वार्षिक प्रतिवेदन
2024-2025

ANNUAL REPORT
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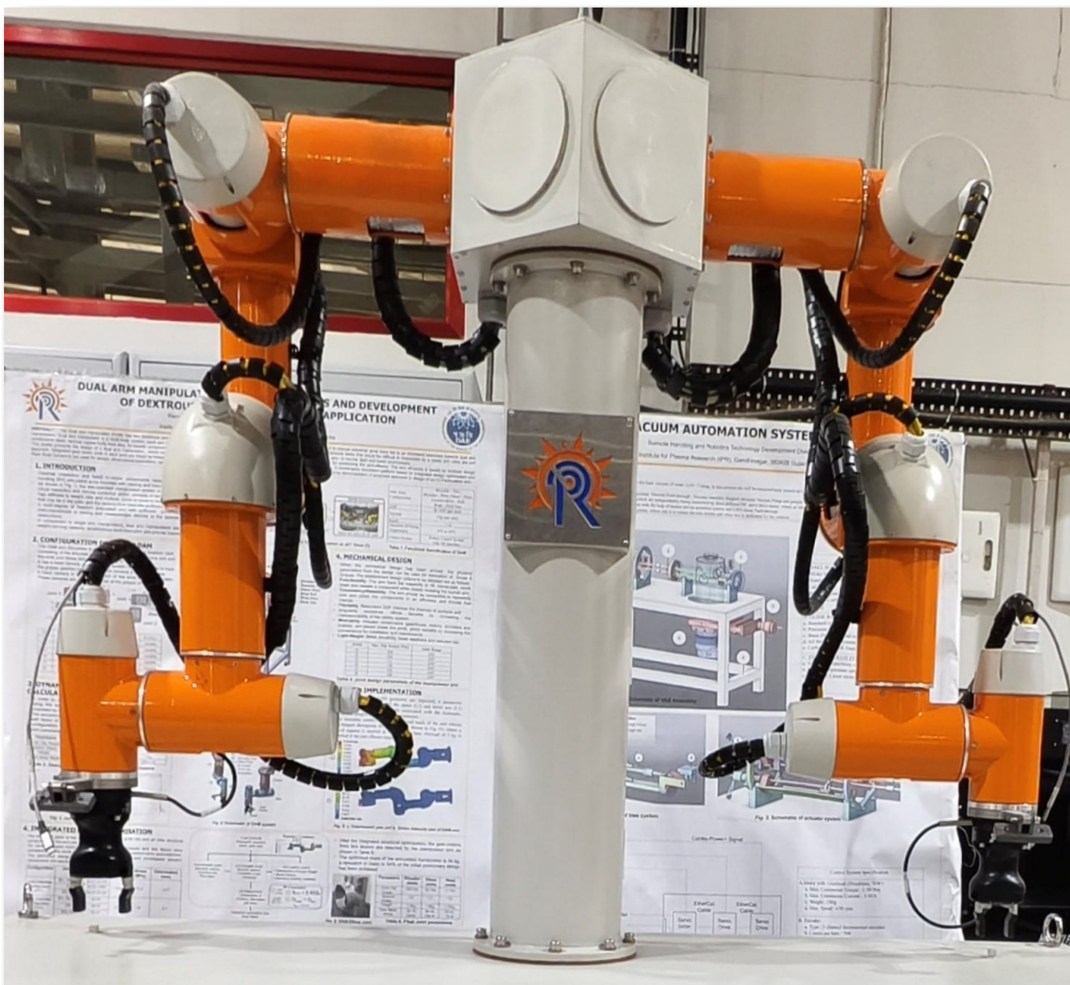

