CPU Nodes	236	9440	0	376	-	40 cores/node
GPU Nodes	22	880	44	376	16	2xP100 GPU cards/node
High Memory Nodes	02	160	0	1007	-	80 cores/node
Visualization Node	01	40	02	376	24	2xP40 GPU cards/ node
Total	261	10520	46	99398	752	-

this end, many good quality In-house developed codes (serial as well as parallel) spanning Computational Fluid Dynamics (CFD), Molecular Dynamics (MD), Particle-in-Cell (PIC), etc. domains have been ported successfully and achieved initial performance enhancement. This has led to an increase in the demand for GPU cards for jobs on ANTYA and the subsequent need to add more GPU-based systems in the existing HPC facilities.

ANTYA Usage Demographics: ANTYA currently serves more than 200 Users spanning the scientific and engineering community of the Institute apart from supporting the academic project collaborations with other Institutes/Universities. In 2020 alone, around 100 new HPC Users have been added and their applications have been ported successfully on ANTYA. ANTYA has more than 60 libraries and more than 30 different codes installed, several of them indigenously developed or open-source as well as commercially licensed software's which are being used for a variety of numerical simulations covering Computational Fluid Dynamics (CFD), Particle-In-Cell (PIC), Molecular Dynamics (MD), MHD, AI, etc.

Utilization of Computational Resources: With more than 2500 million computational hours available for usage in ANTYA in 2020-2021, there was a significant increase in the average and peak usage from the 2nd quarter (Q2) of 2020 to the 1st quarter of 2021 (Q1) due to the migration of existing Users and as well as the addition of new Users from their workstations to ANTYA. The quarterly utilization charts are shown in the figure A.5.1.1.

HPC Community Outreach: Considering the increasingly important role of HPC in the research activities in the Institute, HPC Team IPR has started an informal 2-page monthly HPC Newsletter to disseminate HPC-related technical information to IPRites starting from December 2020. This new HPC newsletter, christened GAṆANAM (गणनम्) meaning Computing, is expected to serve as an informal platform for sharing our scientific research activities amongst IPRites to make the IPR HPC community more vibrant. It is available in the website "*https://www.ipr.res.in/ANTYA/*". The 1st page highlights an interesting research activity carried out using simulation and how the HPC resources helped in achieving the results timely. On the 2nd page, apart from an HPC article focussing on increasing the proficiency of Users towards the available HPC tools, there are ANTYA updates, an HPC picture of the month, other recent HPC-related work published in the IPR library, and Tip of the Month.

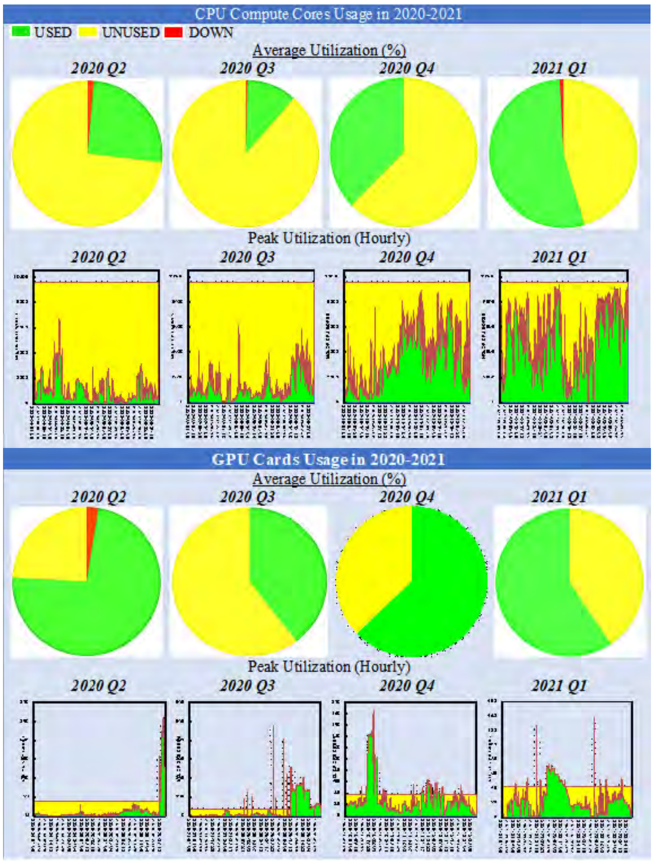


Figure A.5.1.1 Quarterly utilization charts of CPU compute resources (The peak utilization at some hours in each quarter went more than the maximum available limit of 44 cards as multiple jobs having low GPU utilization were allowed to run on the same card.)

AI for Science Bootcamp series: Considering the emergence of Artificial Intelligence (AI) in scientific research, HPC Team IPR along with the help from Nvidia Team planned AI Bootcamp intended to identify AI opportunities for the research work being carried out in various domains in IPR. The Bootcamp familiarized two real-world problems, where the participants followed a step-by-step approach to learn the AI concepts and how they can be applied in real scientific applications. This Bootcamp brought together more than 55 participants throughout two half-days having expertise with different domains/programming languages.

Some of the recent results of simulations performed on ANTYA are given below with short descriptions:

1. ***Mechanism of Blob Formation in the Scrape-off Layer of a Tokamak Plasma***

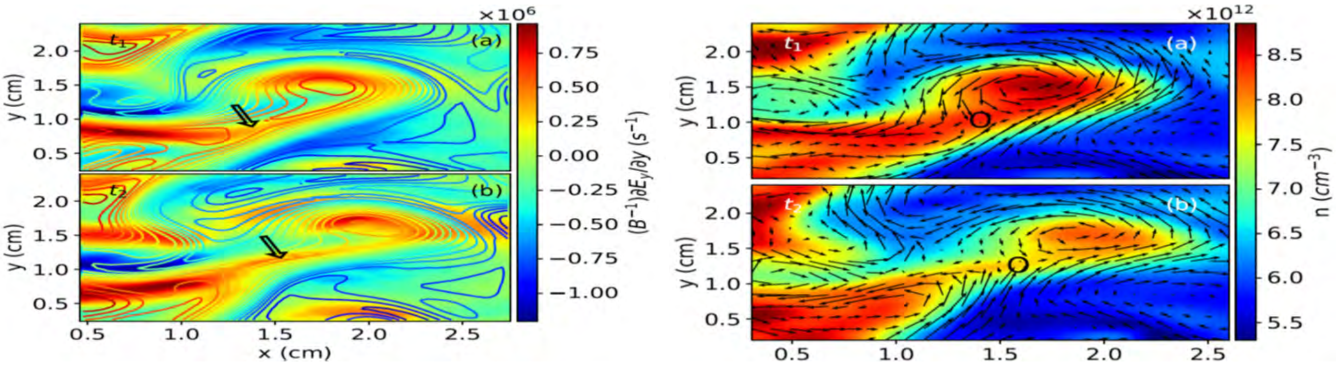


Figure A.5.1.2 Superposition of plasma density (contours) and electric field shear (Left), and Superposition of plasma density and quiver plots (Right).

2. How Fast Do Magnetic Islands Interact in a Plasma

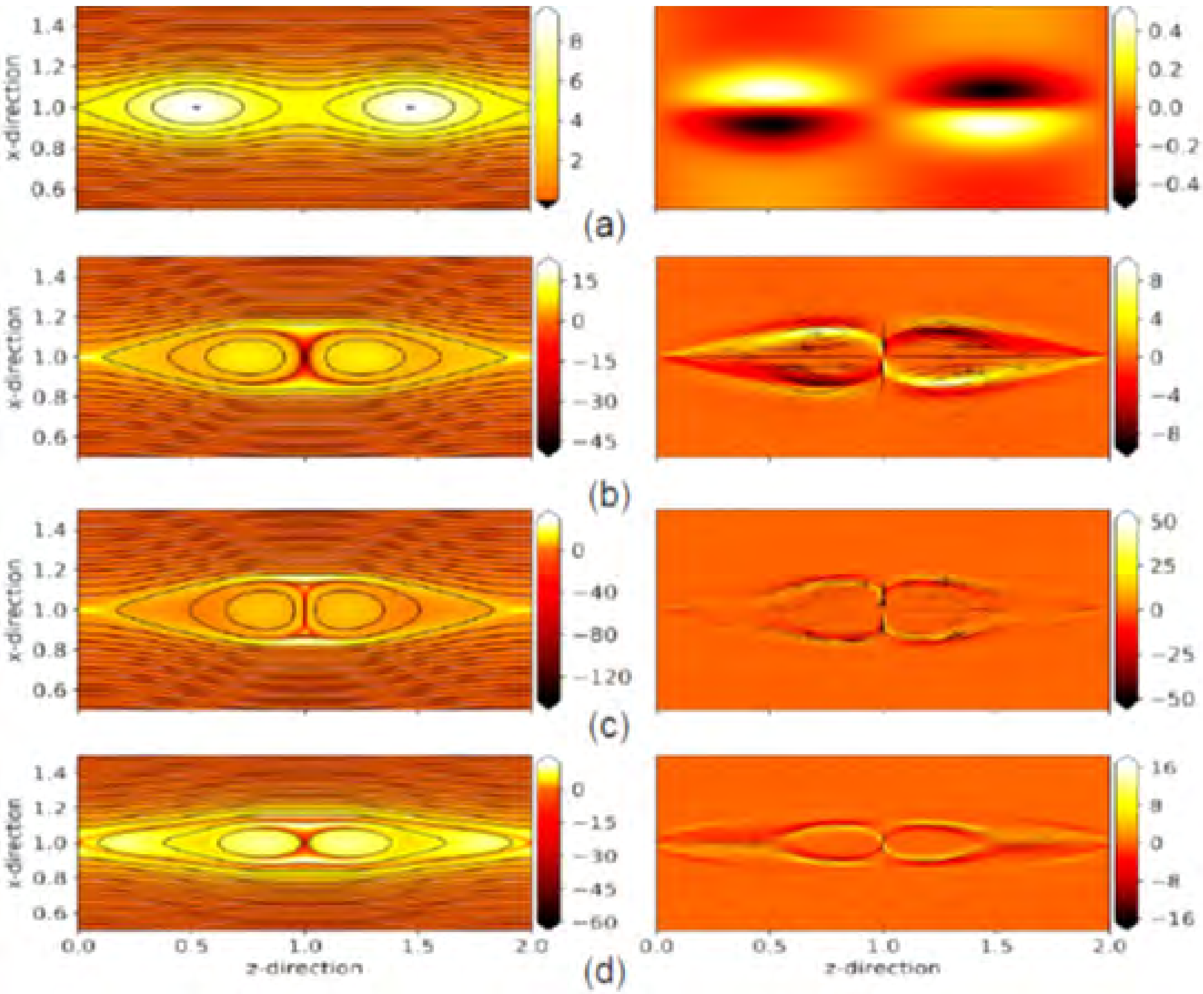


Figure A.5.1.3 Left panel shows current density (colormap), magnetic flux (contours) and right panel shows vorticity (colormap), velocity (streamlines) at various time points t: (a) 0.4tA (b) 2.6tA (c) 3.3tA and (d) 5.0tA

3. Molecular Dynamics Simulation Study of Laser-Cluster Interactions

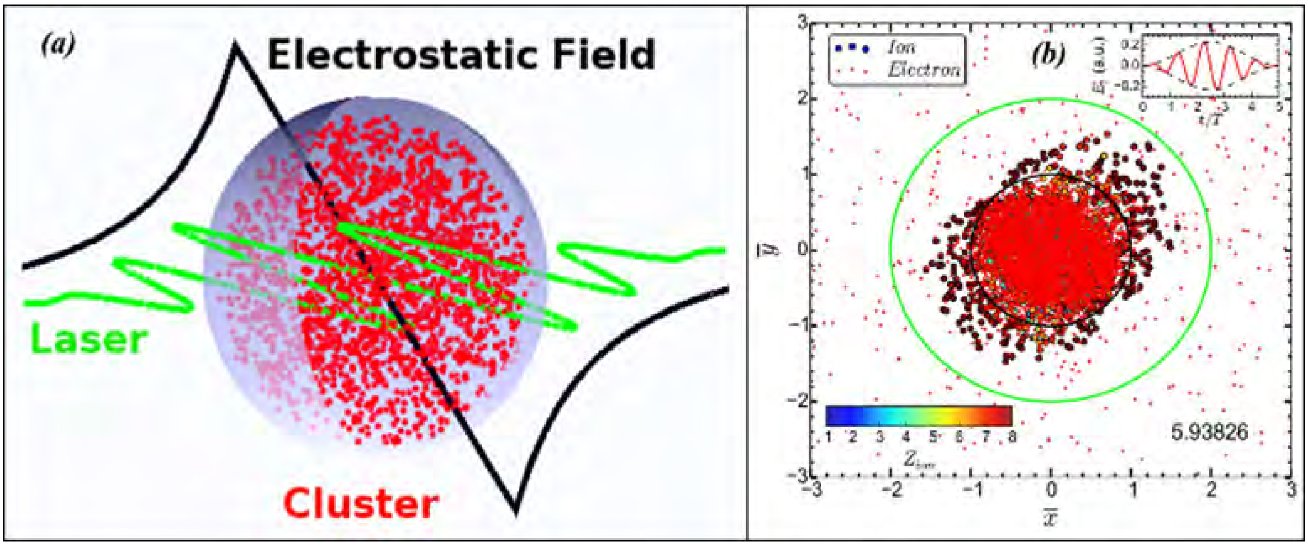


Figure A.5.1.4 Schematic of laser interaction with a spherical argon cluster, (Right) Dynamics of a laser-driven argon cluster shows inner ionization, outer ionization, and Coulomb explosion all happening simultaneously (inset plot shows the electric filed profile of the laser pulse).

4. Solid Hydrogen Extrusion for Fuelling Fusion Tokamaks

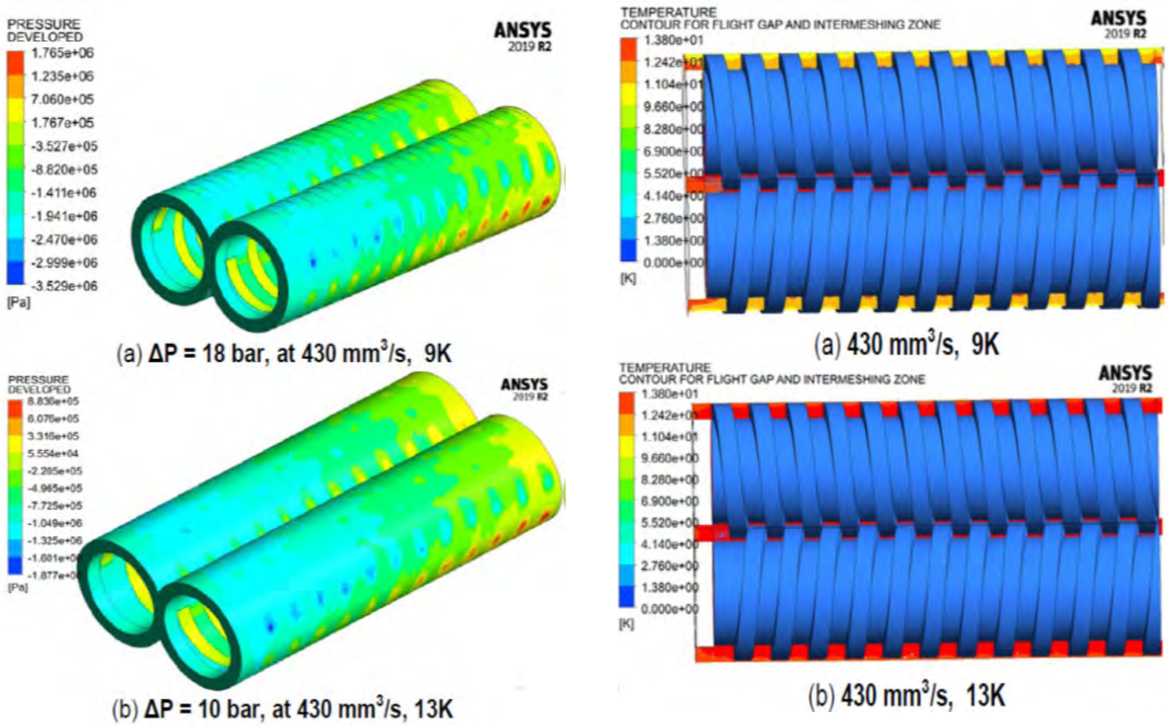
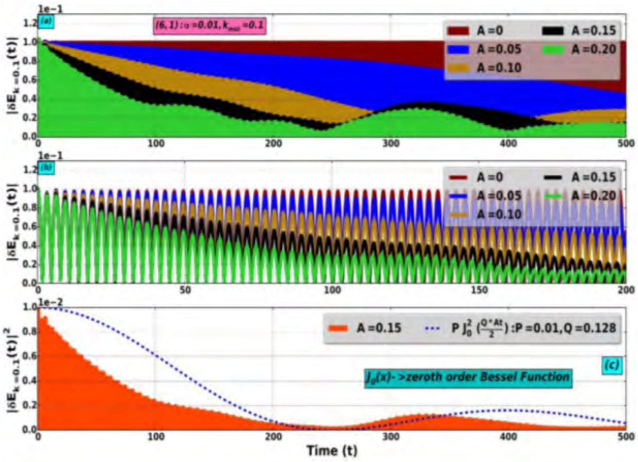


Figure A.5.1.5 : (Left) Comparisons of pressure developed along the extruder for different barrel temperatures at 15 rpm. (Right) Comparisons of temperature distribution along the screw at various locations for different barrel temperatures.

5. Landau Damping In One Dimensional Periodic Inhomogeneous Vlasov Plasmas



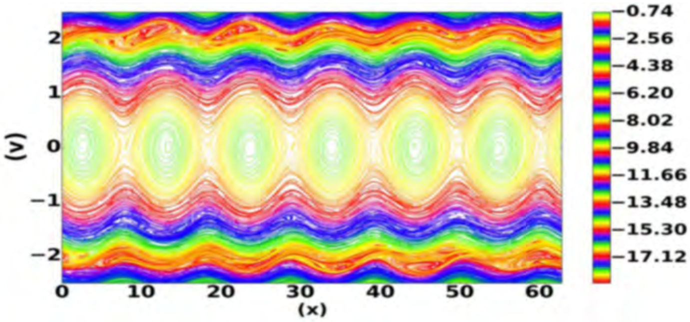


Figure A.5.1.6 (Left) Evolution of Landau damping with inhomogeneity amplitudes (Right) Formation of contour structures due to particle trapping.

6.Particle Phase Controls the Macrostate in Rayleigh-Bénard System

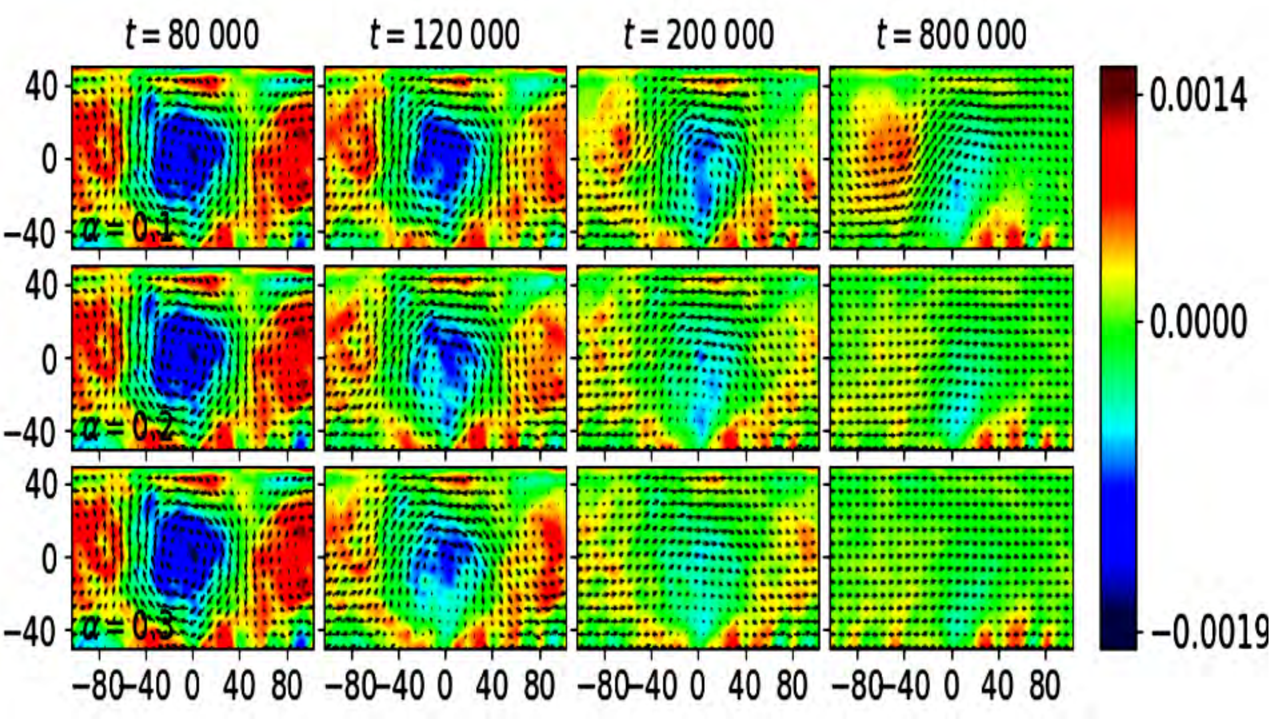


Figure A.5.1.7 : Time-evolution of fluid velocity and vorticity plots for various α values (α represents the amplitude of perturbation with respect to the magnitude of particles velocity and represents the phase of perturbation) under an even-phase, Φ = nπ, n = 0 of particle-level velocity perturbation. Colorbar labels represent local vorticity values and black arrows represents the relative local fluid velocities. The fluid quantities plotted here are constructed by dividing the simulation domain into (30x15) grid and averaging over time, t indicated on each column.

A.5.2 Nonlinear Plasma Theory & Simulation

Precursor Magneto-Sonic Solitons in a Plasma from a Moving Charge Bunch: The nature of fore-wake excitations created by a charge bunch moving in a magnetized plasma is investigated using particle-in-cell simulations. Our studies establish for the first time the existence of precursor magneto-sonic solitons traveling ahead of a moving charge bunch. The nature of these excitations and the conditions governing their existence are delineated. We also confirm earlier molecular dynamic and fluid simulation results related to electrostatic precursor solitons obtained in the absence of a magnetic field. The electromagnetic precursors could have interesting practical applications such as in the interpretation of observed nonlinear structures during the interaction of the solar wind with the Earth and the Moon and may also serve as useful tracking signatures of charged space debris traveling in the ionosphere.

Wave-breaking Amplitudes in Warm, Inhomogeneous Plasmas Revisited: The effect of electron temperature on the space–time evolution of nonlinear plasma oscillations in an inhomogeneous plasma is studied using a one-dimensional particle-in-cell code. It is observed that, for an inhomogeneous plasma, there exists a critical value of electron temperature beyond which the wave does not break. These simulation results, which are in conformity with the purely theoretical arguments published, represent the first numerical elucidation of the effect of plasma pressure on wave breaking amplitude. The results are found to be relevant to experiments where moderate to large amplitude plasma waves are excited, e.g., laser–plasma interaction experiments.

Nonlinear Propagation of Low-Frequency Electromagnetic Disturbances in Plasmas: Electromagnetic (EM) waves/disturbances are typically the best means to understand and analyse an ionized medium like plasma. However, the propagation of EM waves with a frequency lower than the plasma frequency is prohibited by the freely moving charges of the plasma. In dense plasmas, though the plasma frequency can be typically quite high, EM sources at such higher frequency are not easily available. It is, therefore, of interest to seek possibilities where in a low frequency (lower than the plasma frequency) EM disturbance propagates inside a plasma. This is possible in the context of magnetized plasmas. However, in order to have a magnetized plasma response in high-density plasmas, one requires an extremely strong external magnetic field. In this study, it is demonstrated that the nonlinearity of the plasma medium can aid the propagation of a slow (effective frequency lower than the plasma frequency) EM wave inside an over-dense plasma. A possible mechanism of guiding, collimating, and trapping of the EM pulse or electron current pulses by appropriate tailoring of the local plasma density profile is also studied. Certain interesting applications of the propagation of such slow EM pulse through the in homogeneous plasma is also proposed.

A.5.3 Tokamak & Fusion Reactor Studies

Aditya Upgradation - Equilibrium Study: The Aditya tokamak device is used to produce circular plasma for few hundreds of milli-seconds. The edge physics study in this device led to significant contributions. The up-gradation of this device (Aditya-Upgrade) is focused to address issues relevant to heat removal capability at the plasma edge. This requires to construct plasma equilibrium with divertor configuration. In this regard, additional pair of coils at the inboard and outboard are introduced to construct plasma equilibrium. The inboard pair mainly creates the divertor configuration while the outboard pair provides flexibility in increasing the size of the plasma. In this study, it has shown that plasma equilibrium with double and single null configurations can be produced for plasma current up to 100 kA and with plasma poloidal beta of 0.3. The operational space in these plasma parameters is limited by the requirement on gap of 3 cm between null point and the vacuum vessel as well as limited due to maximum allowable current of 150 kA in divertor coil.

Parameter Space Validation through OOPS Simulations of Plasma Burn-through and Discharge Evolution in the SST-1 Tokamak: Plasma burn-through and current ramp-up phases in an SST-1 superconducting tokamak are simulated by the OOPS code. The main purpose of this study is to optimize the operation regime in SST-1 through the input parameters scan for OOPS for both successful and failed shots from the SST-1 database. SST-1 is now equipped with carbon plasma facing components (PFCs). Hence, PFCs are expected to offer a carbon dominated impurity environment. An electrically continuous vacuum vessel and cryostat hinder sufficient loop voltage during start-up, thereby rendering electron cyclotron resonance heating (ECRH) pre-ionization an absolute requirement. OOPS simulation is optimized for the essential plasma initiation parameters like the seed electron density ne $\sim 3\times10^{17}/m^3$ and the initial neutral density $n_0 \sim 1–4\times10^{18}/m^3$ (corresponding to a tailored pre-fill pressure) and for an error magnetic field 20 G. The simulation shows that the ECRH pre-ionization threshold power required for the successful plasma start-up under low available loop voltage conditions is 180 kW.

Effects of Nitrogen Seeding in a Tokamak Plasma: The effects of nitrogen gas seeding in the edge and scrape-off layer (SOL) regions of a tokamak plasma are studied through 2D fluid simulations using the BOUT++ code. Proper account is taken of the presence of multiple charged states of nitrogen ions due to ionization, recombination, and dissociation processes, and a self-consistent study of the interaction of these ions with the turbulent plasma in the edge and SOL regions is carried out. The self-consistent model includes the effects of polarization drifts of the main plasma and impurity ions for determining the plasma vorticity. Nitrogen seeding is found to modify the turbulence as well as to influence the profiles of the equilibrium plasma density and the electron temperature. The densities of N^{3+} to N^{5+} ions are found to be relatively higher than the other charged states. This is understood and further validated by a 0D simulation. The radial profiles of these impurity ions are mapped, and their radiation energy losses are estimated. The radial profile of the radiation losses is maximum near to the edge-to-SOL transition region and becomes broader in the edge region than the SOL region.

Study of Transmutation, Gas Production, and Displacement Damage in Chromium for Fusion Neutron Spectrum: In the present work, gas production, transmutation and displacement damage in chromium are studied for fusion neutron spectra. The nuclear cross-section data are calculated with the TALYS-1.8 code. Transmutated isotopes in chromium, including the radioactive ones, are identified for typical fusion reactor neutron spectrum. Gas production per atom (He and H production) are also predicted for typical fusion neutron spectrum. Molecular dynamics (MD) simulations of damage cascade caused by the self-recoil in chromium are carried out for up to 200 keV damage energies using the LAMMPS code. Time evolution of interstitials and vacancies are studied and discussed. Based on the performed MD simulations, constant parameters of the athermal-recombination corrected dpa (arc-dpa) method are calibrated. Displacement damage cross-section of chromium are calculated using the Norgett-Robinson and Torrens (NRT) and arc-dpa approaches and later used to predict the values of displacement per atoms (dpa) in chromium for typical fusion reactor neutron environment. In the present work, gas production, transmutation and displacement damage in chromium are studied for fusion neutron spectra. The nuclear cross-section data are calculated with the TALYS-1.8 code. Transmutated isotopes in chromium, including the radioactive ones, are identified for typical fusion reactor neutron spectrum. Gas production per atom (He and H production) are also predicted for typical fusion neutron spectrum. Molecular dynamics (MD) simulations of damage cascade caused by the self-recoil in chromium are carried out for up to 200 keV damage energies using the LAMMPS code. Time evolution of interstitials and vacancies are studied and discussed. Based on the performed MD simulations, constant parameters of the athermal-recombination corrected dpa (arc-dpa) method are calibrated. Displacement damage cross-section of chromium are calculated using the Norgett-Robinson and Torrens (NRT) and arc-dpa approaches and later used to predict the values of displacement per atoms (dpa) in chromium for typical fusion reactor neutron environment.

Design and Comparison Study of Steam Generator Concepts and Power Conversion Cycles for Fusion Reactors: While the viability of fusion energy would be demonstrated by the ITER operation, the power extraction from the fusion reactors also needs attention in parallel as it presents its own challenges due to the specific features of tokamaks. A detailed comparison study on different steam generators being used in fission reactors and their viability in fusion reactors has been addressed with the primary and secondary fluids being considered as helium and water respectively. Based on the comparison, the shell & tube heat exchanger (STHE) and the printed circuit heat exchangers (PCHE) have been considered as the potential candidates, assuming 500 MWTh power. The comparative investigations of Brayton and Rankine power cycle along with their efficiencies are also discussed. The Rankine cycle gives 36 % and 38 % efficiency for the STHE and PCHE cases, respectively, whereas that of Brayton gas cycle efficiency is 42 % for PCHE.

A.5.4. Fundamental Plasma Studies

Finite beta Effects on Short Wavelength Ion Temperature Gradient Modes: The electromagnetic effect is studied on the short wavelength branch of the ion temperature gradient mode in the linear regime for the first time using a global gyrokinetic model. The short wavelength ion temperature gradient mode growth rate is found to be reduced in the presence of electromagnetic perturbations at finite plasma beta. The effect on real frequency is found to be weak. The threshold value of gi is found to increase for the mode as the magnitude of beta is increased. The global mode structure of the short wavelength branch of the ion temperature gradient mode is compared with the conventional branch. The magnetic character of the mode, measured as the ratio of mode average square values of electromagnetic potential to electrostatic potential, is found to increase with increasing values of the plasma beta. The mixing length estimate for flux shows that the maximum contribution still comes from the long wave-lengths modes. The magnitude of the flux decreases with increasing beta.

Magnetized Plasma Sheath in the Presence of Negative Ions: The sheath formation in a weakly magnetized collision-less electronegative plasma consisting of electrons and negative and positive ions has been numerically investigated using the hydrodynamic equations. The electrons and negative ions are assumed to follow the Boltzmann relation. A sheath formation criterion has been analytically derived. A focused study on the sheath structure is done by varying the electronegativity. It has been observed that the presence of negative ions has a substantial effect on the sheath structure. The observations made in the present work have profound significance on processing plasmas, specifically in the semiconductor industry as well as in fusion studies.

Landau Damping in One Dimensional Periodic Inhomogeneous Collisionless Plasmas: Landau damping in a collisionless plasma is a well-known example of wave particle interaction. In the past, this phenomenon was addressed for homogeneous equilibria in the linear and non-linear limit of the perturbation amplitude. However, in reality, equilibria are almost always inhomogeneous or non-uniform in space. Considering a one dimensional, collisionless, unmagnetized, electrostatic plasma with stationary ions and kinetic electrons in a periodic inhomogeneous exact equilibrium of scale k^{-10} as the starting point, the fate of a small amplitude (linear) perturbation of scale k^{-1} is investigated using a Vlasov–Poisson solver. Three different spatial regimes, namely, $k_0 > k$, $k_0 \sim k$, and $k_0 < k$, are addressed. In the $k_0 > k$ regime, long wavelength perturbation k is found to generate $(k \pm Nk_0)$ modes (where N is an integer), which allows damping of long wavelength perturbation in an inhomogeneous plasma and formation of phase-space vortices at phase velocities $v\phi = \omega/(k \pm Nk_0)$. Perhaps for the first time, novel phenomena such as "inhomogeneity induced Landau damping arrest" and "inhomogeneity induced plasma echo" are observed in $k_0 \sim k$ and k0 < k regimes, respectively. New scaling laws as a function of inhomogeneity amplitude are also studied

Boundary Driven Unconventional Mechanism of Macroscopic Magnetic Field Generation in Beam-Plasma Interaction: The all-pervading magnetic field in nature has aroused great curiosity and spawned many efforts to understand its generation. We propose, simulate, and experimentally demonstrate another mechanism of long-scale magnetic field generation in the context of a laser-plasma interaction. It relies on two realistic features, namely the finite size of the laser generated electron beam and an initial current imbalance. It is shown that magnetic fields of scale lengths comparable to the transverse beam dimension, are generated much before the onset of conventional instabilities associated with the beam-plasma system. This is due to radiative leakage at the boundaries of the finite beam, wherein even a small but finite current imbalance plays the crucial role of a radiative antenna. These features have been absent in simulations and theoretical analyses using the periodic boundary condition.

Double Layer Formation and Thrust Generation in an Expanding Plasma using 1D-3V PIC Simulation: Due to large particle exhaust velocity and specific impulse, electric propulsion systems have an edge over chemical propulsion for missions targeting regions outside the Earth's atmosphere. Stationary plasma thrusters and helicon plasma thrusters (HPTs) are commonly used electric propulsion devices for a space mission. In HPTs or expanding magnetic field plasma thrusters, plasma expands from the source region to the expansion region in an externally applied expanding magnetic field. Due to plasma expansion in such a magnetic field configuration, a current free double layer is found to form, which accelerates bulk ions, and a directional ion beam is generated, which causes thrust in the opposite direction. A Particle In Cell (PIC) solver with Monte Carlo Collision (MCC) scheme which resolves the axial direction and all three velocity degrees of freedom (1D-3V PIC-MCC) that captures the 2D spatial plasma expansion effect via a 1D flux conserving model is developed to simulate an argon plasma in an expanding magnetic field. Using the 1D-3V PIC-MCC solver, double layer formation due to plasma expansion, thrust generation, and optimization of thrust studies over a large parameter set, such as fill pressure of Ar, is studied. These results are also compared with a particle loss model, which is commonly used as the simplest model for HPTs.

High Frequency Sheath Modulation and Higher Harmonic Generation in a Low Pressure Very High Frequency Capacitively Coupled Plasma Excited by Sawtooth Waveform: A particle-in-cell simulation study is performed to investigate the discharge asymmetry, higher harmonic generations and electron heating mechanism in a low pressure capacitively coupled plasma excited by a saw-tooth like current waveform for different driving frequencies;13.56 MHz, 27.12MHz, and 54.24MHz. Two current densities, 50 A m−2 and 100 A m−2 are chosen for a constant gas pressure of 5 mTorr in argon plasma. At a lower driving frequency, high frequency modulations on the instantaneous sheath electric field near to the grounded electrode are observed. These high frequency oscillations create multiple ionization beam like structures near to the sheath edge that drives the plasma density in the discharge and responsible for discharge/ionization asymmetry at lower driving frequency. Conversely, the electrode voltage shows higher harmonics generation at higher driving frequencies and corresponding electric field transients are observed into the bulk plasma. At lower driving frequency, the electron heating is maximum near to the sheath edge followed by electron cooling within plasma bulk, however, alternate heating and cooling i.e. burst like structures are obtained at higher driving frequencies. These results suggest that electron heating in these discharges will not be described accurately by simple analytical models.

A.5.5. Laser-Plasma Interaction

A New Mechanism of Direct Coupling of Laser Energy to Ions: The well-known schemes (e.g. Brunel mechanism, resonance absorption, J × B heating etc) couple laser energy to the lighter electron species of the plasma. In this work, a fundamentally new mechanism of laser energy absorption directly to the heavier ion species has been proposed. The mechanism relies on the difference between the E × B drifts of electron and ions in the oscillating electric field of the laser and an external magnetic field to create charge density perturbations. The proposed mechanism is verified with the help of particle-in-cell (PIC) simulations using OSIRIS4.0.

Excitation of Lower Hybrid and Magneto-Sonic Perturbations in Laser Plasma Interaction: Lower hybrid (LH) and magneto-sonic (MS) waves are well known modes of magnetized plasma. These modes play important roles in many phenomena. The LH wave is often employed in magnetic confinement fusion experiments for current drive and heating purposes. Both LH and MS waves are observed in various astrophysical and space plasma observations. These waves involve ion motion and have not therefore been considered in high power pulsed laser experiments. A simple mechanism for excitation of LH and magneto-sonic excitations in the context of laser plasma interaction has been shown with the help of particle-in-cell simulations. A detailed study characterizing the formation and propagation of these modes have been studied. The scheme for generating these perturbations relies on the application of a strong magnetic field in the plasma to constrain the motion of lighter electron species in the laser electric field. The magnetic field strength is chosen so as to leave the heavier ions un-magnetized at the laser frequency. This helps in the excitation of the LH waves. At the slower time scale associated with the laser pulse duration, even the ions show a magnetized response and magnetosonic excitations are observed to get excited.

A.5.6. Dusty and Complex Plasmas

Dust Vortex Flow Analysis in Weakly Magnetized Plasma: A non-perturbative update of Schamel's pseudo-potential method is employed to show the diversity in structure formation in collisionless plasmas, manifested already in the solitary wave limit. As an example, the Gaussian-shaped solitary electron hole, known from earlier Bernstein, Greene, and Kruskal (BGK) analyses, known to be a specific, albeit incomplete wave solution, is updated by subjecting it to a nonperturbative pseudo-potential analysis. Only by the latter can a speed be assigned to it. A perturbative trapping scenario is thereby defined by a Taylor expansion of the trapped electron distribution function fet is the single particle energy. It stands for the class of privileged, solitary sech4 -holes, and properly extends undamped linear waves into the nonlinear regime lifting them at a higher level of reliability. A non-perturbative trapping scenario, on the other hand, cannot be handled by a Taylor expansion as it refers to singular terms in the small -limit, affecting the collective dynamics in phase space especially near separatrices. Being not only suitable to update BGK solutions, it opens the door to a much richer world of structure formation than treated before. To face physical reality properly, however, one has to go one step further by locally and self-consistently incorporating a structure dependent collisionality in the kinetic description and in the numerical simulation, as well. By this removal of cusp-singularities, associated with reliable Vlasov–Poisson-solutions, a more realistic approach to intermittent plasma turbulence and anomalous resistivity may be achieved in forthcoming investigations.

Measurement of Temperature of a Dusty Plasma from its Configuration: A new concept called "configurational temperature" is introduced in the context of dusty plasma, where the temperature of the dust particles submerged in the plasma can be measured directly from the positional information of the individual dust particles and the interaction potential between the dust grains. This method does not require the velocity information of individual particles, which is a key parameter to measure the dust temperature in the conventional method. The technique is initially tested using two-dimensional (2D) OpenMP parallel molecular dynamics and Monte Carlo simulation and then compared with the temperature evaluated from experimental data. The experiment have been carried out in the Dusty Plasma Experimental (DPEx) device, wherea2D stationary plasma crystal of melamine formaldehyde particles is formed in the cathode sheath of a DC glow discharge argon plasma. The kinetic temperature of the dust is calculated using the standard particle image velocimetry technique at different pressures. An extended simulation result for the three-dimensional case is also presented, which can be employed for the temperature measurement of a three-dimensional dust crystal in laboratory devices.

The Emergence of Inertial Waves from Coherent Vortex Source in Strongly Coupled Dusty Plasma: The evolution of isotropic, nondispersive, inertial waves emerging from an unsteady initial coherent vortex source is studied for strongly correlated dusty plasma using two-dimensional molecular dynamics simulation. In this study, the effects of azimuthal speed of a vortex source, strong correlation, large screening, and the compressibility of the medium on the propagation of generated inertial waves have been presented. It has been observed that these inertial waves only exist when the angular speed or azimuthal speed of the vortex source (U0) is larger than the transverse sound speed of the system. The estimated speed of the nonlinear wave is found to be always larger and close to longitudinal sound speed of the system for the range of coupling and screening parameters studied. We find that spontaneously generated inertial wave speed in dusty plasma is suppressed by the compressibility and dust-neutral drag of the system and is less sensitive to coupling strength. A transition from "incompressible to compressible" flow has also been found to occur. This transition is found to depend on the screening parameter and azimuthal speed of the vortex source. The existence of a critical Mach number Mc 0:35 is found above which inertial waves are found to exist, indicating the compressible nature of the wave.

Driven Dust Vortex Characteristics in Plasma with External Transverse and Weak Magnetic Field: The two-dimensional hydrodynamic model for bounded dust flow dynamics in plasma is extended for analysis of driven vortex characteristics in presence of external transverse and weak magnetic field (B) in a planner setup and parametric regimes motivated by recent magnetized dusty plasma (MDP) experiments. This analysis has shown that shear in the B can produce a sheared internal field (Ea) in between electrons and ions due to the E × B and grad-B × B-drifts that cause rotation of dust cloud levitated in the plasma. The flow solution demonstrates that neutral pressure decides the dominance between the ions-drag and the Ea-force. The shear ions-drag generates an anti-clockwise circular vortical structure, whereas the shear Ea-force is very localized and gives rise to a clockwise D-shaped elliptical structure which turns into a meridional structure with decreasing B. Effect of the strength of B, shear mode numbers, and the sheath field are analyzed within the weak MDP regime, showing noticeable changes in the flow structure and its momentum. In the regime of high pressure and lower B, the Ea-force becomes comparable or dominant over the ion drag and peculiar counter-rotating vortex pairs are developed in the domain. Further, when the B is flipped by 180-degree, both the drivers act together and give rise to a single strong meridional structure, showing the importance of B-direction in MDP systems. Similar elliptical/meridional structures reported in several MDP experiments and relevant natural driven-dissipative flow systems are also studied.

A.5.7. Material Studies & Plasma Applications

Thermal Performance Analysis and Experimental Validation of Primary Chamber of Plasma Pyrolysis System during Preheating Stage Using CFD Analysis in ANSYS CFX: Plasma pyrolysis is emerging as a very attractive approach for safe disposal of bio-medical wastes worldwide. In this process, the plasma arc plays a vital role for achieving the desired high temperature of ~1000 °C in primary chamber before the waste is fed into this chamber and the waste is decomposed without generating any toxic molecules and by-products. This technology has been indigenously developed at the Facilitation Centre for Industrial Plasma Technologies (FCIPT), Institute for Plasma Research (IPR), having a capacity of processing around 50 kg biomedical waste per hour. The transfer of heat from plasma arc to inner volume of the primary chamber predominantly takes place through radiation and it is further aided by convective heat transfer by nitrogen gas flowing around the arc. Transient CFD (Computational fluid dynamics) simulation has been performed using the commercially available CFD tool ANSYS CFX to determine the temperature and its comparison with experiment. Currently only a preheating analysis without the introduction of waste or any chemical reaction has been performed. This would assist in designing a high capacity (200 kg/h or more) plasma pyrolysis system by validating the methodology and assumptions used in this study. The study has provided information on temperature distribution, heat loss, energy balance, etc. during the pre-heating stage of primary chamber. The CFD results are found to be within a comparable range (<20% for inner surface and <10% for outer surface) for most of the duration of the experiment. The reasons for deviation have also been identified and documented.

Observations of Point Defect Dynamics in the Recrystallization of Cold-Rolled Tungsten Foils: The evolution of point defects with annealing temperature is investigated in cold-rolled tungsten samples using positron annihilation spectroscopy and transmission electron microscopy. We report a correlation between the unexpectedly high intensity of mono-vacancy-like lifetime (201 ps) observed at 1373 K annealing temperature and the initial stages of recrystallization. The formation of large vacancy clusters is also observed at higher annealing temperatures (2000 K), well beyond the defect recovery temperature in tungsten.

Studies on the Near-Surface Trapping of Deuterium in Implantation Experiments: Surface-shifted deuterium profiles are re-examined in deuterium-ion irradiation experiments by using a combined experimental and modelling approach. Recrystallized tungsten foil samples were irradiated with energetic deuterium ions and the defect and deuterium depth profiles were studied using positron annihilation spectroscopy and secondary ion mass spectroscopy. We report direct experimental evidence of trapping of deuterium at the vacancies created by the deuterium ions themselves during the implantation by using positron annihilation studies. The deuterium profile is simulated using a Monte-Carlo diffusion model by taking into account the defect-aided diffusion of deuterium due to the local strain field created by the vacancies. The simulations also elucidate the role of the anisotropy in the diffusion and trapping of deuterium in ion-implantation experiments in metals.

Effect of Temperature on the Evolution Dynamics of Voids in Dynamic Fracture of Single Crystal Iron: A Molecular Dynamics Study: We employ molecular dynamics simulations to investigate the role of temperature on the evolution dynamics of the voids in single crystal iron. We simulate isotropic tension in single crystal iron at a constant strain rate with temperature in the range of 300–1200 K. We find that the number of voids is highest at 1200 K in comparison to that at 300 K indicating high nucleation events at high temperatures. The growth rate of the voids is highest at 300 K in comparison to that at 1200 K, indicating rapid growth of the voids at 300 K. The overall void volume fraction is highest at 300 K. The nucleation and growth of the voids at 1200 K occur earlier in time in comparison to that at 300 K indicating the earlier damage of the material at 1200 K. The individual void volume fraction evolves with many discrete jumps due to the coalescence of the voids. The dislocation density is highest at 300 K in comparison to that at 1200 K.

Evolution of Voids in Single-Crystal Iron under Uniaxial, Biaxial and Triaxial Loading Conditions: We perform molecular dynamics simulations to investigate the void evolution dynamics in single-crystal iron deformed under uniaxial, biaxial and triaxial loading conditions. We find that the void density is highest for the triaxial case while it is lowest for the uniaxial case. The average void growth rate is highest for the uniaxial case while it is lowest for the triaxial case. The individual void volume fraction for the triaxial case evolves with many discrete jumps due to many coalescence events, while it evolves with few discrete jumps for the uniaxial case. For uniaxial and biaxial cases, the shape of the most dominant void is prolate while it is spherical for the triaxial case. The average void spacing of independent voids is highest for the uniaxial case where the void density is lowest, while it is lowest for the triaxial case where the void density is highest. The observations in this study may be useful to develop frameworks for dynamic fracture models for closer comparison with the experiments.

Strain-Rate Effect on Plasticity and ω-phase Transformation in Single Crystal Titanium: A Molecular Dynamics Study: We employ molecular dynamics simulations to investigate the role of applied strain rate on plasticity (twinning and dislocation slip) and ω-phase transformation in single crystal titanium for loading perpendicular to the c-axis under uniaxial strain conditions. We find a significant dependence of microstructural evolution on the applied strain rate. The applied loading leads to the activation of $\{10\bar{1}2\}$ twins and ω-phase transformation. For loading along $< 2\bar{1}\bar{1}0>$ direction, four twin variants activate while for loading along $< 01\bar{1}0>$ direction, only two twin variants activate. The twin number density decreases with a decrease in applied strain rate for both loading conditions. For the case where four twin variants activate, the overall reorientations at each applied strain rate are large in comparison to the case where only two twin variants activate. In addition to this, the overall reorientations decrease with a decrease in applied strain rate for both loading conditions. The ω-phase volume fraction decreases with a decrease in applied strain rate for both the cases of applied loading conditions. For the case where only two variants activate, the overall twin volume fraction is highest at each applied strain rate in comparison to the case where four twin variants activate. In addition to this, the overall twin volume fraction is lowest at highest applied strain rate while it is highest at lowest applied strain rate for both loading conditions. These observations should be useful to develop physics based dynamic material strength models for coupled evolution of plasticity and ω-phase transformation.

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CHAPTER B

Activities of ITER-India

The ITER India team continues to make steady progress in ensuring the deliveries to ITER in a time bound fashion and ensuring that the deliverables meet the desired norms in terms of quality and standards as per requirements of a nuclear installation. Near 100% deliveries related to 4 out of the 9 procurement packages have been achieved. These relate to cryostat, cooling water systems, in-wall shielding and cryolines and cryodistribution systems. These deliveries, despite of pandemic conditions, are in line with supporting ITER towards its goal for a first plasma by the end of 2025.

In parallel construction and commissioning activities are in full swing at ITER site with minimal deviations due to COVID lockdowns. Activities related to machine assembly started on 28th July 2020. Considering the pandemic conditions the ceremony was televised to all the participating member nations and addressed by the heads of all the member countries or their nominated representatives. The message from the honourable Indian prime Shri Narendra Modi was delivered by the Indian ambassador to France Shri Parvez Ashraf. The ITER Council met in November 2020 to review the affairs of the project, and 72% physical progress has been reported and is related to the completion of activities required for the first plasma

Credits received for Indian in-kind deliveries now stand at 132898.02 IUA as compared to 95361 IUA (ITER units of account) reported last year.

The following sections provide a brief overview of the progress made by ITER India towards ensuring the deliverables to IO related to various packages

B.1 Cyrostat

100 % deliveries related to the 29 m tall and 29 m wide world's largest vacuum vessel, the cryostat, have been completed with the last shipment related to the top lid sectors leaving the Indians shores Nov 2020 from the premise of M/S L&T Hazira. A ceremony to flag-off the shipment was graced over video by Dr. V.K. Saraswat (Member-NITI Aayog), Dr. Bernard Bigot (DG-ITER), Shri K.N. Vyas (Secretary DAE and Chairman AEC), Shri A.M. Naik (Group Chairman-L&T) and personnel from different contributing agencies like IPR, ITER-India and L&T. Meanwhile, as the shipments for the top lid got ready in India, a parallel and extremely significant activity happened at ITER site as the base section of the cryostat became the first component of the ITER machine to be installed in the ITER pit. Synchronised movement of two cranes with 4 spreader arms ensured the placement of the 29 m diameter 10 m tall 1250 Tons structure with a positional accuracy of less than 3 mm.. In addition the puzzle pieces of the top cylinder also got assembled and cocooned at the ITER India cryostat workshop in ITER site. Another achievement was the placement of the lower cylinder, weighing ~400 tonnes was on the cryostat base section. The assembled section was handed over to IO in March 2019. Since then it had been cocooned and stored for 18 months. The cylinder was lifted by 1500 ton overhead cranes and precise tactical move-

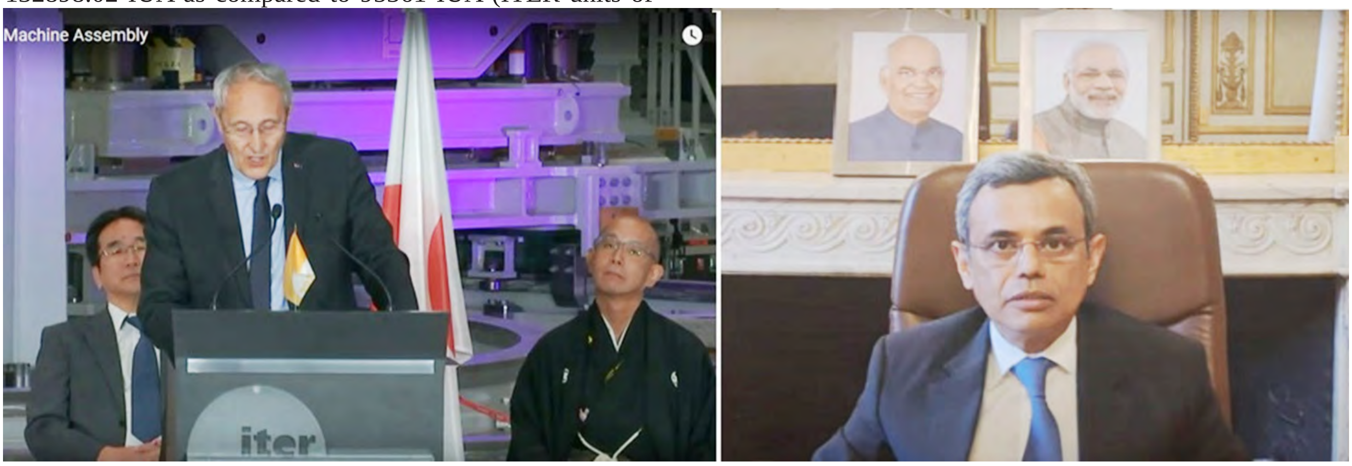


Figure B.1. Start of Machine assembly activities at ITER. Dr Bernard Bigot, Director General ITER organisation addressing the gathering. Shri Parvez Ashraf delivering the message from the Indian prime minister on this occasion

Figure B.2 Clockwise from top: The flag off ceremony being addressed by Dr. V.K. Saraswat (Member-NITI Aayog), Dr. Bernard Bigot (DG-ITER), Shri K.N. Vyas (Secretary DAE and Chairman AEC), Shri A.M. Naik (Group Chairman-L&T) and senior officers from IPR, ITER-India and L&T, Packed top lid sectors at M/S L&T Hazira, Project director ITER India along with L&T officials flagging off the final shipment

ments were performed to ensure its lowering, installation and positioning on the cryostat base section within the acceptable tolerances.