प्लाज़्मा अनुसंधान संस्थान

Institute for Plasma Research

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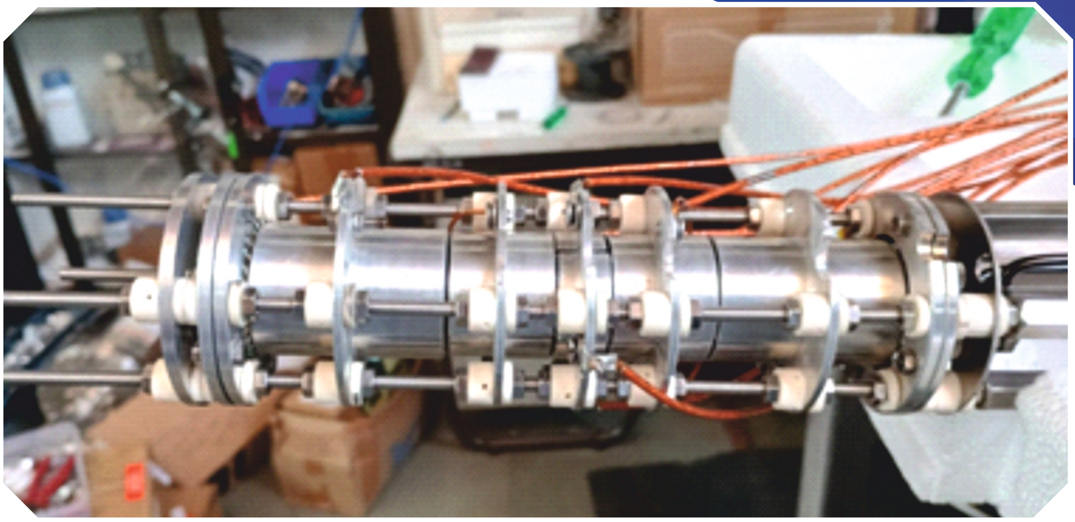
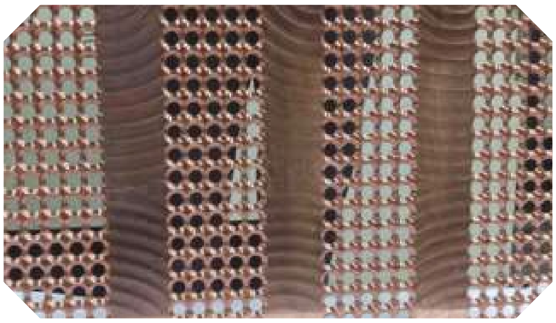


पाँच संकेंद्रित बेलनाकार रिंग इलेक्ट्रोड, ग्रिड और फिलामेंट से निर्मित रेखीय बेलनाकार पेनिंग-माल्मबर्ग ट्रैप

Linear cylindrical Penning – Malmberg Trap made up of five concentric cylindrical ring electrodes, grids and filament



स्वदेश निर्मित इलेक्ट्रो - डिपोज़िटेड ईटर डीएनबी - प्रकार का ग्रिड प्लेट

Indigenously manufactured electro-deposited ITER DNB-type grid plate

स्वदेश विकसित ईसीआर प्लाज़्मा स्रोत

Indigenously developed ECR plasma source

एफसीआईपीटी परिसर में 5 टन प्रति दिन क्षमता वाला रौद्र™ संयंत्र

5 TPD RAUDRA™ Plant at FCIPT Campus

सीपीपी-आईपीआर में विकसित जड़त्वीय विद्युत-स्थैतिक परिरोधन संलयन (आईईसीएफ) आधारित न्यूट्रॉन स्रोत

Inertial Electrostatic Confinement Fusion (IECF) based neutron source developed at CPP-IPR

डुअल आर्म मैनिपुलेटर (डीएएम) : पात्र के अंदर रिमोट हैंडलिंग कार्यों के लिए विकसित किया गया दो भुजाओं वाला एक रोबोटिक मैनिपुलेटर

Dual Arm Manipulator (DAM) developed for in-vessel remote handling tasks

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प्लाज़्मा अनुसंधान संस्थान

Institute for **Plasma Research**

भाट, गांधीनगर / BHAT, GANDHINAGAR–382428

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EXECUTIVE SUMMARY

The Institute for Plasma Research (IPR) is an aided institute of the Department of Atomic Energy, which is primarily focused on R&D activities in the field of plasma and fusion research, spanning the research domain of tokamak development and operation fusion technology development, basic experimental / theoretical / computational plasma sciences, and plasma-based applications. The only two tokamaks in the country today namely Aditya-U and SST-1 are in IPR. National collaborations within universities/institutes, other DAE units and industries as well as international collaborations with mega-science projects – ITER and LIGO – are an integral part of the research engagements of the Institute. In addition to the above, IPR, which is a constituent unit of HBNI, has continued its PhD program which is primarily aimed at producing cutting edge research output in the field of plasma physics and technologies.