B.2 Cooling Water system

The cooling water system at ITER consists of a tokamak cooling water system (TCWS), component cooling water system (CCWS), chilled water system (CHWS) and heat rejection system. Till date 98 % of the supplies to ITER have been completed in accordance with the design and quality requirements. On site installation work of the pipes and supplied components is underway. The hydraulic piping along with the equipment's like cooling tower, heat exchanger, chiller and pumps required for supporting the cryoplant commissioning have been installed. Loopwise testing including

Figure B.3 The Cryostat base section placed with the desired positional accuracy in the tokamak pit

Figure B.4.Pipe in pipe concept for underground piping that of the welds has been completed. Integrated loop testing and pre-commissioning activities are underway to ensure system availability by Q2 2021. One of the major challenges related to the installation of the hydraulic pipes is the qualification of buried hot water piping at ITER site. In the case of buried piping it was observed during analysis that the T joints failed due to thermal expansion during operation. To enable qualification of this failure and as a part of risk mitigation, the concept of pipe in pipe at the joint location has been introduced where the process pipes are surrounded by a protective pipe enclosure with the gap filled with polyurethane foam to accommodate movement of the process pipe under thermal expansion and to avoid build-up of stresses. Such a technique is the first of its kind. Figure B.4 shows an example of such a pipe in pipe joint implemented at ITER

B.3.Vacuum Vessel In-Wall Shielding

The In-Wall Shields (IWS), serves the dual roles of absorbing fusion neutrons and making the magnetic field more uniform. The shields are placed in the space between the two walls of the vacuum vessel sectors. It is a complex assembly of ~9000 borated steel blocks manufactured in active collaboration with M/s Avasarala Technologies, Bengaluru and M/s L&T Hazira. On 24th July, M/s Avasarala completed manufacturing and dispatched the last batch to ITER. A video televised ceremony was organised, the speakers including eminent scientist Dr. Anil Kakodkar as the chief guest, Dr. Bernard Bigot, DG ITER organization and a message from Chairman AEC

Figure B.5. The video televised ceremony – clockwise from top – the ATL team, Dr. Shashank Chaturvedi, Director IPR delivering address on behalf of Shri K.N. Vyas, Chairman Atomic Energy commission, Dr. Bernard Bigot, Director General ITER IO and the chief guest of the function Dr. Anil Kakodkar, member atomic energy commission and ex-chairman atomic energy commission

B.4. Cryoline and Cryo-Distribution system

A 12 km network of cryolines and warm lines alongwith cryodistribution boxes connects the ITER cryoplant with the machine in the tokamak building to ensure the desired cryogen supply to magnets and cryopumps. 95% activities related to cryolines and warmlines have been completed which include onsite delivery and installation at the desired locations in cryoplant buildings at ITER. A total of 16 circuits of Group Y cryolines and 48 circuits of warmlines have been successfully pressure tested in Cryoplant area using gaseous nitrogen with the last test being performed for longest circuit of WDH-1 warmline on during the first quarter of 2021. The ITER cryolines have test pressures ranging from 1.4 MPa (abs.) to 3 MPa (abs.), while the ITER warmlines have test pressure ranging from 0.72MPa (abs.) to 6.2 MPa (abs.). The pressure tests have been conducted in compliance with the IO specified technical specifications, ITER safety (including French law) and quality norms with zero incidents identified for the complete duration. The largest of the seven distribution cold boxes, the 20 m long, 3.5 m diameter and 70 tonne cryoplant termination cold box (CTCB) has been manufactured, assembled and installed at ITER alongwith a 600 kW electrical heater system, DN 200 cryogenic control valves and a SS bubble panel thermal shield. This will ensure the key role of key role of distribution of the cold helium fluid with the highest mass flow rates of 4 kg/s gaseous helium (GHe) coming from one of the 80 K plants and 3.15 kg/s for supercritical helium (SHe) towards the magnet ACBs with the interconnections ensured using nine cryolines with diameters ranging from 0.45 m to 1.0 m.

B.5. Diagnostic Neutral Beam

Steady progress continues with the fabrication of the various components of the diagnostic neutral beam system which include the 8 driver RF driven negative ion source to produce 100 keV 60 A H- beams, neutraliser to convert negative ion beams to a mixture with ion and neutral components and electrostatic residual ion deflector to separate the ionic and the neutral beam components and a calorimeter to diagnose the properties of the accelerated neutral beam. Significant among these is the first of a kind characterisation of the plasma grid segments of the extractor and accelerator system of the ion source for operation at high temperature

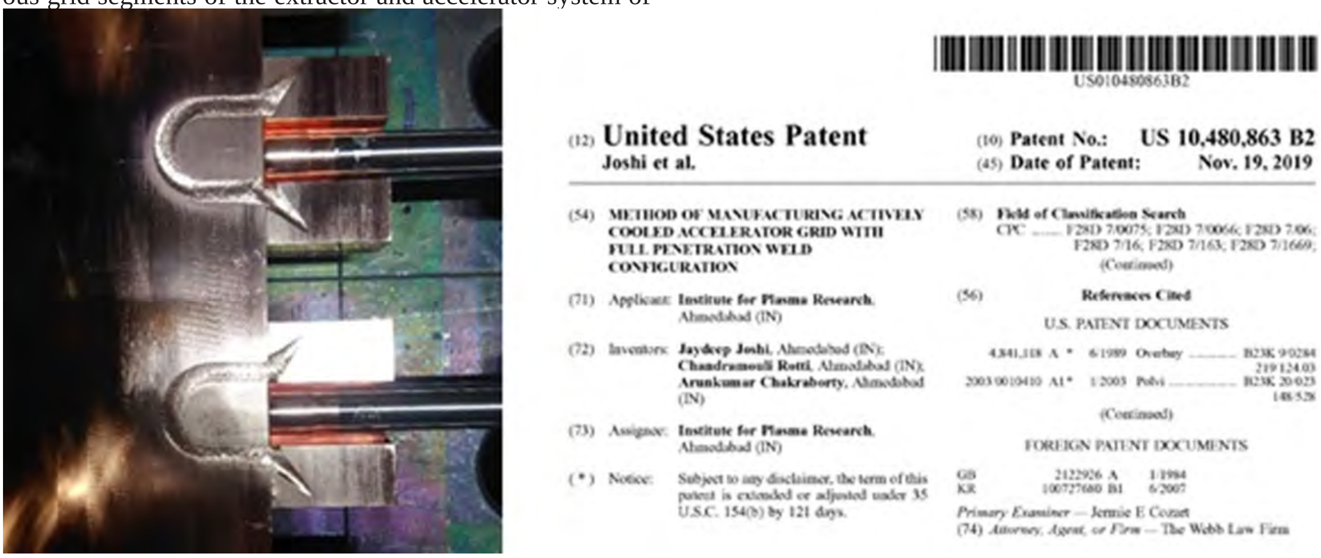
Figure B.6. Installation of 20 m long 3.5 m diameter 70 tonne cryoplant termination cold box (CTCB)

Figure B.7 Plasma grid segments inserted in a vacuum hot furnace in preparation for the hot helium leak test

and high pressure, 150 °C at 25 bar He pressure. The tests, typically termed as hot helium leak tests (HHLT), become more significant as these help to qualify to an extent, the 1.5 mm thick copper layer electrodeposited on copper base plate with milled channels to allow flow of water. The tests have been performed inside a temperature controlled furnace and a global leak rate of < 10^{-9} mbar l/s has been demonstrated. The process so established also finds application for other copper electrodeposited precision fabricated components for application in various part of the fusion machines. Another important aspect of technology development for the neutral beam injector systems is the joining of water stubs to the various grid segments of the extractor and accelerator system of the ion source. A new welding methodology has been developed that overcomes the limitations of conventional welding techniques like friction welding and involves full penetration welding as shown in Figure B.8. This configuration has been applied to the manufacturing of grid segments and tested for all acceptance parameters (destructive, non-destructive and leak rates of 10^{-9} mbar-liter/s as per ITER standards). A US Patent has been granted for this development.

B.6. Ion Cyclotron Resonance Frequency Heating Sources

The in-house developed new type of 3 dB Hybrid MW Level CW Radio Frequency Combiner/Splitter reported last year was tested in the splitter configuration as shown in Figure 15. The need for testing the combiner in the splitter mode was essentially dictated by the presence of only 1 of the 2 amplifier chains of 1.5 MW each to achieve the desired 2.5 MW power at VSWR of 2:1 in the frequency range of 35-60 MHZ/CW operation. The 1.5 MW RF power fed to port 3 of the combiner was split into two halves of 750 kW each with one half fed to port 1 and the other to port 4. The power was detected using MW level matched loads at these ports. Another isolated port on the combiner, port 2, is connected to 200 kW dummy load to absorb reflections from the outputs if any. For power measurement, directional couplers as well as calorimetric measurement embedded in dummy loads were used. The high-power test, Figure 9c,d, was performed at different frequencies and power levels i.e. 36MHz, 40MHz, 45MHz, 50MHz, 55MHz and 60MHz with power level 500kW, 750kW, 1MW, 1.25MW and 1.5MW for 2000s, successfully.



US010480863B2

(12) **United States Patent**
Joshi et al.

(10) **Patent No.: US 10,480,863 B2**
(45) **Date of Patent: Nov. 19, 2019**

(54) **METHOD OF MANUFACTURING ACTIVELY COOLED ACCELERATOR GRID WITH FULL PENETRATION WELD CONFIGURATION**

(71) Applicant: **Institute for Plasma Research**, Ahmedabad (IN)

(72) Inventors: **Jaydeep Joshi**, Ahmedabad (IN); **Chandramouli Rotti**, Ahmedabad (IN); **Arunkumar Chakraborty**, Ahmedabad (IN)

(73) Assignee: **Institute for Plasma Research**, Ahmedabad (IN)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 121 days.

(58) **Field of Classification Search**
CPC F28D 7/0075; F28D 7/0066; F28D 7/06; F28D 7/16; F28D 7/163; F28D 7/1669;
(Continued)

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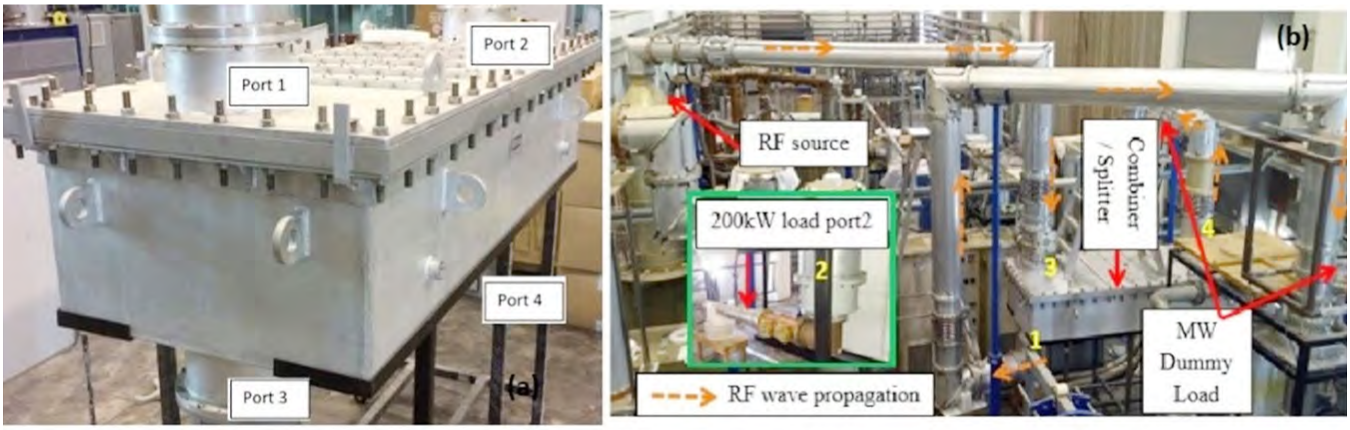
Primary Examiner — Jennie E Cozart
(74) *Attorney, Agent, or Firm* — The Webb Law Firm

Figure B.8. The developed weld joint and the US patent for the same



(c)

Frequency (MHz)	Power level (kW): Input power ~1000kW at Port 3 — Output power Port 1	Output power Port 4	Isolated port power Port2	Input power ~1500kW at Port 3 — Output power Port 1	Output power Port 4	Isolated port power Port2
36	466	565	4.10	708	856	6.13
40	487	543	1.17	734	812	1.89
45	508	524	2.08	766	788	3.76
50	507	511	0.37	769	777	0.56
55	513	532	0.60	763	802	1.07
60	470	531	3.10	703	803	4.83

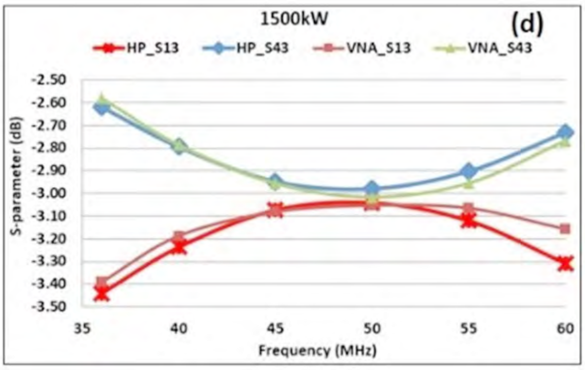


Figure B.9. Inhouse developed 3 dB MW Level CW Radio Frequency Combiner/Splitter tested in splitter mode at ITER India laboratory IPR

B.7. Electron Cyclotron RF heating sources

Preparations in the laboratory continue to enable full power testing and characterisation of the 170 GHz, 1 MW, 3600 s gyrotron sources. These include auxiliaries like the cooling and vauum systems, the data acquisition, control and protection systems, beam diagnostics and power supplies for enabling the tests as shown in the figure B.10. Meanwhile the factory acceptance tests of the source have been completed at the works of M/S Gycom, Russia with the demonstration of ~ 1MW operation for 1000 s at 170 GHz.

B.8. Power Supplies for DNB, ICRF and ECRH

ITER India has supplied a 100 kV, 70 A power supply to RFX to support the beam acceleration on the SPIDER test bed. The power supply has since been commissioned and coupled to the test bed. As the operations steadily progress towards achieving the desired voltage parallel operations on a similar power supply existing in the ITER India laboratory has been steadily used to support operations, problem solving and scenario development. The efforts will be of extreme help during the ion/neutral beam operations on the INTF test bed.

On the indigenous development related to solid state RF generators, experiments with the 40 kW RF generator coupled to the ROBIN test bed has resulted in successful coupling of the rated power to produce plasma. The tests have provided the desired operational experience and laid the basis of the further configurational and control modifications required to make these generators adaptable to RF source operations with varying load conditions. Online frequency tuning holds the key to successful operations with fixed values of the series and parallel capacitors of the matching circuit. On the

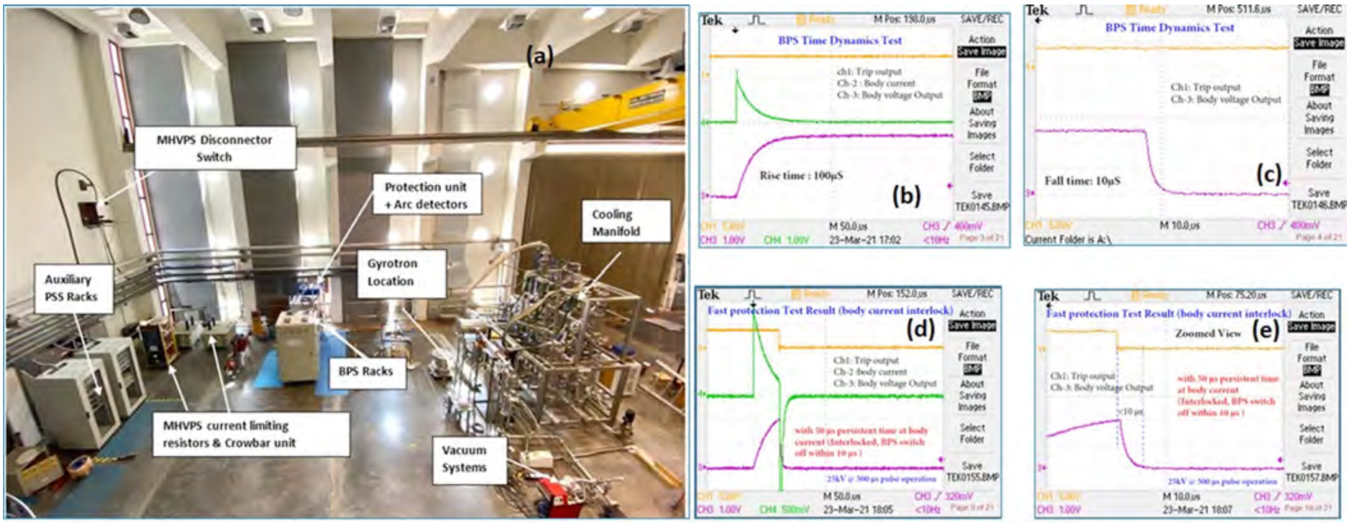


Figure B.10. The EC test bed at ITER India laboratory; (b),(c) measured rise and fall times of the BPS; (d),(e) protection interlocks

development of IC HVPS, upto 3 MW operation was supported by Dual output ICHVPS to validate Tetrode based RF sources for edge frequencies, bandwidth and remaining operating frequencies. ICHVPS has been operated remotely for more than ~300 Hours with loads upto 3MW. This marks 700 Hours operation of ICHVPS with RF source in it's life time since 2016. The activity has resulted in finalization of RF source specifications and also confirmed final specification of ICHVPS for IO deliveries. The in-house developed high voltage system for the EC is a combination of main high voltage power supply (MHVPS) 55kV, 6MW, and a 35 kV/100 mA body power supply (BPS). The MHVPS uses a cost effective modular solution with high voltage solid state switches with rise times < 100 µs and fall time < 10 µs.

B.9. Diagnostics

This year the major areas related to diagnostics which have shown substantial developments are related to ECE diagnostics, development and qualification of boron carbide as a neutron shielding material, and several modifications to the charge exchange recombination spectroscopy – pedestal (CXRS-P) and the XRCS edge systems from their CDR concepts. In the ECE diagnostics simulation studies have shown negligible transmission losses for relative humidity levels less than 1%. A prototype polariser splitter unit has been developed and integrated testing is underway to achieve the desired. On the developments related to the boron carbide material to be used for neutron shielding the chemical composition, mechanical, thermal and physical properties of

Figure B.11. The 55kV, 6MW MHVPS installed at ITER-India Power Supply Lab the material developed in close collaboration with an Indian industry have been studied, verified and found to be in line with ITER requirements.

B.10. Other Actvities

Contributions to the ITER related modelling efforts for disruption prediction and VDE's: A novel tool for quick data visualization and parameter selection for disruption prediction based on a machine learning technique is currently under development at ITER India, IPR. The tool uses artificial neural network techniques and uses ADITYA tokamak data base, with the final aim of disruption prediction about 16-20msec ahead of disruption events in ADITYA with more than 99.9% accuracy. The present study presently involves a data set of ~2200 ADITYA discharges (1D time series data only) and includes both disrupting and non-disrupting discharges. The present development can predict disruptions with about 99% accuracy. This will be further expanded to a larger database and also including 2D profile data for increasing the prediction accuracy to desired level.

In addition simulations related to disruptions and VDE events for ITER are underway using the TSC code through a dedicated task agreement. This involves development of a new halo current model in TSC, which calculates the halo width and temperature self-consistently using open field line transport in the halo region. This model has been validated against earlier similar simulations carried out using the DINA code and further simulations for mitigation with various concentrations of injected Neon and Deuterium is being carried out.

B. 11. Knowledge management

The Indian in-kind contribution to the ITER project is only about 9% of the overall ITER cost and in-kind components, whereas the rest of the >90% of ITER components are also equally critical, some in fact more complex in their design and manufacturing. It would be absolutely essential for us to achieve expertise in these other fusion reactor components to build our own tokamak-based fusion reactor in future. As a member of the ITER project, we also have equal right to the intellectual property of these components and have access to all their design documents, engineering drawings, analysis reports and models. The Knowledge Management group at ITER-India was formed in early 2020 for this purpose. It presently consists of 10 engineers/scientists who have been assigned to work on acquiring knowledge on 5 of the most critical components in ITER machine core, namely the magnets and magnet power supplies, vacuum vessel, neutron shielding blankets, divertor plates and the remote handling system. The team on vacuum vessel also looks into neutronics analysis. These personnel are working rigorously on acquiring, analyzing and understanding the design documents of these components starting from the Project Requirement Documents, detailed Design Description Documents, all Project Change Requests (PCRs) associated with these components to finally Engineering and Manufacturing Drawings. The necessary documentation is collected in well-structured folders. About 70% of the documentation for these packages have already been analysed and stored.

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CHAPTER C, D, E, & F

C. Academic Programme

D. Technical Services

E. Publications and Presentations

F. Other Activities

C. ACADEMIC PROGRAMMES

C.1 DOCTORATE PROGRAMME

Fourteen (14) new students with Physics (09) and with different Engineering background (05) including Nuclear engineering have joined this programme during this year and are going through the course work. After successful completion of this course work, they will be enrolled for their Ph.D, in HBNI. Overall there are total eighty four (84) PhD students are enrolled at present in HBNI including some IPR employees.

Ph.D. THESIS SUBMITTED (during April 2020 - March 2021)

Inferring the Magnetization effect in high density CCRF Discharges- an Electrical Approach
Joshi Jay Kirtikumar
Homi Bhabha National Institute, 2020

Pumping speed of Hydrogen and Helium gases using activated carbons as sorbent material at liquid helium temperature for cryopump applications
Ranjana Gangradey
Nirma University, Ahmedabad, 2020

Laboratory Studies of Stationary and Non-Stationary Structures in Flowing Complex Plasmas
Garima Arora
Homi Bhabha National Institute, 2020

Investigations on Weldability of Aluminide Coated 9cr Steel
Zala Arunsinh Bakulsinh
Homi Bhabha National Institute, 2021

Design, Development and Characterisation of a Passive Active Multijunction RF Launcher Compatible with ADITYA-Upgrade Tokamak
Jain Yogesh Mithalalji
Homi Bhabha National Institute, 2021

Magnetic Field Effects on Cold Hollow Cathode DC Discharge: An Experimental and Modeling Study
Montu Prafulbhai Bhuva
Homi Bhabha National Institute, 2021

Perturbation studies in a plasma confined by multi-pole line-cusp magnetic field
Meenakshee Sharma
Homi Bhabha National Institute, 2021

C.2 SUMMER SCHOOL PROGRAMME (SSP)

This programme was not conducted in this year.

C.3 ACADEMIC PROJECTS FOR EXTERNAL STUDENTS

Around 26 students, pursuing Under Graduate (UG)/ Post Graduate (PG) courses in science and engineering, were engaged to do various academic projects with IPR Faculties under their course curriculum in different fields of science and technology from various Colleges/Universities/Institutes during April 2020 to March 2021.

D. TECHNICAL SERVICES

D.1. SIRC (Library) Services

Scientific Information Resource Centre (SIRC) is providing specialized Information and Publication Management services using modern tools to the scientific community involved in the Research and Development activities of Plasma Physics and Fusion Science and Technology.

The FY 2020-21 was challenging for SIRC as it continued to provide library and publication services remotely during the COVID-19 lockdown period. Post Lockdown, ensuring adherence to the COVID protocols, the library rearranged the physical space and also amended certain services.

The library website (http://www.ipr.res.in/library/) is continuously updated with latest information and access to all the full-text access resources, both subscribed and internal e-resources.

During the year 2020-21 a total budget of Rs. 32821600.00 was utilized and added the following to its collection during

the year 2020-21:
Books – 62 and 24 eBooks; Scientific & Technical Reports from other institutes – 19; Reprints – 260; Pamphlets – 17; Software – 14

The library subscribed to 114 periodicals and added 2 new online journal titles to the e-collection and continued to subscribe to major databases such as SCOPUS, APS-ALL, Online Archives of core journals, and it has access to SCIENCE-DIRECT as part of the DAE Consortium.

Keeping the scientific community updated, the Library continued to provide Current Awareness Services by delivering email-based Fusion News Alerts and REcent Articles to Discover (READ) services to IPR, CPP and ITER-India users. Total 335 News items were sent/displayed and archived as an Alerting Service.

Library continued to collaborate with DAE units and other National and International libraries to provide Inter-Library Loan (ILL) services. 92% of the requests made by staff members were satisfied through ILL service. IPR Library provided documents to other institutes against their queries and 100% of the total need were satisfied.

In 2020-21, Library provided 27723 photocopies/ prints and 8022 scanned copies to the users.

Publication Management Services were carried out efficiently and SIRC continued to subscribe to anti-plagiarism software tool for checking similarity index of the publications. SIRC published the following during the year 2020-21:
Internal Technical Reports – 53; Internal Research Reports – 103; IPR Publications in Journals –161; IPR Publications in Conference Proceedings – 22; Book Chapters – 21.

A total of 236 manuscripts (Abstract/Papers) and 06 Patent information were broadcasted to the Staff through the Pre-Publication Broadcasting System and Pre-Patent Broadcasting System respectively in e-office.

Orientation was given to newly joined members and Research Scholars. Library is actively participating and contributing to other Institutional activities, such as Swacchata Abhiyan, Safety Week, etc. Library is also actively involved in OLIC and promoting usage of Hindi language.

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E. PUBLICATIONS AND PRESENTATIONS

E.1 Articles Publications

E.1.1 Journal Articles

Study of Transmutation, Gas Production, and Displacement Damage in Chromium for Fusion Neutron Spectrum
MAYANK RAJPUT, R. SRINIVASAN
Annals of Nuclear, Energy, 138, 107187, April 2020

Development and Performance of a 14-MeV Neutron Generator
S. J. VALA, M. ABHANGI, RATNESH KUMAR, S. TIWARI, R. KUMAR, H. L. SWAMI and M. BANDYOPADHYAY
Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 959, 163495, April 2020

Microstructure and Mechanical Properties of Tungsten and Tungsten-Tantalum Thin Film Deposited RAFM Steel
S. LAKSHMI KANTH KONURU, V. UMASANKAR, BISWANATH SARKAR and ARUN SARMA
Materials Research Innovations, 24, 97, April 2020

Physicochemical and Biological Assessment of Flowable Resin Composites Incorporated With Farnesol Loaded Halloysite Nanotubes for Dental Applications
TEJAS BAROT, DEEPAK RAWTANI, PRATIK KULKARNI, CHAUDHERY MUSTANSAR HUSSAIN, SATYAPRASAD AKKIREDDY
Journal of the Mechanical Behavior of Biomedical Materials, 104, 103675, April 2020

Transient Heat Transfer Characteristics and Process Intensification with Al2O3-Water and TiO2-Water Nanofluids: An Experimental Investigation
SAYANTAN MUKHERJEE, SHANTA CHAKRABARTY, PURNA CHANDRA MISHRA, PARITOSH CHAUDHURI
Chemical Engineering and Processing - Process Intensification, 150, 107887, April 2020

The Emergence of Inertial Waves from Coherent Vortex Source in Strongly Coupled Dusty Plasma
AKANKSHA GUPTA and RAJARAMAN GANESH
Physics of Plasmas, 27, 050701, April 2020

Parameter Space Validation Through OOPS Simulations of Plasma Burnthrough and Discharge Evolution in the SST-1 Tokamak
AMIT K. SINGH, SANTANU BANERJEE, I. BANDYOPADHYAY, R. SRINIVASAN, U. C. NAGORA, JAYESH RAVAL and K. TAHILIANI
Physics of Plasmas, 27, 042505, April 2020

Sowing the Seeds of an Indian Fusion Programme-An Untold Legacy of Vikram Sarabhai
ABHIJIT SEN
Current Science, 118, 1196, April 2020

Experimental Observation of a First-Order Phase Transition in a Complex Plasma Monolayer Crystal
M. G. HARIPRASAD, P. BANDYOPADHYAY, GARIMA ARORA and A. SEN
Physical Review E, 101, 043209, April 2020

Evolution of Voids in Single-Crystal Iron under Uniaxial, Biaxial and Triaxial Loading Conditions
SUNIL RAWAT and SHASHANK CHATURVEDI
Philosophical Magazine, 1754486, April 2020

In-plane Optical Anisotropy and SERS Detection Efficiency of Self-Organized Gold Nanoparticles on Silicon Nanoripples: Roles of Growth Angle and Postgrowth Annealing
MAHESH SAINI, SEBIN AUGUSTINE, MUKESH RANJAN, TAPOBRATA SOM
Applied Surface Science, 512, 145703, May 2020

Study on Negative Ion Production by Electronegative Gases in a Helicon Source
MONOJIT CHAKRABORTY, NARAYAN SHARMA, NIROD KUMAR NEOG and MAINAK BANDYOPADHYAY
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E.1.3 Book Chapters

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E.2 INTERNAL RESEARCH AND TECHNICAL REPORTS

E 2. 1 Research Reports

EXPERIMENTAL OBSERVATION OF PINNED SOLITONS IN A FLOWING DUSTY PLASMA
GARIMA ARORA, P. BANDYOPADHYAY, M. G. HARIPRASAD and A. SEN
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EXPOSURE OF INDIAN RAFM UNDER VARIATION OF He+ FLUX AND TARGET TEMPERATURE IN THE CIMPLE-PSI LINEAR DEVICE
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AMREEN A. HUSSAIN
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INVESTIGATION OF PHYSICOCHEMICAL PROPERTIES OF PLASMA ACTIVATED WATER AND ITS BACTERICIDAL EFFICACY
VIKAS RATHORE, DIVYESH PATEL, SHITAL BUTANI and SUDHIR KUMAR NEMA
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EXPERIMENTAL INVESTIGATIONS ON BUBBLE DETECTION IN WATER-AIR TWO-PHASE VERTICAL COLUMNS
A. SARASWAT, A. PRAJAPATI, R. BHATTACHARYAY, P. CHAUDHURI and S. GEDUPUDI
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TURBOEXPANDER WHEEL DESIGN FOR HELIUM LIQUEFACTION PLANT
SWAPNIL NARAYAN RAJMANE, MANOJ KUMAR GUPTA and ANANT KUMAR SAHU
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EXCITATION OF PLASMA WAKEFIELDS BY INTENSE ULTRA-RELATIVISTIC PROTON BEAM
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RAM KRUSHNA MOHANTA and G. RAVI
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MEENAKSHEE SHARMA, A. D. PATEL, N. RAMASUBRAMANIAN, Y. C. SAXENA, P. K. CHATTOPADHYAYA and R. GANESH
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EXCITATION OF LOWER HYBRID WAVE BY LASER PLASMA INTERACTION
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A DDPM-DEM-CFD FLOW CHARACTERISTIC ANALYSIS OF PEBBLE BED FOR FUSION BLANKET
CHIRAG SEDANI and PARITOSH CHAUDHURI
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HIGH FREQUENCY SHEATH MODULATION AND HIGHER HARMONIC GENERATION IN A LOW PRESSURE VERY HIGH FREQUENCY CAPACITIVELY COUPLED PLASMA EXCITED BY SAWTOOTH WAVEFORM
SARVESHWAR SHARMA, NISHANT SIRSE and MILES M. TURNER
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APPLICATION OF THE FUNCTION PARAMETERIZATION METHOD FOR THE DETERMINATION OF PLASMA CENTER IN ADITYA-U TOKAMAK
SAMEER KUMAR, KUMUDNI TAHILIANI, DANIEL RAJU, S. K. PATHAK, JAYESH RAVAL, PRAVEENLAL EDAPPA, PRAVEENA KUMARI, DEVILAL KUMAVAT,

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K. T. SANDEEP, B. K. YADAV, A. GANDHI and PARITOSH CHAUDHARI
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DESIGN AND SIMULATION OF HIGH TEMPERATURE BLACKBODY CALIBRATION SOURCE FOR MICHELSON INTERFEROMETER DIAGNOSTIC
NEHA PARMAR, ABHISHEK SINHA and S. K. PATHAK
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M. V. GOPALA KRISHNA, KUMUDNI TAHILIANI, BHAVESH KADIA, PRAVEENLAL E.V., SAMEER KUMAR, DEVILAL KUMAWAT, SANTOSH PANDYA, ROHIT KUMAR, Y. S. S. SRINIVAS and S. K. PATHAK
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N. BISAI and A. SEN
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PACKING CHARACTERIZATION OF DIFFERENT PEBBLE BED ASSEMBLIES USING DISCRETE ELEMENT METHOD SIMULATION
MAULIK PANCHAL and PARITOSH CHAUDHURI
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DESIGN OF NORMAL MODE CIRCULARLY POLARIZED HELICAL ANTENNA AT 5.3 GHz
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DESIGN OF A 3.7 GHz TE10-TE30 MODE CONVERTER USING STEPPED IMPEDANCE TRANSFORMER FOR CW APPLICATIONS
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E 2. 2 Technical Reports

Cleaning of Cesiated RF Negative Ion Source ROBIN
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EPICS Based Control and Monitoring Scheme using Beckhoff Automation Hardware
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Computer Simulation of SiO_2Etching in C_2F_6 Plasma Process using CHEMKIN
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Characterisation of 16-channel IF Receiver System for ECE Radiometer at Aditya Upgrade
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IPR/TR-573/2020 (June 2020)

Preliminary Design of 200W at 4.5K Cryogenics Plant Data Acquisition and Control System
V. B. PATEL, PRIYADARSHINI GADDAM, HARESH DAVE, A. K. SAHU and KIRTI Mahajan
IPR/TR-574/2020 (June 2020)

Hydrogen in Structural Steel and its Reduction for Application in UHV Systems
SAMIRAN MUKHERJEE, PARESH PANCHAL, JYOTI SHANKAR MISHRA, RANJANA GANGRADEY, PRATIK NAYAK and VISHAL GUPTA
IPR/TR-575/2020 (June 2020)

Signal Estimation and Measurement for the Reflectometry Diagnostic at IPR
JJU BUCH, V. RAULJI, PRAVEENLAL E. V., RACHANA RAJPAL and S. K. PATHAK
IPR/TR-576/2020 (July 2020)

Automation of Upgraded NBI Cooling Water System
KARISHMA QURESHI, PARESH PATEL, LAXMI NARAYAN GUPTA, DIPAL THAKKAR, C. B. SUMOD, VIJAY VADHER and UJJWAL BARUAH
IPR/TR-577/2020 (July 2020)

Design and Development of 15kV, 30A Series Connected IGBTs Switch for Tetrode Based HPA3 Stage of ICRH Amplifier
BHAVESH R. KADIA, KIRIT PARMAR, H. M. JADAV, S. V. KULKARNI and SUNIL KUMAR
IPR/TR-578/2020 (July 2020)

Implementing Private Cloud-based File Storage and Collaboration System
SHARAD JASH and PRASHANT KUMAR
IPR/TR-579/2020 (July 2020)

Standard Operating Procedure for Diesel Generator Sets
CHIRAG B. BHAVSAR, C. K. GUPTA, PRAKASH PARMAR and SUPRIYA NAIR
IPR/TR-580/2020 (July 2020)

Inhouse Development and Performance Test of Pressure Relief Valve for High Vacuum System
PARESH PANCHAL, SAMIRAN MUKHERJEE and RANJANA GANGRADEY
IPR/TR-581/2020 (July 2020)

Design, Fabrication, Testing and Commissioning of Power Supplies and DAC System for Electron Drift Injection System on BETA
BHAVESH R. KADIA, JASRAJ DHONGDE, P. PRASAD RAO, TUSHAR RAVAL, ANKUR JAISWAL, YUVAKIRAN PARAVASTU, SIJU GEORGE, UMESH KUMAR, RAJESH KUMAR, Y. S. S. SRINIVAS, SUNIL KUMAR, D. RAJU and E. RAJENDRA KUMAR
IPR/TR-582/2020 (August 2020)

Preliminary Critical Heat Flux Experiments at the High Heat Flux Test Facility
VINAY MENON, MOHIT SHARMA, SAMIR KHIRWADKAR, KEDAR BHOPE, SUNIL BELSARE, SUDHIR TRIPATHI, NIKUNJ PATEL, MAYUR MEHTA, PRAKASH MOKARIA, TUSHAR PATEL, RAJAMANNAR SWAMY and KALPESH GALODIYA
IPR/TR-583/2020 (August 2020)

A Study on Benchmarking of Molflow for Ultra High Vacuum (UHV) System
S. AHMED, S. SUNIL and S. MUKHERJEE
IPR/TR-584/2020 (August 2020)

Conceptual Design of Circular Cross-section U-bend MHD Test Mock-up
A. PATEL, S. VERMA, A. PRAJAPATI, A. SARASWAT and R. BHATTACHARYAY
IPR/TR-585/2020 (August 2020)

Structural Analysis, Design and Implementation of Safety Access to High Pressure Helium Gas Storage Vessels at IPR
RAJIV SHARMA and VIPUL TANNA
IPR/TR-586/2020 (August 2020)

Measurement of Neutral Gas Pressures in a Vacuum Chamber using two Different types of Nude Bayard Alpert Gauges
PRATIBHA JAKHMOLA, KALPESH R. DHANANI, DILIP C. RAVAL and ZIAUDDIN KHAN
IPR/TR-587/2020 (August 2020)

Measurement of Hydrogen Outgassing Rates for SS 304L Make Chamber and Coupons using RGA and BA Gauge
SAMIRAN MUKHERJEE, S. SUNIL, PARESH PANCHAL, ATUL PRAJAPATI, RAKESH KUMAR, ARNAB DASGUPTA, RANJANA GANGRADEY and SUBROTO MUKHERJEE
IPR/TR-588/2020 (August 2020)

Arduino Based Relay Control System with Graphical User Interface (GUI)
A. K. SANYASI
IPR/TR-589/2020 (August 2020)

Sizing and Selection of Vacuum Pump for SMARTEX-C
PRASHANT THANKEY, DILIP RAVAL, ZIAUDDIN

KHAN, LAVKESH LACHHVANI and MANU BAJPAI
IPR/TR-590/2020 (September2020)

Web-based Data Analytics for Automated Status Monitoring of Experiments in Large Volume Plasma Device
K. KARMUR, R. SUGANDHI, V. SOUMYA, P. K. SRIVASTAVA, A. K. SANYASI, PRABHAKAR SRIVASTAV, PRASHANT KUMAR and L. M. AWASTHI
IPR/TR-591/2020 (September 2020)

Installation of Current Leads and Fabrication of Bus-bar Joints for PF#3 Coils of SST-1
U.PRASAD, A. PANCHAL, N. KUMAR, P. RAJ, A. GARG, P. BISWAS, H. PATEL, B. PARGHI, P. VARMORA, K. BHOPE, S. ROY, C. DODIYA, A. MAKWANA, D. KANABAR, H. NIMAWAT, A. BANO, S. J. JADEJA, F. S. PATHAN, P. THANKEY, R. PANCHAL, G. PURWAR, V. L. TANNA, B. R. DOSHI, DIPTI SHARMA, R.SRINIVASAN, D. RAJU, MSD, CRYOGENICS and VESD
IPR/TR-592/2020 (September 2020)

Conceptual Design of a Gridded Ion Source System for Applications of Ion Thrusters and Material Research
S. K. SHARMA, B. S. RAWAT, P. BHARATHI, B. CHOKSI,B. SRIDHAR, L. N. GUPTA, D. THAKKAR, V. PRAHLAD and U. K. BARUAH
IPR/TR-593/2020 (October 2020)

Estimation of Molecular Conductance of Pumping Lines of the SST-1 Vacuum Vessel Using Analytical and Numerical Methods
PRATIBHA JAKHMOLA and ZIAUDDIN KHAN
IPR/TR-594/2020 (October 2020)

A Technical Report on Mechanical Design and Analysis of Source Chamber Assembly of the Experimental Set Up for PPA Facility in CPP-IPR
AMARENDRA BAISHYA, MANOJ KUMAR GUPTA, TRIDIP KUMAR BORTHAKUR, NIROD KUMAR NEOG and SURAMONI BORTHAKUR
IPR/TR-595/2020 (October 2020)

Insulation of Current Leads and Bus-bar Joints for Superconducting PF-3 Coils of SST-1
NITISH KUMAR, SWATI ROY, UPENDRA PRASAD, DEVEN KANABAR, MAHESH GHATE, CHIRAG DODIYA, YOGENDRA SINGH, MAILA PARMESH, UMESH KUMAR PAL, GAURAV PURWAR, HIREN NIMAVAT, ATUL GARG, R. SRINIVASAN, V. L. TANNA and D. RAJU
IPR/TR-596/2020 (October 2020)

Design and Fabrication of the Test Facility based on the Steady-state Radial Heat Flow Technique to Estimate the Effective Thermal Conductivity of Ceramic Pebble Beds
MAULIK PANCHAL, VRUSHABH LAMBADE, VIMAL KANPARIYA and PARITOSH CHAUDHURI
IPR/TR-597/2020 (October 2020)

FPGA Based Real-time Data Acquisition System for ADITYA-U Heterodyne Interferometry
KIRAN PATEL, UMESH NAGORA, H. C. JOSHI, SURYA PATHAK, K. A. JADEJA, KAUSHAL PATEL, R. L. TANNA and ADITYA-U TEAM
IPR/TR-598/2020 (October 2020)

Design and Development of 100GHz Quadrature Heterodyne Interferometer System at IPR
UMESH NAGORA, KIRAN PATEL and S.K.PATHAK
IPR/TR-599/2020 (October 2020)

Conceptual Design Report on Prototype Development of Pulsed Alternators
RAMBABU SIDIBOMMA, PRASADA RAO P, Y. S. S. SRINIVAS and E. RAJENDRAKUMAR
IPR/TR-600/2020 (October 2020)

Cryocooler Experiment: Phase-2
MILIND PATEL, MAHENDRAJIT SINGH, ARUNKUMAR CHAKRABORTY, KAUSHAL PANDYA, HIMANSHU TYAGI, KARTIK PATEL, HIREN MISTRI, HARDIK SHISHANGIYA, KAUSHAL JOSHI, VUPPUGALLA MAHESH and BHAVESH PRAJAPATI
IPR/TR-601/2020 (November 2020)

Design Verification of Radiation Heat Load on 80K-Cryopump for LIGO
NARESH CHAND GUPTA and GAURAV KUMAR SINGH
IPR/TR-602/2020 (November 2020)

Measurement of Thermal Expansion for Stainless Steel 304, Copper, Aluminium &Brass by Push Rod Dilatometry
AROH SHRIVASTAVA, VRUSHABH LAMBADE and PARITOSH CHAUDHURI
IPR/TR-603/2020 (November 2020)

3D Magnetic Field Analyses of Linear Induction Motor (LIM) for Electromagnetic Launching Applications

ANANYA KUNDU, ANKUR JAISWAL, PRASAD RAO PEDADA, ARVIND KUMAR, Y. S. S. SRINIVAS, VILAS CHAUDHARY, RAMBABU SIDIBOMMA and E. RAJENDRA KUMAR
IPR/TR-604/2020 (November 2020)

Design and Manufacturing of Vacuum Chamber for Outgassing Measurement System (OMS) for LIGO-India Project
RAKESH KUMAR, VIJAY BEDAKIHALE, S. SUNIL, SUBROTO MUKHERJEE and LIGO-DIVISION
IPR/TR-605/2020 (December 2020)

An Upgraded 16-channel Radiometer System at SST-1 for Electron Cyclotron Emission Measurements
VARSHA SIJU and S. K. PATHAK
IPR/TR-606/2020 (December 2020)

Effect of Cold Atmospheric Plasma Jet on Human Gingivobuccal Squamous Cell Carcinoma and Breast Adenocarcinoma Cells: Cold Atmospheric Plasma in Cancer Treatment
KSHAMA PANSARE, AKSHAY VAID, SAURAV RAJ SINGH, RAMKRISHNA RANE, ANAND VISANI, MUKESH RANJAN, C. MURALI KRISHNA and ALPHONSA JOSEPH
IPR/TR-607/2020 (December 2020)

Electron Cyclotron Measurements in Aditya-U Tokamak
VARSHA, S., R. L. TANNA, UMESH NAGORA, JAYESH RAVAL, PRAVEENA SHUKLA, S. K. PATHAK and ADITYA-U TEAM
IPR/TR-608/2020 (December 2020)

Development of New SCADA for 1.3 kW Helium Refrigerator cum Liquefier at 4.5 K
PRADIP PANCHAL, GAURANG MAHESURIA and VIPUL TANNA
IPR/TR-609/2020 (December 2020)

Report on Current Feeder System (CFS) for installation of PF3 Current Leads (CLs) Along with Associated Cryogenic Network towards Producing Shaped Plasma in SST-1
ATUL GARG, H. NIMAVAT, P. SHAH, R. PANCHAL, SRIKANTH L. N., G. PURWAR, P. BISWAS, H. PATEL, F. S. PATHAN, P. THANKEY, D. SONARA, D. CHRISTIAN, A. PANCHAL, N. KUMAR, A. PRAKASH, U. PRASAD, V. L. TANNA, B. R. DOSHI, R. SRINIVASAN and D. RAJU
IPR/TR-610/2021 (January 2021)

Development of Standalone Heater Temperature Control Panel using Solid State Power Controller
ARNAB DASGUPTA, S. SUNIL, AMIT K. SRIVASTAVA and HITESH K. GULATI
IPR/TR-611/2021 (January 2021)

Implementation of Web Information System for Large Volume Plasma Device
V. SOUMYA, R. SUGANDHI, M. JHA, P. K. SRIVASTAVA, A. K. SANYASI, A. ADHIKARI and L. M. AWASTHI
IPR/TR-612/2021 (February 2021)

Test Operations on the High Temperature Vacuum (HTV) Tube Furnace
P. SHARMA, M. ABHANGI and C. JARIWALA
IPR/TR-613/2021 (February 2021)

Initial Lab Test Results of Magneto-Optic Current Sensor Diagnostic Developed for Plasma Current Measurement in Tokamaks
SANTOSH P. PANDYA, KUMUDNI ASSUDANI, PRAVEENLAL E. V., LAVKESH T. LACHWANI, SAMEER KUMAR JHA, M. V. GOPALAKRISHNA and SURYA KUMAR PATHAK
IPR/TR-614/2021 (February 2021)

Case Study of Accidental Scenarios Related to Cryopump and Sizing of its Burst Disc for LI_VISTA (LIGO India Vacuum Integrated System Test Assembly (LI_VISTA))
NARESH CHAND GUPTA, RAKESH KUMAR and ATUL PRAJAPATI
IPR/TR-615/2021 (February 2021)

Upgradation of 82.6GHz ECRH System for SST-1
B. K. SHUKLA, D. RAJU, R. SRINIVASAN, P. K. CHATTOPADHYAY, P. K. ATREY and ARUN K. CHAKRABORTY
IPR/TR-616/2021 (February 2021)

Close Circuit Television: On-The-Fly Artificial Intelligence Monitoring Solution
A. ABHISHEK, A. SHARMA, G. GARG, H. CHUDASMA, D. RAJU and M. SHARMA
IPR/TR-617/2021 (February 2021)

Conceptual Design of Cylindrical Reactive Sputter Coating System
P. A. RAYJADA, N. P. VAGHELA, R. RANE, V. CHAUDHURI and A. SIRCAR
IPR/TR-618/2021 (March 2021)

Fabrication Option for LIGO India Beam Tube for on Site &In-House Testing
ATUL PRAJAPATI, VIJAY BEDAKIHALE, RAKESH KUMAR, S. SUNIL and SUBROTO MUKHERJEE
IPR/TR-619/2021 (March 2021)

Development of Software Interface to Assess Functionalities of General Standards make PCIe based AI/AO Boards
HITESH K. GULATI, ARNAB DASGUPTA and AMIT K. SRIVASTAVA
IPR/TR-620/2021 (March 2021)

Overview of Data Acquisition, Control and Interlocks of 42 GHz ECRH System
HARSHIDA PATEL,JATIN PATEL, DHARMESH PUROHIT, MAHESH KHUSHWAH, K. G. PARMAR, HARDIK MISTRY and B. K. SHUKLA
IPR/TR-621/2021 (March 2021)

Design, Analysis, and Fabrication of 100kV, 100mA DC Full-Wave Voltage Multiplier (FWVM) Modular Unit
URMIL THAKER, AMARDAS A., AMAL S., KUMAR SAURABH, ARITA CHAKROBORTY, PAUL CHRISTIAN, ASHOK MANKANI and UJJWAL BARUAH
IPR/TR-622/2021 (March 2021)

E 3. CONFERENCE PRESENTATION

15th Kudowa Summer School "Towards fusion energy", Virtual Edition, Institute of Plasma Physics and Laser Microfusion, Poland, 29 June - 3 July 2020

Spontaneous Generation of Magnetic Dipole Structures in Overdense Plasma
Devshree Mandal

Absorption of Laser Energy by Generation of an Electrostatic Mode in PlasmaAyushi Vashistha

Webinar organized by Central Institute of Technology Kokrajhar (Deemed to be University), Assam in Collaboration with Rajeev Gandhi Memorial College of Engineering and Technology (Autonomous), Nandyal, Andhra Pradesh, 26 July 2020

Research Challenges and Mental Health of Researchers during COVID-19 Pandemic
S.R. Mohanty

International Conference on Recent Advances in Mechanical Infrastructure (ICRAM-2020), IITRAM, Ahmedabad, 22-23 August 2020

Structural Analysis, Design and Implementation of Safety Access to High Pressure Helium Gas Storage Vessels at IPR
Rajiv Sharma

Extreme Laser Infrastructure Summer School 2020, (Virtual), 26 August 2020

Lower hybrid and magneto-sonic excitations in laser plasma interaction"
Ayushi Vashistha

7th International symposium on Negative ions, Beams and Sources (NIBS'20), (virtual), 2 September 2020

Probe for in situ measurement of work function and Cs dynamics
Pranjal Singh

One Day Workshop organised by Department of Physics and Nanotechnology, UIT Barkatullah University, Bhopal, 8 September 2020

Plasma Produced Nanopatterns for medical and Plasmonics Solar Cell Application
Mukesh Ranjan

International eConference on Plasma Theory and Simulations (PTS-2020), Guru Ghasidas Central University, Bilaspur, 15 September 2020

Simulation of runaway electron distribution function following massive gas injections in ITER-like tokamak and beam energy dissipation
Ansh Patel and Santosh Pandya

31st Symposium on Fusion Technology (SOFT2020), Virtual Edition, on 21 September 2020

Numerical Simulation to Estimate the Tritium Permeation in Stainless Steels in Fusion Devices
Vinit Shukla

24th International Workshop on Electron Cyclotron Resonance Ion Sources (ECRIS20), 28-30 September 2020

Characterization of 2.45 GHz ECR Ion Source Bench for Accelerator-Based 14-MeV Neutron Generator
Sudhirsinh Vala, Mitul Abhangi, Mainak Bandyopadhyay, Rajesh Kumar, Ratnesh Kumar

73rd Annual Gaseous Electronics Virtual Conference, Applied Materials, San Diego, USA, 5-9 October 2020

High frequency sheath modulation and higher harmonic generation in a low pressure very high frequency capacitively coupled plasma excited by sawtooth waveform
Nishant Sirse, Sarveshwar Sharma, Miles Turner

8th PSSI-Plasma Scholars Colloquium (PSC-2020), KIIT University, Bhubaneswar, Odisha, 8-9 October 2020

Cross-field Charge Particle Transport inside a Void Created by an Obstacle Inserted in a Magnetized Plasma Column
Satadal Das, S.K. Karkari

Comparative Study of Plasma Antenna and Monopole Metal Antenna
Manisha Jha, Nisha Panghal, Rajesh Kumar

Magnetic Field Effects on 13.56 MHz Capacitive Coupled Radio-Frequency Sheaths
S Binwal, S K Karkari, L Nair

Does the Fate of 2D Incompressible High Reynolds Number Turbulence Depend on Initial Conditions? : A Revisit!
Shishir Biswas, Rajaraman Ganesh

Study on Ion Re-Circulation and Potential Well Structure in an Inertial Electrostatic Confinement Fusion Device using 2D-3V PIC Simulation
D. Bhattacharjee, S. Adhikari, N. Buzarbaruah and S. R. Mohanty

Impact of Energetic Particles in the First-Wall Erosion in Fusion Power Reactors
P. N. Maya and S.P. Deshpande

Disruptions Study in Aditya-U Tokamak
Suman Dolui, Kaushlender Singh, Tanmay Macwan, Harshita Raj, Suman Aich, Rohit Kumar, K A Jadeja, K M Patel, V K Panchal, S. Purohit, M.B. Chowdhuri, R L Tanna, J. Ghosh and ADITYA-U Team

Simultaneous Measurement of Thermal Conductivity and Thermal Diffusivity of Ceramic Pebble Bed using Transient Hot-Wire Technique
Harsh Patel, Maulik Panchal, Abhishek Saraswat, Paritosh Chaudhuri

A DDPM-DEM-CFD flow characteristic analysis of pebble bed for fusion blanket
Chirag Sedani, Paritosh Chaudhuri

Initial Results of Laser Heated Emissive Probes Operated In Cold Condition in Aditya-U Tokamak
A. Kanik, A. Sarma, J. Ghosh, R. L. Tanna, M. Shah, T. Macwan, S. Aich, S. Patel, K. Singh, S. Duloi, R. Kumar, K. Jadeja, K. Patel and ADITYA-U team

Evidence of Non-Local Transport in ADITYA-U Tokamak
T. Macwan, H. Raj, S. Dolui, K. Singh, S. Patel, P Gautam, N. Yadava, J Ghosh, R L Tanna, K A Jadeja, K M Patel, R. Kumar, S. Aich, V K Panchal, U. Nagora, J. Raval, D. Kumawat, M B Chowdhuri, R Manchanda, P. K. Chattopadhyay, A Sen, R Pal and ADITYA-U Team

Parametric Study of SMBI CD Nozzle for ADITYA-U Tokamak
Kaushlender Singh, Suman Dolui, Tanmay Macwan, B Arambhadiya, K A Jadeja, K M Patel, Siju George, Sharvil Patel, Harshita Raj, Ankit Kumar, Suman Aich, Rohit Kumar, Y Pravastu, D C Raval, V K Panchal, R L Tanna, J Ghosh and ADITYA-U Team

Study of Sawtooth Induced Heat Pulse Propagation in the ADITYA Tokamak
S. Patel, J. Ghosh, M. B. Chowdhury, K. B. K. Mayya, T. Macwan, R. Manchanda, S. Aich, S. Dolui, K. Singh, R. Kumar, R. L. Tanna,T. K. A. Jadeja, K. Patel, J. Raval, V. Kumar, S. Joisa, P. K. Atrey, U. C. V. S. Rao, P. Vasu, S. B. Bhatt, Y. C. Saxena, and ADITYA Team

Calculation of Toroidal and Poloidal Rotation in Aditya-U Tokamak
Ankit Kumar, G Shukla, K Shah, Tanmay Macwan, Kaushlender Singh, Suman Dolui, M.B. Chawdhuri, R Manchanda, R.L. Tanna, J. Ghosh and Aditya Team

Simulation of Runaway Electron Generation in Fusion Grade Tokamak and Suppression by Impurity Injection
Ansh Patel, Santosh P. Pandya

Study on Ion Re-Circulation and Potential Well Structure in

an Inertial Electrostatic Confinement Fusion Device using PIC Simulation
D. Bhattacharjee, S. Adhikari and S. R. Mohanty

Effect of Magnetic Field on the Sheath Width of a 13.56 MHz Radio Frequency Capacitive Argon Discharge
S Binwal, S K Karkari, L Nair

4th Asia-Pacific Conference on Plasma Physics (AAPPS-DPP2020), Remote on-line E-conference, 26-31st October 2020

Spatial Control of Plasma Parameters in a Double Plasma Device by Selective Biasing of a Mesh Separator
Prince Alex, A. K. Sanyasi, Prabhakar Srivastav, P. K. Srivastava, R. Sugandhi and L. M. Awasthi

29th International Toki Conference on Plasma and Fusion Research, Ceratopia Toki, Toki-city, Gifu, Japan, 27-30 October 2020

Effect of External Radial Electric Field on the Drift Tearing Modes of ADITYA-U Tokamak
Tanmay Macwan, Harshita Raj, Kaushlender Singh, Suman Dolui, Rohit Kumar, Suman Aich, J. Ghosh, Lavkesh Lachhvani, Pramila Gautam, E. V. Praveenlal, Jayesh Raval, Umesh Nagora, R. L. Tanna, K. A. Jadeja , K. M. Patel, S. K. Jha, N Bisai, D. Raju, P K Chattopadhyay, A. Sen Rabindranath Pal and ADITYA-U Team

Applied Superconductivity Conference-2020, (Virtual), 6th November 2020

Development of a test facility for thermo-hydraulic characterization of superconducting cables and small prototype magnets - first functional result of pressure drop measurement
Hitensinh Vaghela

62nd Annual Meeting of the APS Division of Plasma Physics (Virtual Meeting), USA, 9-13 November 2020

Stochastic webs formation and anomalous chaotic cross-field particle transport in Hall-thruster by E×B electron drift instability
Debraj Mandal, Y Elskens, X Leoncini, N Lemoine, F Doveil, D Sharma

Generation of coherent structures in overdense plasma using intense laser pulse
Devshree Mandal, Ayushi Vashistha, Amita Das

Multiple Gas Puff Induced Improved Confinement Concomitant with Cold Pulse Propagation in ADITYA-U Tokamak
Tanmay Macwan, Harshita Raj, Joydeep Ghosh, Suman Dolui, Kaushlender Singh, Sharvil Patel, Nandini Yadav, Rakesh Tanna, Kumarpalsinh Jadeja, Kaushal Patel, Rohit Kumar, Suman Aich, Vipul Panchal, Umesh Nagora, Jayesh Raval, Malay B. Chowdhuri, Ranjana Manchanda, Manoj Gupta, Narendra Patel, Devilal Kumawat, Kumudni Tahiliani, Prabal Chattopadhyay, Abhijit Sen, Yogesh Saxena, Rabindranath Pal and ADITYA-U Team

7th IEEE Uttar Pradesh Section International Conference on Electrical, Electronics and Computer Engineering (UPCON 2020), organized by MNNIT Allahabad, 28 November 2020

Design of Normal Mode Circularly Polarized Helical Antenna at 5.3 GHz
Ajay Kumar Pandey

International Conference on Recent Innovations in Engineering and Technology-2020 (ICRIET-2020), Nandha Engineering College, Erode, 5 December 2020

Thermal-hydraulic analysis of Cable-In-Conduit Superconductor: A CFD approach
Hitensinh Vaghela, Biswanath Sarkar, Vikas Lakhera and Upendra Prasad

International Conference on Plasma Sciences (ICOPS-2020), IEEE- NPSS, Singapore, on 6-10 December 2020

Charesterstics performance of a multi-aperture ion source for its application in ion thruster and material processing
Bharat Singh Rawat

6th International Virtual Conference on Ion Beams in Materials Engineering and Characterizations. (IBMEC 2020), IUAC, New Delhi, 8-11 December 2020

Low energy ion irradiation on BN-composite materials
Basanta Kumar Parida, Mukesh Ranjan

100 MeV Au Ion Beam Interaction with ITER Grade Al_2O_3:

An Analytical Investigation
Paramita Patra, Sejal Shah, M. Toulemonde

National Conference on Physics and Chemistry of Materials (NCPCM 2020) & Department of Physics, Govt. Holkar Science College, Indore, on 15 December 2020

Comparative Study of Mixed Metal Cation Lead-Free Perovskites for Visible Light Photodetection
Amreen Ara Hussain

11th International Conference on Material Processing and Characterization, IIT Indore, 15 -17 December 2020

Hydrogen outgassing and permeation in stainless steel and its reduction for UHV applications
Samiran Mukherjee, Paresh Panchal, Jyoti Shankar Mishra, Ranjana Gangradey, Pratik Nayak, Vishal Gupta

4th International Conference on Soft Materials (ICSM 2020), Malaviya National Institute of Technology (MNIT), Jaipur, on 18 December 2020

Investigation on hydrogen adsorption on different kinds of activated carbons
A. Sarkar, J. S. Mishra, R. Gangradey, S. Mukherjee, P. Panchal, P. Nayak, V. Gupta

13th International Conference on Plasma Science and Applications (ICPSA 2020), Ravenshaw University, Cuttack, Odisha, 26-28 December 2020

Bench test Experiments on Fiber Optic Current Sensor for Aditya Tokamak
Asha Adhiya, Minsha Shah, Ánkur Pandya, and Rajwinder Kaur

All India Hindi Scientific webinar on "Journey towards Self-Reliant India – Role of Science & Technology", IGCAR, Kalpakkam, 11-12 January 2021

Plazma Ke Kshetra Mein Bharat Ki Atmanirbharta
Pratibha Gupta, Manoj Kumar Gupta, Bharat Doshi, Harsha Machchhar and A.V. Ravi Kumar

Cryogenic sayantra avum ghatak ka swadeshiya vikas – nambhakiya sanlayan dwara bhavishya urja sotra ki disha mein bharat ki atmanirbarta
Rajiv Sharma

DAE-BRNS National Laser Symposium (NLS-29), Indore, 12-15 February 2021
Initial lab test results of Magneto-Optic Current Sensor diagnostic developed for plasma current measurement in tokamaks
Santosh P. Pandya

Trends in Modern Physics-2021, Assam Don Bosco University, Tepesia, Assam, 26-27 February 2021

Programmable Electro-Mechanical Dust Dispenser for Dusty Plasma Experimental Device
Nipan Das, S.S Kausik, and B.K Saikia

Study of damping of ion-acoustic waves in two-electron temperature plasma
G. Sharma, K. Deka, R. Paul, S. Adhikari, R. Moulick, S.S. Kausik, and B.K. Saikia

Study of a dusty plasma sheath in presence of a non-uniform magnetic field
K. Deka, R. Paul, G. Sharma, S. Adhikari, R. Moulick, S.S. Kausik, and B.K. Saikia

Charging of dust grains in presence of two electron groups
R. Paul, G. Sharma, K. Deka, S. Adhikari, R. Moulick, S.S. Kausik, and B.K. Saikia

American Physical Society (APS) March Meeting, APS, 15-19 March 2021

Effective thermodynamic properties of inertial active microswimmers with alignment interaction
Soumen De Karmakar

AWARDS and ACHIEVEMENTS

Devendra Sharma has been recognized as an **Outstanding Reviewer** for the IOP Journal "Plasma Research Express" for the year 2019 (Announced on 4-6-2020)

Absorption of laser energy by generation of an electrostatic mode in plasma

Ayushi Vashistha received **Best Presentation Award** at the 15th Kudowa Summer School "Towards fusion energy", Virtual Edition, Institute of Plasma Physics and Laser Microfusion, Poland, 29 June - 3 July 2020

Neelanjan Buzarbaruah, gave a webinar on "Experimental Studies on Discharge Plasma in Cylindrical IEC Fusion Device" at 3rd National Conference on Recent Advances in Science and Technology 2020, and recieved **Best participant award** on 17 August 2020

Shishir P. Deshpande has been appointed on the **Board of Editors** of the Journal "Nuclear Fusion" until December 2023 (Announced on 16-9-2020)

Mr. Abhishek Saraswat gave a talk on "Experimental investigations on bubble detection in water-air two-phase vertical columns" at 2nd International Conference on Recent Advances in Mechanical Engineering (RAME-2020), Delhi Technological University (DTU), awarded **2nd Prize under Best Paper Awards** category and also a **Best Presenter award** for Technical Session-2 on 18th September 2020

Mainak Bandyopadhyay, Jervis R Mendonca and Shantanu Kumar Karkari were Awarded **IOP Trusted Reviewer**. 'IOP trusted reviewer' status will be achieved following the submission of a top-quality review report, as graded by our experienced editors. It indicates a high level of peer review competence and the ability to constructively critique scientific literature to an exceptional standard. (For more information: https://ioppublishing.org/peer-review-excellence/) (Announced on 23-9-2020)

Shantanu Kumar Karkari gave an invited talk on "Negative Ion Research in Laboratory Devices: Physics and Modeling" at the e-Conference: 4th Asia-Pacific Conference on Plasma Physics (AAPPS-DPP2020) on 27 October 2020, and have received an **appreciation award** (USD 250) from the conference organizers for presenting this talk

Shashi Kant Verma, received **Young Researcher Award 2020** from Institute of Scholars (InSc2020) experimental investigation of effect of spacer single phase turbulent mixing rate on simulted subchannel of AHWR published in Annals of Nuclear Energy, December 2017 issue

The presentation entitled "Manufacturing and Assembly of ITER Cryostat Welding Challenges and Experiences" by Mitul Patel et. al., at the International Congress-2020 (IC-2020), CIDCO Exhibition Centre, Navi Mumbai, 6-8th February 2020, has been adjudged as the winner of **ESAB India Award-2020** for the best paper across all categories. The Award is a cash prize of Rs. 30,000/- for the team. The Award will be handed over during the inaugural ceremony of National Welding Seminar 2020-21 to be held at Vadodara, Gujarat, on 8th of April 2021

E 4. INVITED TALK DELIVERED BY IPR STAFF

S. SUNIL

Gave a live YouTube lecture entitled "Operating Parameters of Laser Interferometer Gravitational wave Observatory (LIGO)" on 24th April 2020. The lecture series was organized by the LIGO India Education and Public Outreach group under GW@Home - A LIGO India Initiative: An Online lecture series

Gave a webinar on "An Introduction to LIGO: Challenges and Opportunities" organized by Sathyabama Institute of Science and Technology, Chennai on 3 June 2020

MUKESH RANJAN

Gave a webinar on "Plasma and its Application" in a webinar series about Conceptual and Applied Physics, jointly organized by Department of Physics, Saurashtra University, Rajkot, 5-8 May 2020

Gave a webinar on "Plasma for Plasmonics" Amity University, Noida, on 13 May 2020

Gave a webinar on "Plasma and its Industrial Application" at a webinar "Prospective of Interdisciplinary Research in Science and Technology in the Present Scenario" organized by Department of Physics, Ch. Charan Singh University, Meerut, UP, on 16 May 2020

Gave an invited talk on "Plasmonics for SERS and Solar Cell Application" at Recent Advances in Optical and Magnetic Materials, NIT Uttarakhand, 14-18 December 2020

CHIRAG SEDANI

Gave a webinar on "Nuclear Science & Technology" organized by Mechanical Engineering Department, R. N. G. Patel Institute of Technology, Bardoli. Surat, on 26 May 2020

SHASHIKANT VERMA

Gave a webinar on "Introduction to CFD and career opportunities in CFD for UG Students" organized by Bharati Vidyapeeth's College of Engineering, Pune, on 26 May 2020

SAROJ DAS

Gave a webinar on “Crafting an Impactful Job Interview: What and What Not” organized by School of Library and Information Science, Central University of Gujarat, Gandhinagar, on 17 June 2020

MUKTI RANJAN JANA

Gave a webinar on “Physics and Technology of Ion Acceleration System for Fusion Research” at National Webinar on Advancement of Plasma Physics and Nanoscience, organized by Department of Physics, Kharagpur College, West Bengal, on 30 June 2020

Gave an invited talk on “Ion Extraction and Acceleration from Plasma and its Applications” at National Science Day 2021 Webinar, Assam Donbosco University, Assam, 28 February 2021

PINTU BANDYOPADHYAY

Gave a webinar on “Physics of Dusty Plasmas: Recent Experiments” at National Webinar on Advancement of Plasma Physics and Nanoscience, organized by Department of Physics, Kharagpur College, West Bengal, on 30 June 2020

SHASHANK CHATURVEDI

Gave a Plenary Talk in 2nd International Conference on Future Learning Aspects of Mechanical Engineering (FLAME -2020) on 5th August 2020. During his talk, he covered all the Applications of Plasma from Tokomaks to Industrial Plasma

A. K. SANYASI

Gave a webinar talk on “Plasma and Electromagnetic Waves in Earth Magenosphere” at Recent Advancement in Physics - 2020, Dept. of Physics, Shri Vaishnav Vishwa Vidyalaya, Indore, MP, on 07 August 2020

SARVESHWAR SHARMA

Gave a webinar talk on “Plasma: Key Tool for Energy Production and Industrial Applications” Organized by Theoretical and Applied Physical Science (Current Trends and Future Perspectives), Kamla Nehru College of Women, Jai Narayan Vyas University, Jodhpur, Rajasthan, during 24-25 August 2020

Gave an invited talk on “Driving frequency effect on the plasma parameters and electron heating in very high frequency (VHF) capacitive discharges” at 8th ICMAP (International Conference on Microelectronics and Plasma Technology) & 9th ISFM (International Symposium on Functional Materials), Korea, 17-20 January 2021 [Co-authors: Nishant Sirse, Miles M Turner]

RAJWINDER KAUR

Gave a talk on “Nuclear Fusion: The Perennial Source of Clean Energy” at Indian Institute of Science Education and Research (IISERB) Physics Club, IISERB, Bhopal, 25 September 2020

Invited talks given at the e-Conference: 4th Asia-Pacific Conference on Plasma Physics (AAPPS-DPP2020), 26-31 October 2020

L. M. AWASTHI gave an Invited talk on “Investigations on Electron Temperature Gradient (ETG) Turbulence and Plasma Transport in LVPD” (Co-authors: Prabhakar Srivastav, A. K. Sanyasi, Rameswar Singh, P. K. Srivastava, R. Sugandhi, S. K. Singh and R. Singh)

A. K. SANYASI gave an Invited talk on “Observations on Whistler Turbulence Induced Reduced Particle Transport in Large Volume Plasma Device” (Co-authors: Prabhakar Srivastav, L. M. Awasthi, P. K. Srivastava, R. Sugandhi and D. Sharma)

DEVENDRA SHARMA gave an invited talk on “Kinetic mode ‘cloaking’ of nonlinear waves in plasmas”

LAVKESH LACHHVANI gave an invited talk on “Toroidal Electron Plasma Experiment: SMARTEX-C”

SHANTANU KUMAR KARKARI, gave an invited talk on “Negative Ion Research in Laboratory Devices: Physics and Modeling”

A. SATYAPRASAD

Gave an invited talk on “SEM and TEM for Surface Morphology” at National STTP (Online) on “Fostering

Instrumental Techniques for Effective Research–2020", Nirma University, 27-31 October 2020

P.N. MAYA

Gave an invited talk on "Magnetic trapping of charged particles and the pursuit of fusion energy on Earth" at CAPSS Seminar series - 'Nature as we unfold it', Organized by Center for Astroparticle Physics and Space Science, Bose Institute, Kolkata, 26 December 2020

Invited talks given at 13th International Conference on Plasma Science and Applications (ICPSA 2020), Ravenshaw University, Odisha on 26-28 December 2020

AYAN ADHIKARI gave an invited talk on "Pressure Gradient Induced Electrostatic Plasma Turbulence in LVPD" [Co-authors: A.K. Sanyasi, L. M. Awasthi, P. K. Srivastava and Ritesh Sugandhi]

MUKTI RANJAN JANA gave an invited talk on "Development of Technology for PINI Ion Source Back Plate and Ion Extractor Grids for Tokamak Plasma Heating"

S.R. MOHANTY, gave an invited talk on "Inertial electrostatic confinement fusion device and it's applications" [Coauthors are D. Bhattacharjee and N. Buzarbaruah]

MAYUR KAKATI, gave an invited talk on "ITER relevant plasma surface interaction studies in the CPP-IPR CIMPLE-PSI Device, recent irradiation experiments with India specific reduced activation ferritic martensitic steel (IN-RAFM)"

SURAMONI BORTHAKUR gave a talk on "Gas injection system and its use in pulsed plasma accelerator"

VINIT SHUKLA

Gave an invited talk on "ITER Project and Cryogenic Aspects in Fusion Energy" at Ajay Kumar Garg Engineering College, Ghaziabad, 8th January 2021

N. I. JAMNAPARA

Gave an invited talk on "Plasma Technology as Green Manufacturing Alternative – Application Overview" at GUJCOST-DST sponsored webinar on "Green Manufacturing Processes" organized by Government Engineering College Gandhinagar, Metallurgy Department, 30th January, 2021

Gave an invited talk on "Overview of plasma technology applications in metallurgy & materials science" at a Webinar "Metallurgy for All" organized by Govt. Engg. College, Gandhinagar, 3rd February 2021

Gave an invited talk on "Introduction to plasma processed composites" at a Webinar "Advances in Materials & Design (AMD-2021)" organized by SVNIT, Surat, 12th February 2021

NITIN BAIRAGI

Gave an invited talk on "High Temperature Superconductors (HTS) for Sustainable Technology" at International E-conference on "Synthesis, Characterization & Applications of Emerging Materials with Special Reference to Sustainable Technologies" organized by Jabalpur Engineering College, Jabalpur, under Technical Education Quality Improvement Program (TEQIP-III), 22-24th February 2021

NAVEEN RASTOGI

Gave an invited talk on "Remote Handling and Robotics Application in Tokamaks" for the Faculty Development Programme (FDP) on Artificial Intelligence, Robotics and Automation, Banasthali Vidyapeeth, Rajasthan, 20-25 March 2021

E.5 TALKS DELIVERED BY DISTINGUISHED VISITORS AT IPR

Mr. Mandeep Singh, Nanatom Technologies, Bengaluru, gave a talk on "Introduction to Nanatom's Multirole Multiscale Material Characterization Solutions" on 19th June 2020

Dr. Jyoti Pandey, G.B. Pant Univeristy, Uttarakhand, gave a talk on "Nuclear Data for Fusion Reactor Design" on 8th July 2020

Dr. Infant Solomon, Vellore Institute of Technology, Chennai, gave a talk on "Diamond like Carbon Coating: Fundamentals and Related Applications in Automotive Parts" on 17th July 2020

Dr. Mariammal Megalingam, Vellore Institute of technology, Chennai, gave a talk on "An Experimental Investigation of Oscillating Plasma bubbles and its Nonlinear Structure (evolution and effects) in a Magnetized Plasma System" on 24th July 2020

Dr. Avijit Dewasi, Indian Institute of Technology, Roorkee gave a talk on “UV-Visible Photodetection Properties of Pulsed Laser Deposited TiO2 and Nb:TiO_2 Thin Films Grown on Si Substrate” on 3rd August 2020

Dr. Mahesh Saini, Institute of Physics, Bhubaneswar, India, gave a talk on “Nanoscale functionalization of ion-beam fabricated ripples and facets” on 11th August 2020

Dr. Rohan Dutta, Indian Institute of Technology Kharagpur, gave a talk on “Cryogenic Processes for Sustainable Power Generation and Energy Storage Systems” on 18th August 2020.

Dr. Abhinav Kumar, Lovely Professional University, Punjab, gave a talk on “Mechanical, Electrical, Magnetic and Thermal Analysis on High Temperature Superconducting Magnet used for Power Grid Applications” on 25th August 2020

Dr. Eshita Mal, Indian Institute of Technology Guwahati, Assam, gave a talk on “Characterization of Laser Induced Plasma in Air using Time and Space Resolved LIBS” on 8th September 2020.

Dr. Nikita Makwana, Indian Institute of Technology Bombay, Mumbai, gave a talk on “Fast Solution of Time-Domain Maxwell’s Equations Using Large Time Steps” on 11th September, 2020.

Dr. Yogendra Kumar, Indian Institute of Technology, Indore, gave a talk on “Size and Shape Controlled CoFe2O4 Nanoparticles for Developments of Permanent Magnet Applications” on 18th September 2020.

Dr. Prachi Venkat, BITS, Pilani, Jaipur, gave a talk on “Ultra-short laser pulse interaction with atomic clusters” on 21st September 2020.

Dr. Kaushik Choudhury, PhD from IIT Bombay and Monash University, Melbourne, Australia, gave a talk on “Interferometric Observation of Laser-Plasma Induced Shockwaves and Laser Confocal Imaging” on 1st October 2020

Dr. Suman Chatterjjee, NIT, Rourkela, gave a talk on “Laser Material processing of Advanced Engineering Materials” on 9th October 2020

Dr. Ashis Manna, Institute of Physics, Bhubaneswar, gave a talk on “Ion implanted TiO2, ZnO thin films for investigating structural phase transition, dynamics of surface evolution, resistive switching and photo-absorbance property” on 21st October 2020

Dr. Vikram Dharodi, Post Doc. Fellow, Michigan State University, USA, gave a talk on “Sculpted Ultracold Neutral Plasmas” on 23rd October 2020

Dr. Gaurang Joshi, Pandit Deendayal Petroleum University (PDPU), Gandhinagar, gave a talk on “Developments of friction stir welding process for dissimilar copper - stainless steel Joints” on 29th October 2020

Dr. Sabuj Gosh, Saha Institute of Nuclear Physics, Kolkata, gave a talk on “Transitions among different kinds of nonlinear oscillations in glow discharge plasma” on 13th November 2020

Dr. Tejendra Patel, SVNIT, Surat, gave a talk on “Condensation heat transfer and frictional pressure drop in a horizontal circular mini-channel” on 20th November 2020

Dr. Ashok Dave, University of Ulster, UK, gave a talk on “GHG capture by physical solvent DMEPEG at a pre-combustion IGCC power plant (390 MWe net power generation)” on 25th November 2020

Dr. Prateek Varsheney, IIT, Delhi, gave a talk on “Terahertz Emission Using Laser-Plasma Methods” on 4th December 2020

Dr. Pramod Pandey, Research Establishment Officer, IIT Kanpur, gave a talk on “Study of colliding plasmas dynamics and stagnation layer parameters for applications in analytical techniques (LA-ICP-MS)” on 23rd December 2020

Dr. Niraj Kumar Rai, Banaras Hindu University, Varanasi, gave a talk on “Role of nuclear dissipation in heavy ion fusion-fission reactions” on 30th December 2020

Dr. Shivam Gupta, Indian Institute of Technology Roorkee, gave a talk on “Spectroscopy modeling of laboratory plasma through a detailed plasma model using the reliable electron impact excitation cross-sections” on 08th January 2021.

Dr. Meenu Kaushik, CSIR-Academy of Scientific and Innovative Research, Ghaziabad, gave a talk on “Electromagnetic Analysis of Electron Gun and RF cavities for Inductive Output Tube” on 12th January 2021.

Dr. Mahesh V. P., Indian Institute of Technology, Gandhinagar, gave a talk on “Mechanical and Electrochemical Performance of Aluminium Matrix Friction Stir Surface Composites” on 22nd January 2021

Dr. Sandeep Rimza, CIPET, Ahmedabad, gave a talk on “Design and Development of Helium Cooled Heat Sink Mock-up for Tokamak based Fusion Reactor Applications” on 29th January 2021

Dr. Rajashree Sahoo, Kalinga Institute of Industrial Technology, Bhubaneshwar, gave a talk on “Heterogeneous Photocatalytic dye degradation using Zinc Oxide (ZnO) Semiconductor nanoparticles prepared from its Laboratory grade powder” on 5th February 2021

Dr. Sheetal Punia, Indian Institute of Technology, Delhi, gave a talk on “Tunable THz Radiation and Positron Generation by Dark Hollow Laser Beams” on 12th February 2021.

Dr. Vaishnvi Tiwari, University of Paris-Saclay, France, gave a talk on “A consistent approach for coupling lumped-parameter and phase-field models for in-vessel corium to thermodynamic databases” on 19th February 2021

Dr. Vishakha Baghel, Amity University, UP, gave a talk on “Moist Air Condensation in Drop Mode” on 26th February 2021

Dr. Pravesh Dyani, Czech Technical University in Prague, gave a talk on “Study of Compound Sawtooth Oscillations, Observation of EGAM in KSTAR and Development of Probe for the Measurements of Runaway Electrons inside the Golem Tokamak Plasma Edge” on 05th March 2021

Dr. Sudheer, Institute of Physics (IOP), Bhubaneswar, gave a talk on “Fabrication and characterization of nanostructured metallic thin films and periodic nanostructures for plasmonic applications” on 16th March 2021

Dr. Rohit Mathur, Indian Institute of Technology, Dhanbad, gave a talk on “Design and Implementation of Printed Ultra-Wide Band MIMO Antenna for Wireless Communication Application” on 26th March 2021

Dr. Pravin Dwivedi, Indian Institute of Technology, Delhi, gave a talk on “Development of Nanostructured Metal Oxides-Carbon Composites for Rechargeable Ion Battery” on 31st March 2021

E 6. SCIENTIFIC MEETINGS HOSTED BY IPR

IPR Outreach Webinar/Events

Webinars were conducted for the science students of 10th, 11th and 12th classes of the Delhi Public School, Bopal, Ahmedabad on 9th and 10th of July, 2020. Over 175 participants from 10-12th standards as well as teachers participated in the interactive webinar.

Apart from webinars for students of educational institutions, due to popular demand, IPR Outreach conducted the first webinar for teachers, students and general public, and due to the overwhelming response, it is decided that such a webinar programme for general public will be organized once a month.

From 30-31 July 2020 at Ganpat University, Mehsana a two Days webinar on plasma & its applications was conducted. Similarly from 6-7th August 2020 and 13-14th August 2020 two Days webinar on plasma & its applications was conducted at MG Science Institute and St. Xavier’s College, Ahmedabad respectively. For general participants a one day webinar was conducted on 19th August 2020 on the topic plasma & its applications where 31 school / college teachers, students and general public participated.

On 26th August 2020 and 16th September 2020 a two hour webinar on Plasma & its Applications was conducted at Bhavan's Adarsha Vidyalaya, Cochin, Kerala (Batch 1: 56 students of class 12 and 4 teachers; and Batch 2: 61 students of class 12 and 6 teachers). Similarly one day webinar was conducted on 9th September 2020 for General Participants (31 Participants consisting of students, teachers and public) and on 10-11th September 2020 two days webinar on “Plasma and it’s Applications” at H&HB Kotak Institute of Science, Rajkot was attended by 36 BSc Physics students and 1 teacher

On 24-25th Sept, 2020 a 2-day, 4 hour webinar on Plasma & its Applications was attended by 59 science teachers of Bhavan's Vidyalaya group and other schools in Cochin. 2-Day, 4 hour webinar on 8-9-Oct, 2020 was attended by 60 BSc Physics students and 2 teachers of Mar Thoma College for Women, Perumbavoor, Kerala. Webinar on 14-Oct, 2020 was attended by 46 students (XII, BSc, MSc, MPhil) and 7 teachers. On 21st Oct, 2020 a special programme on Plasma with emphasis on experiments was attended by 40 children of 8-12 years age group.

Vigilance Awareness Week 2020

As part of the activities of the Vigilance Awareness Week being observed at IPR from 27-Oct-2020 to 2nd Nov-2020, an “Integrity Pledge” was undertaken by the employees on 27th Nov, 2020, with Dr. Shashank Chaturvedi, Director and Dr. Anitha V P (CVO, IPR) leading the pledge. In view of COVID-19 pandemic related restrictions, the ceremony was conducted via video streaming, while only few officials were physically present. On 28th Nov, 2020, a webinar on "Synergy between Vigilance and Technology" by Shri Rajnish Kumar, Director (Digital Education), Ministry of Education, New Delhi, was organized. Participants from IPR joined the webinar though video conferencing as well as live video streaming.

Banners /posters based on the subject, "Satark Bharat, Samriddh Bharat" ("Vigilant India, Prosperous India") were displayed at various locations at the main campus of IPR. An on-line quiz related to vigilance was also organized for IPR/ FCIPT and ITER-India staff on 2nd Nov, 2020.

IPR Outreach Activities (November 2020 to January 2021)

On 4th Nov. 2020 a two hour webinar on Plasma and its Application was conducted at Shakti Higher Secondary School, Rajkot. Where 37 Students from class twelve and one Teacher participated.

A two day long four hour webinar on Plasma & its applications for BTech/MTech/MSc Students was conducted on 5-6th Nov. 2020 at L. D. College of Engineering, Ahmedabad and 73 Students & 1 Faculty participated the webinar.

In Sir P. T. Science College, Modasa & Trainers of Gujcost Recognized District Community Science Centre, Aravall a two day long four hour webinar on Plasma & its applications for BSc/MSc students & Science trainers carried out on 9-10th Nov. 2020 and 54 Students & 2 Faculty members attended the webinar.

On 11th Nov. 2020 a four hour long webinar on Plasma & its Applications for BSc / MSc Students was carried out at P. D. Patel Inst. of App. Sci., CHARUSAT, Anand. Where 70 Students and one Faculty participated the webinar.

A Two day long four hour webinar on “Plasma & its Applications for PGT Physics teachers” for PGT Physics Teachers from various schools of Bhavans Education Trust across Kerala was carried out on 19-20th Nov. 2020 and Thirty-three +2 science/physics teachers attended it.

On 3-4th Dec. 2020, a Two day long four hour webinar on “Plasma & its Applications” was conducted in Providence Women's College, Calicut, Kerala about 64 BSc/MSc Physics Students and 4 Teachers participated in the webinar.

In Unmesh Secondary & Higher Secondary School, Jabalpur a two hour webinar on “Plasma & its applications” was carried out on 14th Dec. 2020 and 28 students and 3 teachers attended.

On 15th Dec.2020 a four hour long webinar on “Plasma & its applications” was carried out at Government Science College, Jabalpur and 36 BSc/MSc Students and 2 Teachers attended the webinar.

A four hour long webinar on “Plasma & its applications for PG Students and science teachers” was carried out at Sir Syed College, Taliparamba, Kannur, Kerala for two days from 21st to 22nd Dec. 2020 and 64 BSc/MSc Students & 2 Teachers attended the webinar.

On 6th Jan 2021, a 2 hour webinar on Plasma & its applications was attended by 60 students from Adani Vidya Mandir, Ahmedabad. On 7-8th Jan, 2021 a 2 day, 4 hour webinar for 35 BSc physics (3rd year) students of M A M O College, Manassery, Calicut, Kerala was organized. On 11-12th Jan-2021, 66 BSc physics students from KKTM. Govt.College, Pullut, Kerala attended the webinar. On 13th Jan-2021 20 students of 12th standard from Amrita Vidyalayam, Ahmedabad attended the webinar on Plasma & its applications.

National Science Day-2021 @ IPR

The National Science Day (NSD) was celebrated at IPR during 8-12 February, 2021. Due to the Covid-19 pandemic, all the programmes of NSD-2021 were conducted either as offline or online events. Competitions like essay and poster were conducted offline while those like eloquence, quiz and science models (for both teachers and students) were conducted online. The webinar facility of Outreach Division was used to conduct the online events. No. of participating schools were 51, No. of registered participants were 100, No. of events organized were 12, No. of prizes won were 52. In spite of the Covid-19 pandemic, there was good participation in the online events organized as part of the NSD-2021. Students who, by now, have had ample experience in on-line learning activities were found to be very comfortable participating in the online quiz, eloquence and science model competitions.

Teachers also took active part in the competition for educational models in science. The concluding ceremony was conducted online on 19-Feb-2021. Over 70 participants and teachers from various schools attended the event. Dr. P. K. Atrey, Dean R&D, IPR spoke to the participants and teachers. The prizes for the various competitions were also announced by him. The certificates were also distributed online to the winners of the various competitions. Following this, the participants shared their experiences and also gave their feedback on the NSD-2021.

National Science Day-2021 @ CPP-IPR

The National Science Day - 2021 was celebrated at CPP-IPR during the last week of February and first week of March, 2021. It was a week-long program where both online and offline competitions were held among the students of various schools of Sonapur and Guwahati. Due to Covid-19 pandemic, this year the competitions were held online which included essay, drawing, extempore speech and poster.

The competitions were conducted in three groups - Group A (classes 2-5), Group B (classes 6-8) and Group C (classes 9-11). However, drawing and extempore speech competitions were held among the students of Nazirakhat Primary School at their school premises offline (which is few blocks away from CPP-IPR), with the help of the teachers and following covid-19 protocol. These were conducted among the students in two groups of class 1-2 and class 3-5. An online concluding session was organized on 1st March, 2021. Prof. Jiban Jyoti Das of Cotton University, Guwahati, delivered a popular science talk. The names of the winners of various competitions were announced in the concluding session. The prizes were later distributed to the respective schools that participated in the events.

Swachhata Pakhwada 2021

“Swachhta-Pakhwada” was observed at IPR and its campuses during 16-28 February, 2021 as a part of the “Swachh Bharat Mission” to promote cleanliness. As part of this drive, IPR staffs were motivated to clean their offices and laboratory spaces and clear away unwanted materials. All employees of IPR were effectively involved in mass cleaning activities during this fortnight. The activities carried out during of Swachhta Pakhwada -2021 were as follows:

• Ensuring general cleanliness of all the campuses of IPR

• Removal of all unwanted waste items collected from offices, laboratories and various open spaces of the institute campus. These items were segregated at one place for sorting and disposed them accordingly.

• Survey of several location of IPR campus waste collection disposal.

• Online Quiz (on ‘Swachhata’) and Eloquence (on the topic on ‘Cleanliness is our responsibility’ in Hindi/English/Gujarati) competition were organized for the Schools students in Ahmedabad-Gandhinagar districts.

• Poster, Slogan (Hindi/English/Gujarati) and Essay (Hindi/English/Gujarati) competition (for IPR staff and family) were organized for IPR staff and their families on the following topics:

o Clean and Healthy India: A collective responsibility for all Indians

o Role of Public sectors and Industries in clean India drive

o How to inculcate cleanliness awareness among school children

A webinar on “Plasma Technologies for Waste Management” was organized in which Dr. S. K. Nema, Senior Scientist in IPR discussed about the plasma based technologies is used for the treatment and management of waste developed at IPR. Apart from the above activities, the Swachhaha Pakhwada committee, based on the nominations received from IPR staff, selected four 'Swachhata Senani' taking into consideration their contribution and involvement in various Swachhata activities since several years and felicitated them during the concluding session program. Prizes were also given out by Dr. P. K. Atrey, Dean R&D to the winners of various competitions conducted under the auspices of Swachhata Pakhwada 2021.

Extensive collection of waste and garbage from office rooms, laboratories and other areas in all the campuses was undertaken over the week. These waste were then segregated and disposed off appropriately. As part of campus beautification, tree trunks were painted with terracotta to enhance their look as well as protect them from termites. Quiz and Eloquence competitions for schools in Ahmedabad /Gandhinagar cities were conducted on-line in association with Outreach Division. Awards were also given to the "Swachhata Senani" who, on their own, have contributed to keeping their surroundings clean and green and also for spreading the concept of "Swachhata hi seva hai" in the society. They were Mr. Raj Singh, Mr. Gautam Vadolia, Ms Deepa Singh (wife of Dr. Rajesh Singh) and Mr & Mrs D. K. Gupta. Our hearty congratulations to them, and we hope that they will continue their good work.

50th National Safety Week-2021 @ IPR

The 50th National Safety Week was celebrated at IPR from 4-10 March 2021. This year's theme was "Learn from Disaster and Prepare for a Safer Future." Due to COVID-19 situation, the institute organized various competitions online during this week to create safety awareness among its employees. Competitions were organized on Slogan in Gujarati, Hindi & English, Online Quiz and Essay Writing in Gujarati, Hindi & English based on decided topics for the employees of IPR, FCIPT & ITER-India. Overwhelming response was received from the employees for various competitions. Safety Training cum Awareness Program was also conducted by Shri D. Modi for the Safety co-ordinators during the week. The Concluding Session was conducted online on 10th March, with the following activities,

• A welcome address delivered by Shri Devendra Modi.

• A presentation on "Safety Measures at High Heat Flux Test Facility at IPR" by Shri Sunil Belsare.

• Safety Pledge read out by the Dr. P.K.Atrey, Dean (R&D).

• The Director delivered a Message on Safety. He emphasised that our preparedness towards any disaster may minimize its adverse effects. He informed that Preparation through education is less costly than learning through tragedy. Don't learn safety by accident. He congratulates all the winners of various competitions.

•Announcement of the winners of various competitions.

• Shri D Modi gave the vote of thanks on behalf of Shri Sunil Kumar, Chairman-Safety Committee.

50th National Safety Week – 2021 @ CPP-IPR

CPP-IPR observed the 50th National Safety Week campaign with a 2-day programme on 4th & 10th March, 2021. Various competitions, like poster and slogan writing on safety issues, and a quiz competition were conducted among the employees. The quiz was conducted on-line on 4th March, 2021 and a total of 12 participants took part in the event. 4 nos. of slogan each in Assamese and Hindi and 5 nos. in English were received. The concluding function was held on 10th March, 2021. The program started with the welcome address by the Acting Centre Director. A brief talk on 'Electrical Safety' was delivered by Mr. Pallab Das, Electrical Engineer (Project). After this, the winners of various competitions were announced and rewarded.

IPR Outreach Activities

On 10th March 2021, Sophia College, Mumbai, 110 students of BSc (Physics/Chemistry) and 4 teachers attended a webinar on Plasma & its applications and on 15-16 March 2021, Smt. Shantaben Haribhai Gajera Engineering College, Amreli, 32 B. Tech (ECE) students and 5 faculty members attended the webinar on Plasma & its applications.

Felicitation to Professor P. I. John

An on-line function was organized on 18th March, 2021 to mark the 80th birthday of Padmashree Prof. P.I. John. This event had felicitations and talks on his contributions to various areas of plasma science & technology. Over 25 of Prof. John's colleagues and PhD students participated in the online meeting to felicitate him. Director IPR, Dr. Shashank Chaturvedi gave the welcome address and also revealed the book of felicitations as well as the Plasma physical vapour deposition TiN coated brass plaque with a stippling style sketch of Prof. John created by Shri. Narendra Chauhan of Outreach Division. Prof. S Mukherjee gave the vote of thanks. Professor John also gave his views on future of plasma based applications and encouraged scientists at FCIPT to think ahead and work towards developing more societal applications of plasma.

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F. OTHER ACTIVITIES

F.1 Outreach

Due to covid related restrictions, there were neither educational visits to IPR nor did IPR participate in any outstation outreach activities. However, the webinar programmes for school/college students as well as for science teachers were continued.

The National Science Day (NSD) was celebrated at IPR during 8-12 February, 2021. Due to the Covid-19 pandemic, all the programmes of NSD-2021 were conducted either as offline or online events. Competitions like essay and poster were conducted offline while those like eloquence, quiz and science models (for both teachers and students) were conducted online. The webinar facility of Outreach Division was used to conduct the online events. Over 50 schools with over 100 students and teachers participated in the various online events.

During the period April 2020 to March 2021, a total of 27 webinar events were conducted for various levels of students as well as for science teachers across India. The total number of participants for these events was 1475.

Several working models of plasma such as (a) Demonstration of hot & cold plasma (b) Plasma jets (c) Tesla coil and gas filled tubes (d) Model of generic tokamak were added to the outreach exhibition.

F.2 Official Language Implementation

According to the instructions of the Government of India, continuous efforts are being made for the smooth

Figure F.1 Events from National Science Day 2021 conducted online (top) quiz competition (bottom) event for teachers implementation of the Official Language Policy in the Institute, the details of which are as follows:

Hindi quarterly/half yearly progress reports were sent on time to Department of Atomic Energy and Town Official Language Implementation Committee, Gandhinagar. All quarterly reports were filled within the stipulated time in the online portal of Department of Official Language.

Incentive Scheme: Under the ATOLIS incentive scheme of Department of Atomic Energy, employees/officers are enthusiastically participating in the incentive scheme to do official work in Hindi and are getting cash prizes.

Hindi Patrika: An edition of the Institute's Hindi home magazine 'Plasma Jyoti' was E-published during this period. The 28th edition of 'Plasma Jyoti' (e-published) was published on December 2020 and a soft copy link was sent to all the offices/organizations of the department and member offices of TOLIC, Gandhinagar.

Translation work: Completed translation work of annual reports, activity reports, abstracts of technical/scientific articles, documents received from sections, letters, forms etc.

The 15th Half Yearly Meeting of the Town Official Language Implementation Committee was organized online on 24th September, 2020 by Baroda Apex Academy, Gandhinagar through Microsoft Teams. In this meeting, awards for the year 2019 were announced for the best performance in the field of Official Language at the level of TOLIC, Gandhinagar. The Institute for Plasma Research received the first prize for the year 2019 for the best performance in the field of Official Language.

Ms. Pratibha Gupta, Scientific Officer-F of the Institute awarded the third prize for the article “Superconductors ki Adbhoot Duniya” for “Dr. Homi Bhabha Science Writing Competition 2019” (All India Level) organized by Hindi Vigyan Sahitya Parishad, Bhabha Atomic Research Centre, Mumbai.

On 5 and 6 November, 2020, a two-day Hindi seminar was organized online, in which 7 participants gave power points presentations on the scientific activities of the institute. Two invited talks were also presented at the beginning of the session.

On the occasion of World Hindi Day on January 10, 2021, Dr. Alok Srivastava, Eminent Scientist of UR Rao Satellite Center, Bangalore delivered a lecture in Hindi on the topic “Mars Travelogue – ISRO: Tomorrow, Today and Tomorrow”.

Three scientific officers from IPR participated in the All India Hindi Webinar organized by IGCAR, Kalpakkam on 11-12 January, 2021 on the topic 'Contribution of Science and Technology to Self-reliant India'.

- Potential Contribution of plasma technology to Self-reliant India - Dr. Suryakant Gupta, Scientific Officer-G

- Indigenous development of cryogenic plants and components - India's self-reliance towards future energy source through nuclear fusion - Mr. Rajiv Sharma, Scientific Officer D

- India's self-reliance in the field of plasma - Ms. Pratibha Gupta, Scientific Officer-F

Organizing Competition at TOLIC Level: Online Essay Competition was organized by the Institute of Plasma Research (IPR), Gandhinagar in December 2020 by TOLIC, Gandhinagar, in which members of the offices/banks located at TOLIC Gandhinagar participated enthusiastically and the entries sent by email.

Participation in TOLIC competition: Two employees of IPR participated in Online Hindi Quiz Competition organized by Income Tax Office, Gandhinagar under the auspices of TOLIC, Gandhinagar. Title written by Shri Laxmi Narayan Gupta, Scientific Officer-D secured second position in the title competition organized by Union Bank, Gandhinagar under the auspices of TOLIC Official Language Implementation Committee, Gandhinagar. Dr. Ritesh Sugandhi, Scientific

Officer-F has been honored with 1st prize for "Chitra Dekho, Kahani Likho" competition conducted during November, 2019 by Office of the Chief Commissioner of Income Tax, Gandhinagar at TOLIC gandhinagar level.

Hindi article publication: An Hindi article title : Hindi Article Publication: An Hindi article title : "Superconductors ki Adbhoot Duniya" written by Ms. Pratibha Gupta, Scientific Officer-F was Published in Hindi magazine "Vaigyanik" (Published by Hindi Vigyan Saahitya Parishad, Bhabha Atomic Research Institute in July-sept 2020)

Hindi Competition Committee: A Hindi Competition Committee has been formed to conduct Hindi programs. In the month of July 2020 online Hindi Slogan writing competition on the topic ''महामारी और हमारी जीवनशैली'' and online Story writing competition on the given image was conducted. In the month of August, Technical/Non-Technical essay writing competition was conducted. IPR Employees enthusiastically participated in these events.

Hindi Pakhwada Celebration 2020: The Institute celebrated Hindi Pakhwada from 1st September, 2020 to 14th September, 2020. Mostly events were conducted online. During this period total 7 competitions (Hindi email, Crossword, Noting & Drafting, Hindi Poster, Hindi Quiz, Extempore & poetry recitation) were conducted successfully for IPR employees. Poems of famous Hindi poets and posters made by staff members were displayed during Hindi Pakhwara. This year Inter Sectional running Official Language Shield was awarded to Stores Section for excellent performance in the field of Official Language.

Rajbhasha Award: In the 15th half-yearly TOLIC , Gandhinagar meeting held online on 24th September 2020, the Institute for Plasma Research has been awarded the first prize under TOLIC, Gandhinagar Rajbhasha Puraskar: 2019 for its excellent performance in the implementation of Official Language.

Hindi Workshop: Hindi workshop is organized every quarter to motivate the employees to work in Hindi. An online Hindi workshop was organized to train the employees to do technical work in Hindi. Prof. Ramgopal singh, Head of Hindi Dept., Gujarat Vidyapith gave a lecture on the topic "Issues Regarding Technical Translation & Their Solutions''. Training was given to employees for working in Hindi on computer and also to make them familiar about Hindi software, voice typing, text to speech etc. IPR two staff members also attended the online Hindi workshop conducted under the auspices of TOLIC. A talk was given by Hindi Officer, IPR on the topic "Implementation of Official Language" in the Hindi workshop organized by the subordinate office CPP-IPR, Guwahati.

Hindi Inspection: During this period the Official Language Implementation Inspection of Stores Section, Library Section and Subordinate Office CPP-IPR were done by the Inspection Committee of IPR and the review report has been submitted to the Director.

F.3 Right To Information

During the report period 2020-21, a total of 46 RTI applications were received, out of which 42 were of new RTI Application, while the other 4 were of Appeal nature. All of them have been disposed off by the Public Information Officer and Appellate Authority concerned within the prescribed time-limit..

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Audited Statements of Accounts as on 31st March 2021

INSTITUTE FOR PLASMA RESEARCH

Registration No.GUJ/88/GANDHINAGAR

CA N. B. SHAH, B. Com., F.C.A.
CA T. N. SHAH, B. Com., F.C.A., DISA

T. N. Shah & Co.
CHARTERED ACCOUNTANTS
PHONE : +91 079 23222152
Fax : +91 079 23241432
Firm Reg. No. 109802/w
C. & A. G. Reg. No. WR/0534
Email : tnshahincometax@gmail.com

INDEPENDENT AUDITOR'S REPORT

Report on the Financial Statements

1. We have audited the attached Balance Sheet of **INSTITUTE FOR PLASMA RESEARCH, BHAT, GANDHINAGAR – 382 428** as at 31st March 2021, Income & Expenditure Account and also Receipts and Payments Account for the year ended on that date thereto.

Management's Responsibility for the Financial Statements

2. These Financial Statements are the responsibility of the Institute's management. This responsibility includes the design, implementation and maintenance of internal control relevant to the preparation and presentation of the financial statements that give a true and fair view and free from material misstatement, whether due to fraud or error.

Auditor's Responsibility

3. Our responsibility is to express an opinion on these financial statements based on our audit. We conducted our audit in accordance with the Standards on Auditing issued by the Institute of Chartered Accountants of India. Those Standards require that we comply with ethical requirement and plan and perform the audit to obtain reasonable assurance about whether the financial statements are free from material misstatement. An audit involves performing procedures to obtain audit evidence about the amounts and disclosures in the financial statements. The procedures selected depend on the auditor's judgment, including the assessment of the risks of material misstatement of the financial statements, whether due to fraud or error. In making those risk assessments, the auditor considers internal control relevant to the Institute's preparation and fair presentation of the financial statements in order to design audit procedures that are appropriate in the circumstances. An audit also includes evaluating the appropriateness of accounting policies used and the reasonableness of the accounting estimates made by management, as well as evaluating the overall presentation of the financial statements. We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our audit opinion.

Opinion

4. In our opinion and to the best of our information and according to the explanations given to us, the financial statement give the information required by the Act in the manner so required and give a true and fair view in conformity with the accounting principles generally accepted in India:

   (a) In the case of Balance Sheet, of the state of affairs of the Institute as at 31st March, 2021;

   (b) In the case of the Income & Expenditure Account, of the excess of Income over Expenditure for the year ended on that date;

   (c) In the case of the Receipts and Payments Account, of the receipt and payments for the year ended on that date.

For T.N.Shah & Co.,
Chartered Accountants
Firm Registration No.109802/W

Place: Gandhinagar
Date: 07/09/2021

T. N. SHAH & CO. CHARTERED ACCOUNTANTS M.NO. 42748 GANDHINAGAR

(Tushar N.Shah)
Partner
Membership No.042748
UDIN : 21042748AAAAAOJ4997

INSTITUTE FOR PLASMA RESEARCH,
BHAT, GANDHINAGAR- 382 428
(Sponsored by Dept. of Atomic Energy, Govt. of India, Mumbai)
Registration No.GUJ/88/GANDHINAGAR

BALANCE SHEET AS AT 31ST MARCH, 2021

CORPUS/CAPITAL FUND AND LIABILITIES	SCH.	2020-2021	2019-2020
CORPUS/CAPITAL FUND	1	6,98,35,39,716.00	6,81,51,49,605.00
RESERVES AND SURPLUS	2	23,78,86,94,293.00	21,13,18,18,650.00
EARMARKED/ ENDOWMENT FUNDS	3	53,26,20,388.00	41,26,17,103.00
CURRENT LIABILITIES AND PROVISIONS	4	4,92,17,32,317.00	4,52,97,59,463.00
TOTAL		**36,22,65,86,714.00**	**32,88,93,44,821.00**

ASSETS			
FIXED ASSETS	5	16,22,26,99,199.00	10,51,14,54,405.00
CURRENT ASSETS, LOANS, ADVANCES ETC.	6	20,00,38,87,515.00	22,37,78,90,416.00
TOTAL		**36,22,65,86,714.00**	**32,88,93,44,821.00**
Excess of Income over Expenditure		-	-
SIGNIFICANT ACCOUNTING POLICIES	13		
CONTINGENT LIABILITIES AND NOTES ON ACCOUNTS	14		

As per our report of even date attached.

For T N Shah & Co
Chartered Accountants
Firm Registration No.109802/w

-Sd-	-Sd-	-Sd-	-Sd-
(Dr.Shashank Chaturvedi)	**(Dr. Subroto Mukherjee)**	**(Falguni Shah)**	**(Tushar N Shah)**
Director	Dean	Accounts Officer-I	Partner
			Membership No.042748

Place : Gandhinagar
Date : 07/09/2021

INSTITUTE FOR PLASMA RESEARCH,
BHAT, GANDHINAGAR- 382 428
(Sponsored by Dept. of Atomic Energy, Govt. of India, Mumbai)
Registration No.GUJ/88/GANDHINAGAR

INCOME AND EXPENDITURE ACCOUNT FOR THE PERIOD ENDED ON 31ST MARCH, 2021

A.INCOME	SCH.	2020-2021	2019-2020
Grants- Department of Atomic Energy, Govt. of India	7	7,46,71,00,000.00	8,40,20,00,000.00
Interest Earned	8	7,73,52,306.00	12,74,22,420.00
Other Income	9	52,62,775.00	19,40,092.00
TOTAL (A)		**7,54,97,15,081.00**	**8,53,13,62,512.00**
B. EXPENDITURE			
Establishment Expenses	10	1,72,92,46,707.00	3,02,84,86,460.00
Other Administrative Expenses	11	54,06,13,689.00	66,20,02,437.00
Depreciation & Ammortisation of Intengible Assets	12	51,59,17,923.00	49,67,02,900.00
Less : Transfer from Corpus/Capital Fund		-51,59,17,923.00	-49,67,02,900.00
Loss on Disposal of Capital Assets/Write Off		6,15,276.00	35,65,634.00
Cash Contribution to ITER IO		1,81,25,96,213.00	46,46,14,840.00
TOTAL (B)		**4,08,30,71,885.00**	**4,15,86,69,371.00**
Balance being excess of Income over Expenditure/ (Excess of Expenditure over Income)		3,46,66,43,196.00	4,37,26,93,141.00
Transfer to Corpus Fund for addition to Movable & Immovable Properties		68,94,07,598.00	1,32,32,79,396.00
Transfer From Corpus Fund for w/off to Movable & Immovable Properties		50,99,564.00	41,30,664.00
Transfer to Iter-India Fund (Interest Earned)		2,83,87,658.00	4,32,81,471.00
Transfer to/from unspent Grant A/c		2,75,39,47,504.00	3,01,02,62,938.00

SIGNIFICANT ACCOUNTING POLICIES	13
CONTINGENT LIABILITIES AND NOTES ON ACCOUNTS	14

As per our report of even date attached.
For T N Shah & Co
Chartered Accountants
Firm Registration No.109802/w

-Sd-	-Sd-	-Sd-	-Sd-
(Dr.Shashank Chaturvedi)	**(Dr.Subroto Mukherjee)**	**(Falguni Shah)**	**(Tushar N Shah)**
Director	Dean	Accounts Officer-I	Partner
			Membership No.042748

Place : Gandhinagar
Date : 07/09/2021

INSTITUTE FOR PLASMA RESEARCH
BHAT, GANDHINAGAR – 382 428

(Sponsored by Dept. of Atomic Energy, Govt. of India, Mumbai)

Registration No. GUJ/88/GANDHINAGAR

RECEIPTS AND PAYMENTS FOR THE PERIOD ENDED ON 31ST MARCH, 2021

RECEIPTS	2020-2021	2019-2020	PAYMENTS	2020-2021	2019-2020
I. Opening Balances			**I. Expenses**		
a) Cash in hand	69,740.00	15,894.00	a) Establishment Expenses	1,33,42,48,318.00	1,43,86,59,262.00
b) Bank Balances			b) Administrative Expenses	57,64,14,081.00	66,20,43,124.00
i) In Current accounts	6,87,69,515.00	21,15,85,658.00	c) Interest Income paid to DAE	12,54,59,519.00	33,69,01,575.00
ii) In deposit accounts	1,18,77,41,891.00	1,69,74,85,386.00	d) Cash Contribution to ITER-IO	1,81,25,96,213.00	46,46,14,840.00
iii) Savings accounts	28,34,950.00	1,75,92,111.00			
II. Grant Received			**II. Exp. on Fixed Assets, Cap. WIP & Others**		
a) From Govt. of India- DAE	7,46,71,00,000.00	8,40,20,00,000.00	a) Purchase of Fixed Assets & other exp.	68,69,69,388.00	55,33,78,456.00
			b) Expenditure on Capital WIP	5,54,51,71,873.00	42,62,81,541.00
III. Interest Received			**III. Refund of Surplus money/Loans**		
a) On Bank Deposits	8,28,88,276.00	12,46,41,702.00	a) Deposits with Government Auth. & Suppliers	85,95,664.00	55,13,458.00
b) Loans, Advances etc.	18,76,465.00	13,78,554.00	b) Payments against Earmarked Funds	15,00,89,486.00	8,02,35,583.00
c) Int on I.T Refund	15,519.00	26,194.00			
IV. Other Income			**IV. Other Payments (Specify)**		
a) Misc Income	40,84,148.00	12,23,882.00	a) Advances to Contractors & Suppliers (Including Adv. for Capital Works)	-	5,29,52,33,592.00
b) Royalty & Transfer Fee Income	11,70,090.00	7,10,528.00	b) Security Deposit	-	4,04,39,683.00
			c) Payment of LT Advances to Empl.	68,96,118.00	65,57,685.00
V. Any Other receipts			d) Others (including Inter Branch)	1,84,18,156.00	1,30,18,316.00
a) Amount received for Earmarked/Endowment Funds	26,70,55,943.00	9,35,91,269.00			
b) Security Deposits	1,09,17,735.00	1,59,16,391.00	a) **Cash in hand**	28,140.00	69,740.00
c) Stock (Change in closing Bal.)	11,54,348.00	30,56,291.00	b) **Bank Balances**		
d) Advances to Contractors & Suppliers (Including Adv. for Capital Works)	2,11,89,94,799.00	-	i) In Current accounts	2,23,62,973.00	6,87,69,515.00
e) Receipt of LT Adv. to Empl.	22,92,445.00	24,83,800.00	ii) In deposit accounts	93,43,39,486.00	1,18,77,41,891.00
f) Sale of Capital Assets	3,16,420.00	5,40,276.00	iii) Savings accounts	46,49,259.00	28,34,950.00
g) Others (including interbranch)	89,56,390.00	1,00,45,275.00			
TOTAL	**11,22,62,38,674.00**	**10,58,22,93,211.00**		**11,22,62,38,674.00**	**10,58,22,93,211.00**

As per our report of even date attached.

For T N Shah & Co.,
Chartered Accountants
Firm Registration No.109802/w

-Sd-	-Sd-	-Sd-	-Sd-
(Dr.Shashank Chaturvedi)	**(Dr.Subroto Mukherjee)**	**(Falguni Shah)**	**(Tushar N Shah)**
Director	Dean	Accounts Officer-I	Partner
			Membership No.042748

Place : Gandhinagar
Date :07/09/2021

INSTITUTE FOR PLASMA RESEARCH,
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(Sponsored by Dept. of Atomic Energy, Govt. of India, Mumbai)
Registration No.GUJ/88/GANDHINAGAR

SCHEDULE FORMING PART OF BALANCE SHEET AS AT 31ST MARCH, 2021

PARTICULARS	2020-2021		2019-2020	
SCHEDULE 1 - CORPUS/CAPITAL FUND :				
Balance as at the beginning of the year		6,81,51,49,605.00		5,99,27,03,773.00
Add : Contribution towards Corpus/Capital Fund	68,94,07,598.00		1,32,32,79,396.00	
Less : Adjustement to Fixed Assets In-Kind Support from External Agencies				
(Deduct) : Depreciation & Ammortisation charged on Capital Assets for FY 2020-21 transferred to Income & Expenditure A/c	(51,59,17,923.00)		(49,67,02,900.00)	
Addition/Deduction in Fixed Assets during the year (transfer to/from I & E Account)	50,99,564.00	16,83,90,111.00	41,30,664.00	82,24,45,832.00
BALANCE AS AT 31ST MARCH, 2021		**6,98,35,39,716.00**		**6,81,51,49,605.00**
SCHEDULE 2 - RESERVE AND SURPLUS :				
1. Unspent Grant :				
a) As per last Account	21,08,85,37,179.00		18,35,80,16,703.00	
Less : Previous year Interest income traf to DAE	(8,21,78,048.00)		(27,60,07,462.00)	
Addition/Deduction during the year (transfer to/from I & E A/c)	2,75,39,47,504.00		3,01,02,62,938.00	
Addition/Deduction during the year	-	23,76,03,06,635.00	(37,35,000.00)	21,08,85,37,179.00
2. Interest earned on Unspent Grant (ITER-India Fund) :				
a) As per last Account	4,32,81,471.00		6,08,94,113.00	
Addition during the year	2,83,87,658.00		4,32,81,471.00	
(transfer to/from I & E A/c)				
Addition/Deduction during the year	4,32,81,471.00	2,83,87,658.00	6,08,94,113.00	4,32,81,471.00
BALANCE AS AT 31ST MARCH, 2021		**23,78,86,94,293.00**		**21,13,18,18,650.00**

* Note
Against Unspent Grant of 2376.03 Crore at year end contain Advance to Suppliers towards ITER-India Projects Rs.1870.56 Crore

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SCHEDULE FORMING PART OF BALANCE SHEET AS AT 31ST MARCH, 2021

SCHEDULE-3A - ENDOWMENT FUND

Dr.Parvez Guzdar Memorial Endowment Fund	**2020-2021**	**2019-2020**
a) Opening Balance of the fund	5,63,441	6,01,116
b) Additions to the Funds		
i. Donation/Grants		
ii. Income from Investments made on account of fund	72,595	12,325
iii. Other additions		
TOTAL (a+b)	**6,36,036**	**6,13,441**
c) **Utilisation/Expenditure towards objectives of the fund**		
i. Revenue Expenditure		
Dr.Parvez Guzdar Memorial award for Plasma physics	50,000	50,000
ii. Capital Expenditure		
TOTAL (c)	**50,000**	**50,000**
NET BALANCE AS AT THE YEAR END (a+b-c)	**5,86,036**	**5,63,441**

Represented by		
Cash And Bank Balance	6,405	13,441
Investments - FD with SBI	6,00,000	6,00,000
Interest Accrued but not due	29,631	-
	6,36,036	**6,13,441**
CURRENT YEAR (2020-2021)	-50,000.00	-50,000.00

SCHEDULE FORMING PART OF BALANCE SHEET AS AT 31ST MARCH, 2021								
SCHEDULE 3B - EARMARKED/ ENDOWMENT FUNDS :			a) Opening Balance of the fund 01-04-2020	b) Additions to the Funds	TOTAL (a+b)	c)Utilisation/ Expenditure towards objectives of funds	NET BALANCE AS AT 31ST MARCH, 2021 (a+b-c)	NET BALANCE AS AT 31ST MARCH, 2020
		FUND-WISE BREAK UP						
		Earmarked Fund						
1	9981	Plasma Processing Fund	-	2,73,61,721.00	2,73,61,721.00	2,73,61,721.00	-	-
2		Iter India Fund - Surplus On Task	37,00,17,751.00	9,70,96,722.00	46,71,14,473.00	4,84,890.00	46,66,29,583.00	37,00,17,751.00
	Sub Total (a)		**37,00,17,751.00**	**12,44,58,443.00**	**49,44,76,194.00**	**2,78,46,611.00**	**46,66,29,583.00**	**37,00,17,751.00**
		Sponsored Projects						
1	9106	BRNS - EPIA - AD	38,876.00		38,876.00	-	38,876.00	38,876.00
2	9109	TIFAC - EMF	3,20,782.00	-	3,20,782.00	-	3,20,782.00	3,20,782.00
3	9204	DST - DADD	96,097.00	-	96,097.00	-	96,097.00	96,097.00
4	9213	SPACE-DEBRIS Research	2,498.00	-	2,498.00	-	2,498.00	2,498.00
5	9222	BRNS-SRC-OIA-SP	30,01,566.00	-	30,01,566.00	-	30,01,566.00	30,01,566.00
6	9224	INSA Senior Scientist Position	1,33,304.00	6,90,000.00	8,23,304.00	4,58,227.00	3,65,077.00	1,33,304.00
7	9309	FCIPT-DU-CDPS	1,11,345.00	-	1,11,345.00	1,11,345.00	-	1,11,345.00
8	9310	FCIPT-DU-PPNS	1,14,190.00	-	1,14,190.00	1,14,190.00	-	1,14,190.00
9	9311	FCIPT-DU-WGPS	8,16,921.00	-	8,16,921.00	8,16,921.00	-	8,16,921.00
10	9320	FCIPT-EXCEL	1,89,787.00	-	1,89,787.00	-	1,89,787.00	1,89,787.00
11	9335	FCIPT MOEF	3,59,382.00	-	3,59,382.00		3,59,382.00	3,59,382.00
12	9339	VSSC-MoU-IPR	89,083.00		89,083.00		89,083.00	89,083.00
13	9340	FCIPT-IIT-Indore	2,01,415.00		2,01,415.00		2,01,415.00	2,01,415.00
14	9345	FCIPT-DST-RAD	20,236.00	546.00	20,782.00		20,782.00	20,236.00
15	9347	FCIPT-DST-TEX	1,99,434.00		1,99,434.00		1,99,434.00	1,99,434.00
16	9348	FCIPT-AMRITA	2,71,385.00		2,71,385.00		2,71,385.00	2,71,385.00
17	9349	FCIPT-NPN	24,23,984.00	65,448.00	24,89,432.00		24,89,432.00	24,23,984.00
18	9350	FCIPT-MSU	1,82,980.00		1,82,980.00		1,82,980.00	1,82,980.00
19	9352	FCIPT-IISUPNS	16,03,152.00		16,03,152.00	24,500.00	15,78,652.00	16,03,152.00
20	9355	FCIPT-LXM	2,55,885.00		2,55,885.00		2,55,885.00	2,55,885.00
21	9357	FCIPT-AAU-DBD	3,39,563.00		3,39,563.00		3,39,563.00	3,39,563.00
22	9358	FCIPT-ABREF	93,531.00		93,531.00		93,531.00	93,531.00
23	9359	FCIPT - APPJIITK	97,383.00		97,383.00		97,383.00	97,383.00
24	9361	FCIPT-VEGPL	12,773.00		12,773.00		12,773.00	12,773.00
25	9362	FCIPT-DST-SOLVENT	1,25,659.00		1,25,659.00	1,25,659.00	-	1,25,659.00
26	9363	FCIPT-NPCIL	2,96,747.00		2,96,747.00	39,618.00	2,57,129.00	2,96,747.00
27	9364	FCIPT-IITGN-INP	6,93,566.00	2,98,350.00	9,91,916.00	1,88,312.00	8,03,604.00	6,93,566.00
28	9365	FCIPT-PSED-SERB-CZTS	2,19,425.00	4,00,000.00	6,19,425.00	5,36,807.00	82,618.00	2,19,425.00
29	9366	Dr. Ashish Adak-SERB	1,81,358.00		1,81,358.00	1,81,358.00	-	1,81,358.00
30	9367	FCIPT CIPET	9,89,444.00		9,89,444.00	1,07,578.00	8,81,866.00	9,89,444.00
31	9368	Dr. Amreen Ara Hussain-DST Inspire	22,85,476.00	23,75,000.00	46,60,476.00	29,81,896.00	16,78,580.00	22,85,476.00
32	9369	AOARD	22,34,306.00	21,95,595.00	44,29,901.00	12,48,241.00	31,81,660.00	22,34,306.00
33	9370	CPIS-SAC-CP	22,61,556.00	30,00,000.00	52,61,556.00	13,53,144.00	39,08,412.00	22,61,556.00
34	9371	ARMREB-DRDO	14,66,672.00	6,45,493.00	21,12,165.00	18,06,159.00	3,06,006.00	14,66,672.00
35	9372	FCIPT-PSED-SU	2,75,707.00		2,75,707.00	7,434.00	2,68,273.00	2,75,707.00
36	9373	FCIPT-PSED-NU	1,24,688.00		1,24,688.00		1,24,688.00	1,24,688.00
37	9374	IPR-TBRL-CGN	(93,800.00)	26,16,000.00	25,22,200.00	9,52,380.00	15,69,820.00	(93,800.00)
38	9375	IPR-AAU-VS	1,06,823.00		1,06,823.00		1,06,823.00	1,06,823.00
39	9376	FCIPT-SPIX-III	1,49,84,886.00		1,49,84,886.00	3,79,867.00	1,46,05,019.00	1,49,84,886.00
40	9377	FCIPT-VSSC	44,71,090.00	95,48,784.00	1,40,19,874.00	12,24,046.00	1,27,95,828.00	44,71,090.00

SCHEDULE FORMING PART OF BALANCE SHEET AS AT 31ST MARCH, 2021

SCHEDULE 3B - EARMARKED/ ENDOWMENT FUNDS :			a) Opening Balance of the fund 01-04-2020	b) Additions to the Funds	TOTAL (a+b)	c)Utilisation/ Expenditure towards objectives of funds	NET BALANCE AS AT 31ST MARCH, 2021 (a+b-c)	NET BALANCE AS AT 31ST MARCH, 2020
1	9069	F.C.I.P.T. - DST - UP	(8,20,592.00)	-	(8,20,592.00)	-	(8,20,592.00)	(8,20,592.00)
2	9081	F.C.I.P.T. - RHVPS	(2,23,35,127.00)	87,755.00	(2,22,47,372.00)		(2,22,47,372.00)	(2,23,35,127.00)
3	9095	F.C.I.P.T. - DST2	(55,69,425.00)	-	(55,69,425.00)	-	(55,69,425.00)	(55,69,425.00)
4	9164	BARC - EED - Project	(15,50,420.00)	-	(15,50,420.00)	-	(15,50,420.00)	(15,50,420.00)
5	9203	DST - TSG- GYRO- RF	(22,17,752.00)	1,91,000.00	(20,26,752.00)	-	(20,26,752.00)	(22,17,752.00)
6	9211	DGFS-PhD	(1,86,24,207.00)	-	(1,86,24,207.00)	35,71,200.00	(2,21,95,407.00)	(1,86,24,207.00)
7	9215	DST-WOSA	(6,68,809.00)	-	(6,68,809.00)		(6,68,809.00)	(6,68,809.00)
8	9216	DST-INSPIRE	(60,009.00)	-	(60,009.00)		(60,009.00)	(60,009.00)
9	9226	IPR-DDT-TBRL	10,510.00	11,38,232.00	11,48,742.00	11,83,064.00	(34,322.00)	10,510.00
10	9227	APD-CEBS	(9,31,695.00)	-	(9,31,695.00)		(9,31,695.00)	(9,31,695.00)
11	9306	FCIPT-DST-IPT	(90,254.00)	-	(90,254.00)		(90,254.00)	(90,254.00)
12	9312	FCIPT-DU-SEPS	(3,47,161.00)	7,02,209.00	3,55,048.00	3,55,048.00	-	(3,47,161.00)
13	9331	LPSC THUSTER	(22,414.00)	-	(22,414.00)		(22,414.00)	(22,414.00)
14	9334	FCIPT-DST INT ITALY	(3,57,849.00)	-	(3,57,849.00)	-	(3,57,849.00)	(3,57,849.00)
15	9337	FCIPT-CSMCRI-MoU	(14,125.00)	-	(14,125.00)	-	(14,125.00)	(14,125.00)
16	9343	DST-PKK-GITA	(3,17,725.00)	-	(3,17,725.00)	-	(3,17,725.00)	(3,17,725.00)
17	9353	FCIPT-PERD	(2,15,598.00)	2,15,598.00	-	-	-	(2,15,598.00)
			-		-		-	-
Sub Total (c)			**(5,41,32,652.00)**	**23,34,794.00**	**(5,17,97,858.00)**	**51,09,312.00**	**(5,69,07,170.00)**	**(5,41,32,652.00)**
Dr. Parvez Guzdar Fund (3a)			(50,000.00)	15,18,414.00	14,68,414.00	15,18,414.00	(50,000.00)	(50,000.00)
BALANCE FOR YEAR 2020-21 (3a + 3b)			**41,26,17,103.00**	**29,44,17,664.00**	**70,71,34,767.00**	**17,74,51,207.00**	**53,26,20,388.00**	**41,26,17,103.00**

SCHEDULE FORMING PART OF BALANCE SHEET AS AT 31ST MARCH, 2021

PARTICULARS	2020-2021	2019-2020
SCHEDULE 4 - CURRENT LIABILITIES AND PROVISIONS:		
A. CURRENT LIABILITIES :		
1. Sundry Creditors		
a) For Goods	24,80,658.00	35,70,211.00
b) Others	19,16,719.00	8,43,339.00
2. Other Current Liabilities		
a) Security Deposits	3,27,55,589.00	2,73,51,315.00
b) Other Liabilities	5,07,122.00	21,07,276.00
c) Outstanding Expenses	3,08,95,693.00	2,97,22,597.00
d) Salary Payable	6,41,11,823.00	
3) Divisions		
a) CPP-IPR	2,681.00	-
a) ITER-India	-	-
TOTAL (A)	**13,26,70,285.00**	**6,35,94,738.00**
B. PROVISIONS		
1. Gratuity	44,63,34,864.00	40,28,07,681.00
2. Superannuating/Pension	3,83,05,99,763.00	3,64,82,00,957.00
3. Accumulated Leave Encashment	51,21,27,405.00	41,51,56,086.00
TOTAL (B)	**4,78,90,62,032.00**	**4,46,61,64,724.00**
TOTAL (A+B)	**4,92,17,32,317.00**	**4,52,97,59,462.00**

SCHEDULE FORMING PART OF BALANCE SHEET AS AT 31ST MARCH, 2021

SCHEDULE 5 - FIXED ASSETS

DESCRIPTION	Rate	GROSS BLOCK Cost as at beginning of the year	Addition during the year	Ded./Adj during the year	Cost as at the year end	DEPRICIATION Up-to beginning of the year	for the year	on deductions/Adj	Total up to the year end	NET BLOCK As at the Current year - end	As at the Previous year - end
A. FIXED ASSETS:											
1 LAND:				-							
a) Freehold		4,36,440.00	-	-	4,36,440.00	-	-	-	-	4,36,440.00	4,36,440.00
1. Bhat Land	-	56,75,519.00	-	-	56,75,519.00	-	-	-	-	56,75,519.00	56,75,519.00
2.GIDC Land	-	83,52,433.00	-	-	83,52,433.00	-	-	-	-	83,52,433.00	83,52,433.00
2 BUILDINGS :				-							
On Freehold Land				-							
a) Bhat Main Building/ITER Lab	1.63%	46,64,94,380.00	-	98,931.00	46,63,95,449.00	11,06,55,231.00	76,15,555.00	-	11,82,70,786.00	34,81,24,661.00	35,58,39,149.00
b) Guest House/Hostel Building	1.63%	6,34,10,013.00	-	-	6,34,10,013.00	1,00,62,048.00	10,54,058.00		1,11,16,106.00	5,22,93,907.00	5,33,47,965.00
c) Staff quarters	1.63%	28,55,711.00	-	-	28,55,711.00	16,99,002.00	46,548.00	-	17,45,550.00	11,10,161.00	11,56,709.00
d) FCIPT Building	1.63%	8,68,90,582.00	14,85,646.00	-	8,83,76,228.00	1,16,29,711.00	14,28,425.00	-	1,30,58,136.00	7,53,18,092.00	7,52,60,873.00
e) Additional Building	1.63%	9,29,41,236.00	-	-	9,29,41,236.00	81,83,651.00	15,14,943.00	-	96,98,594.00	8,32,42,642.00	8,47,57,585.00
f) Laboratory & Auxi. Building	1.63%	79,74,06,320.00	47,95,758.00	-	80,22,02,078.00	1,93,24,489.00	1,32,44,945.00	-	3,25,69,434.00	76,96,32,644.00	77,80,81,831.00
g) HVAC Building	1.63%	1,21,77,052.00	-	-	1,21,77,052.00	8,38,857.00	1,98,485.00	-	10,37,342.00	1,11,39,710.00	1,13,38,195.00
h) MSH Building	1.63%	1,76,23,290.00	-	-	1,76,23,290.00	15,71,154.00	2,87,260.00		18,58,414.00	1,57,64,876.00	1,60,52,136.00
i) Pre Feb Building/Apporach Road		1,74,91,177.00	-	-	1,74,91,177.00	13,32,280.00	2,85,107.00	-	16,17,387.00	1,58,73,790.00	1,61,58,897.00
3 PLANT MACHINERY & EQUIPMENTS				-			-				
a) Scientific Equipments	4.75%	7,80,60,77,930.00	59,22,54,553.00	1,05,96,841.00	8,38,77,35,642.00	3,32,98,63,829.00	35,51,39,254.00	68,01,076.00	3,67,82,02,007.00	4,70,95,33,635.00	4,47,62,14,106.00
c) Workshop Equipments /CPP Machinery & Equip.	4.75%	1,88,84,685.00	4,20,000.00	-	1,93,04,685.00	1,33,58,801.00	5,69,715.00	-	1,39,28,516.00	53,76,169.00	55,26,160.00
d) Workshop Tools / (CPP Mechanical Works)	4.75%	5,66,483.00		-	5,66,483.00	5,07,182.00	22,009.00	-	5,29,191.00	37,292.00	59,301.00
4 FURNITURE, FIXTURES	6.33%	11,07,01,293.00	18,56,697.00	1,38,600.00	11,24,19,390.00	6,37,37,981.00	59,76,226.00	1,33,910.00	6,95,80,297.00	4,28,39,093.00	4,69,63,312.00
5 OFFICE/GEN. EQUIPMENTS	4.75%	7,72,72,610.00	27,18,526.00	24,255.00	7,99,66,881.00	3,40,30,704.00	31,76,138.00	23,272.00	3,71,83,570.00	4,27,83,311.00	4,32,41,905.00
6 COMPUTER / PERIPHERALS*	16.21%	83,94,83,251.00	1,77,63,707.00	15,37,913.00	85,57,09,045.00	47,32,88,860.00	7,89,41,875.00	3,38,718.00	55,18,92,017.00	30,38,17,028.00	36,61,94,392.00
7 ELECTRIC INSTALLATION	4.75%	5,07,91,540.00	1,19,97,029.00	-	6,27,88,569.00	1,39,70,957.00	22,67,451.00	-	1,62,38,408.00	4,65,50,161.00	3,68,20,583.00
8 LIBRARY BOOKS/ JOURNALS	4.75%	35,78,08,143.00	3,13,15,701.00	-	38,91,23,844.00	15,69,36,164.00	1,49,56,694.00	-	17,18,92,858.00	21,72,30,986.00	20,08,71,979.00
CURRENT YEAR		**10,83,33,40,088.00**	**66,46,07,617.00**	**1,23,96,540.00**	**11,48,55,51,165.00**	**4,25,09,90,901.00**	**48,67,24,688.00**	**72,96,976.00**	**4,73,04,18,613.00**	**6,75,51,32,550.00**	**6,58,23,49,471.00**
B. INTENGIBLE ASSETS											
1 Computer Softwares*		19,86,04,473.00	2,26,54,494.00	31,888.00	22,12,27,079.00	17,52,06,168.00	1,58,98,968.00	-	19,11,05,136.00	3,01,21,943.00	2,33,98,305.00
2 Patents		81,380.00	-	-	81,380.00	81,380.00	-	-	81,380.00	-	-
CURRENT YEAR		**19,86,85,853.00**	**2,26,54,494.00**	**31,888.00**	**22,13,08,459.00**	**17,52,87,548.00**	**1,58,98,968.00**	**-**	**19,11,86,516.00**	**3,01,21,943.00**	**2,33,98,305.00**

DESCRIPTION	Rate	Cost as at beginning of the year	Addition during the year	Ded./Adj during the year	Cost as at the year end	Up-to beginning of the year	for the year	on deductions/Adj	Total up to the year end	As at the Current year - end	As at the Previous year - end
C. ASSETS AT IGCAR											
1 Building	1.63%	3,35,67,457.00	-	-	3,35,67,457.00	38,31,080.00	5,47,149.00	-	43,78,229.00	2,91,89,228.00	2,97,36,377.00
2 Office & General Equipment	4.75%	1,92,46,116.00	-	-	1,92,46,116.00	57,78,161.00	9,14,190.00	-	66,92,351.00	1,25,53,765.00	1,34,67,955.00
3 Computers & Furniture		1,67,738.00	-	-	1,67,738.00	1,08,760.00	27,190.00	-	1,35,950.00	31,788.00	58,978.00
4 Office Furniture at IGCAR		4,84,673.00	-	-	4,84,673.00	1,00,409.00	30,680.00	-	1,31,089.00	3,53,584.00	3,84,264.00
5 Scientific Equipments at IGCAR	4.75%	20,49,08,977.00	21,45,487.00	-	20,70,54,464.00	5,86,47,085.00	1,01,40,708.00	-	6,87,87,793.00	13,82,66,671.00	14,62,61,892.00
CURRENT YEAR		**25,83,74,961.00**	**21,45,487.00**	**-**	**26,05,20,448.00**	**6,84,65,495.00**	**1,16,59,917.00**	**-**	**8,01,25,412.00**	**18,03,95,036.00**	**18,99,09,466.00**
D. ASSETS -External Projects											
COMPUTER / PERIPHERALS*	16.21%	26,35,247.00	-	-	26,35,247.00	24,99,225.00	4,261.00	-	25,03,486.00	1,31,761.00	1,36,022.00
Computer Softwares*	16.67%	4,53,965.00	-	-	4,53,965.00	4,53,965.00	-	-	4,53,965.00	-	-
OFFICE/GEN. EQUIPMENTS	4.75%	4,71,106.00	-	-	4,71,106.00	2,44,839.00	22,095.00	-	2,66,934.00	2,04,172.00	2,26,267.00
FURNITURE, FIXTURES	6.33%	5,04,198.00	-	-	5,04,198.00	4,55,553.00	5,379.00	-	4,60,932.00	43,266.00	48,645.00
Scientific Equipments	4.75%	3,37,82,937.00	-	-	3,37,82,937.00	1,47,01,509.00	16,02,615.00	-	1,63,04,124.00	1,74,78,813.00	1,90,81,428.00
CURRENT YEAR		**3,78,47,453.00**	**-**	**-**	**3,78,47,453.00**	**1,83,55,091.00**	**16,34,350.00**	**-**	**1,99,89,441.00**	**1,78,58,012.00**	**1,94,92,362.00**
D. CAPITAL WORK-IN-PROGRESS		3,69,63,04,808.00	6,68,85,12,712.00	1,14,56,26,139.00	9,23,91,91,381.00	-	-	-	-	9,23,91,91,381.00	3,69,63,04,808.00
TOTAL		15,02,45,53,163.00	7,37,79,20,310.00	1,15,80,54,567.00	21,24,44,18,906.00	4,51,30,99,035.00	51,59,17,923.00	72,96,976.00	5,02,17,19,982.00	16,22,26,98,922.00	10,51,14,54,412.00
PREVIOUS YEAR		**12,34,25,13,086.00**	**3,66,38,21,868.00**	**2,72,88,62,530.00**	**13,27,74,72,424.00**	**3,67,97,28,813.00**	**41,51,42,205.00**	**1,68,39,697.00**	4,07,80,31,321.00	10,51,14,54,412.00	

SCHEDULE FORMING PART OF BALANCE SHEET AS AT 31ST MARCH, 2021

PARTICULARS	2020-2021	2019-2020
SCHEDULE 6 - CURRENT ASSETS, LOANS, ADVANCES ETC:		
A. CURRENT ASSETS :		
1 Inventories:		
a) Stores and spares	44,20,035.00	55,74,383.00
2 Sundry Debtors:		
a) Debts outstanding for a period exceeding six months	23,70,000.00	36,48,802.00
b) Debts outstanding for a period less then six months	3,00,91,038.00	99,45,210.00
c) Others		-
3 Cash balances in hand (including cheques/drafts and imprest)	28,140.00	69,740.00
4 Bank Balances:		
a) With Scheduled Banks:		
- On Current Accounts		
State Bank of India, IPR.Branch, Gandhinagar A/c.30185519770	21,79,345.00	1,10,27,053.00
State Bank of India, IPR.Branch, Gandhinagar A/c.30360884053	1,77,81,995.00	22,24,617.00
State Bank of India, Naroda Branch, Ahemdabad A/c.10159920115	15,41,658.00	70,41,597.00
State Bank of India, Naroda Branch, Ahemdabad A/c.30360272380	7,34,049.00	10,28,518.00
State Bank of India, A/c No.35052592927	25,926.00	8,28,681.00
State Bank of India, A/c No.39503998940 (GEM A/c)	1,00,000.00	-
- On Deposit Accounts		
State Bank of India	93,43,39,486.00	1,18,77,41,891.00
- On Savings Accounts		
State Bank of India, A/c No. 30767137485	13,059.00	20,06,269.00
CPP-IPR State Bank of India, A/c No.31012661865	46,36,200.00	4,74,47,730.00
TOTAL (A)	**99,82,60,931.00**	**1,27,85,84,491.00**
B. LOANS, ADVANCES AND OTHER ASSETS :		
1 Loans:		
a) Staff		
House Building Advance (Including accrued interest)	2,55,55,227.00	2,08,08,281.00
Computer Advance (Including accrued interest)	46,82,718.00	54,93,591.00
Vehicle Advance (Including accrued interest)	15,44,057.00	20,27,469.00
2 Advances and amounts recoverable in cash or in kind or for value to be received:		
a) Advances to Non Govt. Contractors & Suppliers (Including adv. For Capital Works)	18,56,03,32,929.00	20,65,44,83,756.00
b) Advances to Govt.Institutions/Organisations	34,15,74,221.00	35,42,29,415.00
(Refer Note 5 of Schedule-14)		
c) Deposit with Government Authorities	1,68,97,335.00	1,68,88,835.00
d) Deposit with Others	69,20,592.00	1,00,11,295.00
e) TDS Receivable	12,63,162.00	11,42,861.00
f) Patents Applied for	4,59,374.00	3,96,600.00
g) Advance for Travelling Expenses	23,52,830.00	60,11,637.00
h) General Advance *	2,29,15,896.00	2,93,451.00
i) Project Leader Imprest Advance	-	1,64,470.00
j) LTC Advance	26,29,626.00	9,37,275.00
k) Festival Advance	7,59,000.00	-
l) CPP-IPR	(2,682.00)	-
m) CGST Receivable	9,52,939.00	9,52,939.00
n) IGST Receivable	3,47,264.00	3,47,263.00
o) CPP-NPS	-	5,01,654.00
p) SGST Receivable	9,82,209.00	9,82,209.00
q) RCM CGST Receivable	2,56,735.00	2,56,735.00
r) RCM SGST Receivable	2,56,735.00	2,56,735.00
s) GST	1,56,020.00	49,306.00
t) TDS of CGST	-	3,12,577.00
u) TDS of SGST	-	3,12,585.00
v) GSLI	5,446.00	-
w) Prepaid Expenses	44,40,819.00	55,10,168.00
3 Income Accrued:		
a) On Bank Fixed Deposits	1,03,44,132.00	1,69,34,818.00
TOTAL (B)	**19,00,56,26,584.00**	**21,09,93,05,925.00**
TOTAL (A+B)	**20,00,38,87,515.00**	**22,37,78,90,416.00**

* yet to be recovered towards Two Increment (FY2020-21)

SCHEDULE FORMING PART OF INCOME & EXPENDITURE FOR THE YEAR ENDED 31ST MARCH, 2021

PARTICULARS	2020-2021	2019-2020
SCHEDULE 7 - GRANTS/SUBSIDIES :		
(Irrevocable Grants & Subsidies Received)		
1) Central Government (Dept. of Atomic Energy, Govt. of India)	7,46,71,00,000.00	8,40,20,00,000.00
TOTAL	**7,46,71,00,000.00**	**8,40,20,00,000.00**
SCHEDULE 8 - INTEREST EARNED :		
1) On Term Deposits & Savings Deposits:		
a) With Scheduled Banks- State bank of India	7,62,97,590.00	12,65,09,234.00
2) On Loans:		
a) Employees/Staff		
- On Vehicle Advance	57,522.00	54,694.00
- On Computer Advance	88,938.00	1,35,441.00
- On House Building Advance	8,92,737.00	6,96,857.00
3) Interest on TDS refund	15,519.00	26,194.00
TOTAL	**7,73,52,306.00**	**12,74,22,420.00**
SCHEDULE 9 - OTHER INCOME :		
1) Miscellaneous Income	37,82,030.00	5,76,616.00
2) Rent	3,02,118.00	6,47,266.00
3) Royalty & Technology Tranfer Fee Income	10,03,590.00	-
4) Other receipts for Facility utilisation	1,66,500.00	7,10,528.00
5) Surplus on Sale of Assets	8,537.00	5,682.00
TOTAL	**52,62,775.00**	**19,40,092.00**

SCHEDULE FORMING PART OF INCOME & EXPENDITURE FOR THE YEAR ENDED 31ST MARCH, 2021

	PARTICULARS	2020-2021	2019-2020
	SCHEDULE 10 - ESTABLISHMENT EXPENSES :		
a)	Salaries and Wages	82,05,54,557.00	77,47,63,737.00
b)	Allowances and Bonus	54,10,98,281.00	58,81,08,819.00
c)	Contribution to Provident Fund (Including NPS Contribution)	5,52,93,068.00	5,23,52,532.00
d)	Staff Welfare Expenses	1,89,260.00	19,55,716.00
e)	Medical Expenses	2,57,11,336.00	2,35,68,584.00
f)	Expenses on Employees' Retirement and Terminal Benefits	28,69,00,727.00	1,59,17,96,430.00
g)	NPS charges	65,350.00	68,725.00
	Less: PF Contribution Receipt for PF Trust on Option change CPF to GPF	-5,65,872.00	-41,28,083.00
	TOTAL	**1,72,92,46,707.00**	**3,02,84,86,460.00**
	SCHEDULE 11 - OTHER ADMINISTRATIVE EXPENSES ETC. :		
a)	Purchases- Consumable Stores & Spares	15,18,29,422.00	19,52,68,917.00
b)	Electricity and Power	10,39,58,002.00	11,43,11,591.00
c)	Repairs and Maintenance	9,80,01,234.00	8,96,26,674.00
d)	Rent, Rates and taxes	2,74,80,799.00	3,68,56,013.00
e)	Transport Hire Charges	1,34,44,499.00	1,78,36,305.00
f)	Postage & Telegraph	2,43,361.00	3,99,142.00
g)	Telephone and Trunck	41,90,623.00	42,15,467.00
h)	Printing and Stationary	34,92,397.00	33,33,154.00
i)	Travelling and conveyance Expenses	21,87,114.00	2,39,32,760.00
j)	Travelling Expenses-International	4,69,816.00	1,77,94,101.00
k)	Expenses on Seminar/Workshops	15,73,339.00	58,87,966.00
l)	Membership	35,735.00	31,464.00
m)	Auditors Remuneration - Internal	2,21,250.00	1,88,800.00
n)	Auditors Remuneration - Statutory	2,36,000.00	2,36,000.00
o)	Professional/Legal Charges	21,48,049.00	19,84,020.00
p)	Security Expenses	5,10,37,177.00	5,52,12,668.00
q)	Visiting Scientist Expenses	4,13,465.00	37,00,805.00
r)	Advertisement and Publicity	9,35,392.00	18,58,349.00
s)	Admin/Office Exp	3,92,814.00	2,24,592.00
t)	Expenses on Acedemic Programmes	36,10,680.00	37,48,135.00
u)	Honorarium	20,82,358.00	11,38,682.00
v)	Bank Charges	13,66,568.00	6,17,235.00
w)	Remuneration & Wages	2,42,16,754.00	4,03,01,239.00
x)	Canteen Subsidy	23,76,750.00	46,45,857.00
y)	Collobrative Research Expenses	1,46,86,932.00	71,81,698.00
z)	Technical & Professional Consultancy	12,23,782.00	12,30,814.00
aa)	TA to Candidate	-	-6,51,054.00
ab)	Reimbursement of Exp to IO	2,86,69,123.00	3,05,70,280.00
ac)	Freight & Cartage Expense	90,254.00	3,20,763.00
	TOTAL	**54,06,13,689.00**	**66,20,02,437.00**
	TOTAL EXPENSES	**2,26,98,60,396.00**	**3,69,04,88,897.00**

SCHEDULE FORMING PART OF INCOME & EXPENDITURE FOR THE YEAR ENDED 31ST MARCH, 2021

	PARTICULARS	2020-2021	2019-2020
	SCHEDULE 12 - DEPRECIATION ON FIXED ASSETS:		
a)	Main Building/Lab Buidling	82,88,714.00	83,70,192.00
b)	Guest House / Hostel Building	10,54,058.00	10,54,058.00
c)	Staff Quarters Building	46,548.00	46,548.00
d)	FCIPT Building	14,28,425.00	14,14,473.00
e)	Additional Office Building	15,14,943.00	15,14,943.00
f)	HVAC Building/Lab & Aux. Building	1,27,70,271.00	64,58,045.00
g)	MSH Building	2,87,260.00	2,87,260.00
h)	Scientific Equipments	35,51,39,254.00	35,00,81,296.00
i)	Workshop Equipments	5,69,715.00	4,18,428.00
j)	Workshop Tools	22,009.00	22,009.00
k)	Furniture & Fixture	59,76,226.00	57,59,257.00
l)	Office/General Equipments	31,76,138.00	29,87,615.00
m)	Computers/Peripherals	7,89,41,875.00	7,32,87,871.00
n)	Electric Installations	22,67,451.00	27,11,559.00
o)	Library Books/Journals	1,49,56,694.00	1,41,54,781.00
p)	Pre-Fab Building / Approach Road	2,85,107.00	2,83,495.00
	TOTAL (A)	**48,67,24,688.00**	**46,88,51,830.00**
	AMMORTISATION ON INTENGIBLE ASSETS :		
a)	Computer Softwares	1,58,98,968.00	1,49,84,809.00
b)	Patents	-	-
	TOTAL (B)	**1,58,98,968.00**	**1,49,84,809.00**
	ASSETS AT IGCAR		
a)	Building	5,47,149.00	5,47,149.00
b)	Office & General Equipment	9,14,190.00	9,14,190.00
c)	Computer & Furniture	27,190.00	27,190.00
d)	Office Furniture at IGCAR	30,680.00	30,680.00
e)	Scientific Equipments	1,01,40,708.00	97,33,065.00
	TOTAL (C)	**1,16,59,917.00**	**1,12,52,274.00**
	ASSETS -External Projects		
a)	Computer	4,261.00	(16,806.00)
b)	Office Equipment	22,095.00	22,262.00
c)	Office Furniture	5,379.00	5,916.00
d)	Scientific Equipments	16,02,615.00	16,02,615.00
	TOTAL (D)	**16,34,350.00**	**16,13,987.00**
	TOTAL (A+B + C + D)	**51,59,17,923.00**	**49,67,02,900.00**

SIGNIFICANT ACCOUNTING POLICIES

SCHEDULE- 13:

1. **BASIS FOR PREPARATION OF ACCOUNTS**

   The Financial statements are prepared on the historical cost convention, and on accrual method of Accounting, unless otherwise stated and on going concern basis.

2. **INVENTORY VALUATION**

   Stores & spares are valued at the weighted average cost.

3. **INVESTMENT**

   Investments are valued at cost.

4. **FIXED ASSETS**

   a) Fixed Assets are recorded at cost which includes incidental expenses incurred up to the date of Commissioning of assets, net of liquidated damages/other recoveries prior to /post commissioning of the assets.

   b) **Intengible Assets**

   i) Softwares are recorded at cost which includes incidental expenses incurred up to the date of Commissioning.

   ii) Patents are recorded at legal cost in the year in which granted. Legal cost includes Governemnet fees and lawer's fees etc., incurred on getting patents.

5. **DEPRECIATION**

   i) Depreciation is provided on Straight Line Basis at the following rates:

Sr	*Particular*	Rate of Depreciation
1	Building	1.63%
2	Plant Machinery & Equipments	4.75%
3	Furniture & Fixtures	6.33%
4	Office / Gen.Equipments	4.75%
5	Computers / Peripherals	16.21%
6	Electric Installation	4.75%
7	Library Books / Journals	4.75%

   ii) Asset Costing Rs.5000.00 or less each are fully depreciated.

   iii) Depreciation on additions to Assets other than Buildings and Library Books/Journals is provided on prorata basis from the month of addition.Depreciation on additions to Buildings and Library Books/Journals is provided at 50% of the applicable rate.

6. **AMMORTISATION**

   i) Computer Softwares are ammortised during the period of six (6) years.

   ii) Patents are ammortised during the period of 10 years from the date of application.

7. **GOVERNMENT GRANTS**

   Government Grants are accounted for on the basis of the Income Approach on receipt basis.Grants received in respect of Fixed Assets are transferred to the Corpus Fund through the Income & Expenditure Account at the time of acquisition of Fixed Assets.

8. **FOREIGN CURRENCY TRANSACTION**

   i) Foreign currency transactions during the year are recorded at rates of exchange prevailing on the date of transactions.

   ii) Foreign Currency Assets and Liabilities are not translated into rupees at the rates of exchange prevailing on Balance-Sheet date, since this would have notional impact on unspent grant. Impact of not translation as above is not quantified.

9. **CONTRIBUTIONS TO PROJECTS**

   Contributions to collaborative projects are accounted on the basis of the respective project agreements/Project Memorandum of Understanding. Further accounting for utilization of contribution given for collaborative projects is done on the basis of information regarding utilization received from partner organization.

10. EXTERNALLY FUNDED PROJECTS

Receipts & utilization for Externally Funded Projects are being accounted in a specific project account. On closure, surplus/deficit is being transferred to Plasma Processing Fund.

11. RESEARCH & DEVELOPMENT

Revenue expenditure on research and development is charged against the grant of the year in which it incurred, Capital expenditure on research and development is shown as an addition to fixed assets. Expenditure on research and development resulting into tangible asset is accounted as fixed asset or intengible assets as the case may be.

12. RETIREMENT BENEFITS

Liability for all Retirement benefits like Pension, Gratuity, Leave Encashment are accounted for on actuarial valuation basis.

As per our report of even date attached.

Institute for Plasma Research
Bhat, Gandhinagar

For T.N.Shah & Co.,
Chartered Accountants
Firm Registration No.109802/w

-Sd-	-Sd-	-Sd-	-Sd-
(Dr.Shashank Chaturvedi)	**(Dr.Subroto Mukherjee)**	**(Falguni Shah)**	**(Tushar N Shah)**
Director	Dean	Accounts Officer-I	Partner
			Membership No. 042748

Place : Gandhinagar
Date :07/09/2021

NOTES TO THE ACCOUNTS

SCHEDULE- 14:

1 Hitherto, as per rules of ITER-India Empowered Board, seprate set of accounts & records were to be maintained and separate Audited Statement of Accounts were to be presented for the ITER-India Project w.e.f. April 1,2008. However in accordance with Department of Atomic Energy directive vide their letter No.18/1/2010-R&D-II/9309 Dated October 5, 2010, Audited Statements of Accounts for ITER-India Project are to be presented on branch accounting concept.

2 CONTINGENT LIABILITIES :

(i) Contingent Liabilities in respect of claims against the IPR not acknowledged as debts Rs.--NIL-- (Previous year - Rs.NIL).

(ii) Guarantees and Letter of Credits given by Bank on behalf of the Institute for Plasma Research is Rs.248.89 Crore (Previous Year Rs.190.36 Crore).

3 CAPITAL COMMITMENTS

Estimated value of Contracts remaining to be executed on Capital Account and not provided for Rs.753.05 Crore (Previous Year Rs.1091.093 Crore).

4 DEPRECIATION

Depreciation for the year 2020-2021 Rs.51,59,17,923.00 (Previous Year Rs. 49,67,02,900.00) has been debited to the Income & Expenditure Account and the like amount has been transferred from the Corpus Fund to the Income & Expenditure Account

5 ACCOUNTING OF PROJECT ASSETS

Fixed Assets set out in the Schedule-5 do not include Scientific Equipment of Rs.3,98,56,235.00 (Previous Year Rs. 3,98,56,235.00 as on 31.03.2021 purchased out of funds of closed sponsered projects as on 31.03.2021, held and used by Institute, as Project sanctions include stipulations that all such assets puchased out of the project funds will remain the property of the sponsors.

6 FOREIGN CURRENCY TRANSACTION

		2020-2021	**2019-2020**
i)	Value of Imports Calculated on C.I.F. Basis :		
	- Capital Goods	44,24,72,972.00	36,22,98,217.00
	- Consumables & Spares	3,77,51,882.00	3,95,65,353.00
ii)	Expenditure in foreign currency :		
	- Travel	9,88,318.00	1,08,06,750.00
	- Cash Contribution to ITER-Organisation	1,84,12,65,336.00	49,51,85,120.00
	- Technical Consultancy	-	-
iii)	Earnings :		
	- Value of Exports on F.O.B. basis	Nil	Nil

7 Advance to Govt.Institutions / Organaisation stated in Schedule - 6B.2.b) includes:

An amount of Rs. 3.40 Crore (Previous year Rs. 4.02 Crore) has been paid to Indira Gandhi Centre for Advance Atomic Research for colloborative research on Development of ITER Test Blanket Modules which is pending for adjustment in absence of information regarding its utilisation.

8 Total demand outstanding of In-Cash Contribution to ITER Organisation as on 31.03.2021 is Euro 159639295.62 (Approx Rs.1396.00 Crores taking SBI TT Selling rate Rs.87.47 per Euro as on 31.03.2021)

9 **a)** One reactor for aprox. Rs. 8.00 Lacs (Rupees Eight Lacs) included in present value of Assets is lost. No provision is made for loss,as lower court has decided the case in favour of the Institute and the matter is pending before Hon.High Court of Gujarat.

b) Since 2011, ITER-India has given advances to contractor aggregating to Rs.48,406,387.00 for implementation of SAP software. These advances has been shown under Current Assets (Advance to Non-Govt.Contractors). A Committee consisting of Senior Scientists had been formed by Project Director - ITER-India, to review implementation status of SAP and closure of contracts related thereto. The recommendation of the Committee is received and same is under review with Management for final decision. Accounting treatment of above advances will be decided upon receipt of final decision of Management.

10 No Insurance Policy is taken for the Movable & Immovable assets as per the usual practice.

11 Previous year's figures have been regrouped wherever necessary to correspond with the current year's figures.

12 Balances of Suppliers/Contractors are subject to confirmations & adjustment, if any.

As per our report of even date attached.

Institute for Plasma Research
Bhat, Gandhinagar

For T.N.Shah & Co.,
Chartered Accountants
Firm Registration No.109802/w

-Sd-	- Sd-	-Sd-	-Sd-
(Dr.Shashank Chaturvedi)	**(Dr. Subroto Mukherjee)**	**(Falguni Shah)**	**(Tushar N Shah)**
Director	Dean	Accounts Officer-I	Partner
			Membership No. 042748

Place : Gandhinagar
Date :07/09/2021

Audited Statements of Accounts
as on 31st March 2021
INSTITUTE FOR PLASMA RESEARCH

Employees Provident Fund

IPR EMPLOYEE'S PROVIDENT FUND.

BALANCE SHEET AS AT 31ST MARCH, 2021

2019-20		CORPUS/CAPITAL FUND AND LIABILITIES	2020-21	
		MEMBERS PF SUBSCRIPTION :		
		(Net of Loans & including Interest on Subscription)		
42,26,65,269.30		Balance as on 1st April 2019	46,34,03,382.30	
7,28,58,340.00		Addition During the year	7,23,29,539.00	
3,21,20,227.00	**46,34,03,382.30**	**Less :** Debit During the year	1,98,36,190.00	**51,58,96,731.30**
		INSTITUTE'S PF CONTRIBUTION :		
		(Including Interest)		
14,39,909.15		Balance as on 1st April 2019	1,80,526.15	
30,280.00		Addition during the year	-	
12,89,663.00	**1,80,526.15**	**Less :** Debits during the year	-	**1,80,526.15**
		LAPSE & FORFEITTURE A/c		
16,42,343.49		Balance as on 1st April 2019	16,42,343.49	
-	**16,42,343.49**	Addition during the year	-	**16,42,343.49**
		CURRENT LIABILITIES :		
11,81,166.00	**11,81,166.00**	Sundray Credit Balances.	95,862.00	**95,862.00**
		INCOME & EXPENDITURE A/c		
4,23,14,630.22		Openig Balance	3,95,86,162.22	
-27,28,468.00	**3,95,86,162.22**	**Add/Less :** Tranfer from Income & Expenditure A/c	-42,54,274.50	**3,53,31,887.72**
	50,59,93,580.16	**TOTAL**		**55,31,47,350.66**
		ASSETS		
	44,00,28,829.00	FIXED DEPOSIT with State Bank Of India / Public Financial Institute.	50,31,92,085.00	
		S/B A/c with :		
	1,34,77,100.03	State Bank Of India	1,16,85,570.53	**51,48,77,655.53**
	5,23,39,355.13	Interest accrued but not due on Fixed Deposits with a Scheduled Bank / Public Financial Institute.	3,81,21,399.13	**3,81,21,399.13**
		Income-Tax Deducted at source :		
1,48,296.00		Balance as on 1st April 2019	1,48,296.00	
-		Addition during the year	-	
-	**1,48,296.00**	**Less :** Refund Received	-	**1,48,296.00**
	50,59,93,580.16	**Total**		**55,31,47,350.66**
	-			-

Note : Loan transactions are merged with members subscription accounts. **Rs. 5,22,538/-** were given during the year ended as on 31st March 2021, **Rs.75,24,141/-** are outstanding in loan accounts.

Examined and Found correct.
For T.N.Shah & Co.,
Chartered Accountants
FRN.109802/W

-Sd-
(Dr.Subroto Mukherjee)
Senior Professor - H
Chairman

-Sd-
(Falguni Shah)
Accounts Officer-I, IPR
Member

-Sd-
(Tushar N.Shah)
Partner
Membership No.042748

Place : Bhat, Gandhinagar
Dated : June 14,2021

IPR EMPLOYEE'S PROVIDENT FUND.

INCOME AND EXPENDITURE ACCOUNT FOR THE PERIOD ENDED ON 31ST MARCH, 2021

2019-20	INCOME	2020-21
2,14,680.00	Interest On Savings Bank Account & Others	3,51,341.00
2,98,44,867.00	Interest On Fixed Deposit	2,89,45,300.00
27,28,468.00	Excess of Expenditure over Income transferred to Income & Expenditure A/c	42,54,274.50
3,27,88,015.00	TOTAL	3,35,50,915.50

	EXPENDITURE	
3,28,18,040.00	Interest on Members Subscription	3,35,50,591.00
-	Bank Charges	324.50
(30,025.00)	Interset on Institute's Contribution	-
3,27,88,015.00	TOTAL	3,35,50,915.50
-		-

Examined and Found correct.
For T.N.Shah & Co.,
Chartered Accountants
FRN.109802/W

-Sd-
(Dr.Subroto Mukherjee)
Senior Professor - H
Chairman

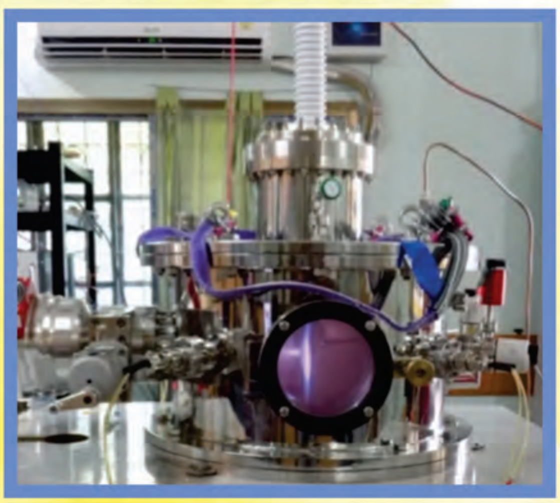
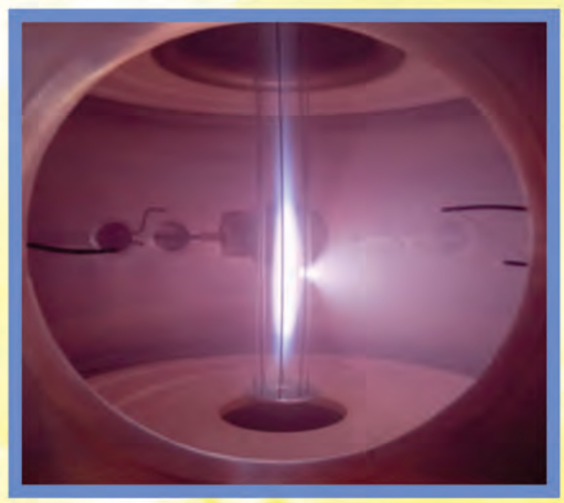
-Sd-
(Falguni Shah)
Accounts Officer-I. IPR
Member

-Sd-
(Tushar N.Shah)
Partner
Membership No.042748

Place : Bhat, Gandhinagar
Dated : June 14,2021

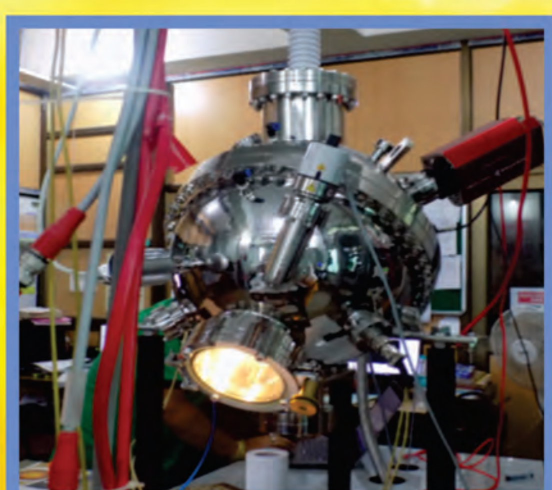

आइपीआर आउटरीच प्रभाग द्वारा विकसित टेरेला डिवाइस की प्रारंभिक छवियां। (बाएं) एक ओर का चित्र (दाएं) चुंबक के साथ हॉलो स्फियर की भूमध्य रेखा के चारों ओर रिंग करंट का ऊपरी दृश्य

Preliminary images of the Terrella Device developed by IPR Outreach Division. (L) Side View (R) Top View of the ring current around the equatorial line of a hollow sphere with a magnet

बेलनाकार इनर्शियल इलेक्ट्रोस्टैटिक कन्फाइनमेंट फ्यूज़न डिवाइस और उसमें उत्पन्न प्लाज़्मा

The cylindrical Inertial Electrostatic Confinement Fusion device and its Plasma




सीपीपी-आईपीआर में गोलाकार इनर्शियल इलेक्ट्रोस्टैटिक कन्फाइनमेंट फ्यूज़न डिवाइस और उसमें उत्पन्न प्लाज़्मा

The Spherical Inertial Electrostatic Confinement Fusion Device and its Plasma at CPP-IPR

30 अक्टूबर 2020 को ''आत्मनिर्भर भारत'' कार्यक्रम के तहत
आईपीआर इंक्यूबेशन सेंटर का वर्चुअल उद्घाटन

Virtual Inauguration of IPR Incubation Center as part of "Aatmanirbhar Bharat" on 30 Oct 2020

30 अक्टूबर 2020 को प्लाज़्मा पायरोलिसिस प्रौद्योगिकी के हस्तांतरण के लिए प्रौद्योगिकी जानकारी और लाइसेंस करार

Technology knowhow and license agreement for transfer of Plasma Pyrolysis technology on 30 Oct 2020