In the area of Tokamak research, numerous experiments with hydrogen (**H_2**) and deuterium (**D_2**) discharges in Aditya-U have been carried. The installation of a Passive Active Multi-junction antenna for Lower Hybrid Current Drive (LHCD) is an important addition to the existing systems at Aditya-U, enabling us to explore possibilities of longer plasma operations at Aditya-U. Energy confinement time reached a maximum of 11 ms in **D_2** plasmas, about 1.5 times higher than in **H_2**, showing good agreement with neo-Alcator and ITER-89P L-mode scaling. Vertical position control coils were upgraded to copper-based poloidal field coils with double-pancake windings, supporting up to 5 kA and reducing power consumption by four-fold. Horizontal plasma control was improved via a Compact-RIO PID feedback system, allowing ~400 ms long discharges and precise parameter tuning. Key experiments at Aditya-U included: impurity seeding (Ne/Ar) enhancing edge toroidal rotation by 5–15 km/s, Electron Cyclotron Resonance Heating at 42 GHz demonstrating improved plasma performance, and Runaway Electron (RE) mitigation using Local Vertical Field perturbations achieving up to 90% RE de-confinement, supported by PARTICLE-3D numerical simulations. High-power LHCD and circulator components were tested up to 140 kW, with further improvements ongoing. At the SST-1 Tokamak, to control plasma-wall interactions, impurity accumulation, and plasma burn-through an Ion Cyclotron Resonance system operating at 35–65 MHz for wall conditioning systems was developed and integrated. Experiments achieved neutral breakdown and sustained plasma for short and long pulses ~50 seconds at less than 30 kW, monitored using spectroscopy, fast cameras, and pressure measurements. To support ECR-based plasma experiments, a 5 kV, 25 A IGBT series switch was developed enhancing the performance of a 1 kW, 2.45 MHz magnetron requiring −4.2 kV, 1 A DC bias in continuous and pulsed modes. The Transmission Line Phase Shifter (TL-PS) for the ICRH system provided variable phase shift from 50° to 110° within 40–60 MHz, maintaining Voltage Standing Wave Ratio below 1.2 and return loss better than 25 dB. Cryogenic operations revealed excessive heat loads at 4.5 K, approximately five times higher than the designed value, affecting PF and TF coil cooling. These aspects are now being addressed and several refurbishment measures are being planned. Further, a new indigenous steady-state tokamak SST-Bharat is now being designed, thereby bridging the gap between current experimental devices and future commercial reactors such as DEMO. SST-Bharat builds upon the technological foundation established by Aditya-U and SST-1, and will integrate the knowledge gained from India’s participation in ITER.

In the area of fusion technologies, significant progress has been made indigenously. These are: (a) high-temperature and low-temperature superconducting (HTS, LTS) magnet development, including fabrication and testing of D-shaped HTS magnets (dimensions of 1.1 m and 0.7 m) and NbTi Cable-In-Conduit Conductors for high current applications (completed by IPR and Atomic Fuel Division of BARC); (b) High Heat Flux Test

Facility experiments with copper and tungsten mock-ups, including Tungsten Fiber Tungsten Composite (W/Wf) material development as part of the MoU between IPR and ARCI (Hyderabad) reporting fracture toughness values 4.2 MPa√m for pure tungsten and 5.9 MPa√m for W/W_f composite with uncoated fibers. The fracture toughness was the highest with a value of 12.1 MPa√m for W/W_f composite with Erbium Oxide coated fibers along with thermal successful analyses; (c) Fusion Blanket Technologies including engineering of liquid metal loops (Sn-Li, Pb-16Li), lithium injectors, cold traps, and MHD experiments were carried out, along with thermal conductivity measurements and chemical compatibility studies for breeder materials; (d) Large Volume Cryogenic systems, including the helium refrigerator-cum-liquefier, turbine subassembly (1 kW, 1.6 lakh RPM), and HTS magnet cooling loops are made operational along with a new 65 K pressurized helium circulation system being built for HTS magnet and cryopump cooling; (e) Robotic systems for inspection and maintenance, including dual-arm manipulators, hyper-redundant inspection systems, and vacuum automation have been developed and tested; (f) Negative ion sources (TWIN and ROBIN) reported hydrogen plasma at low pressures, high current neutral beams, and automated control via DACS as well as plasma modeling of ROBIN with COMSOL; (g) Neutronics studies included irradiation tests on electronics, medical radioisotope production (Mo-99, Cu-64, Cu-67), reaction cross-section measurements, and neutron radiography system development with optimized imaging parameters.

In the domain of Fundamental Experimental Plasma Physics several experiments were reported: (a) In Large Volume Plasma Device (LVPD) electromagnetic waves (~50 kHz) were excited using a loop antenna and detected with a 3-axis magnet probe, Helmholtz coils enable magnetic null (~0 G), aligned (+20 G), and anti-aligned (−20 G) configurations, revealing wave deviations and high-frequency modes (~150 kHz), magnetic mirror fields were produced using shaped solenoids with diagnostics and simulations mimicking the Earth-like fields; (b) In Non-Neutral Plasma Device SMARTEX-C, charge collector diagnostics reported stored electron charge upto 30s, plasma temperature (3–6 eV); (c) Applied Plasma Physics Experiments (APPEL) enabled plasma–material interaction and tokamak-relevant studies, generating 0.4 T magnetic fields and helium plasmas (density ~ 10^{17}–10^{18} m^{-3}) along with validation of an m = 0 spiral antenna for RF pre-ionization with a 20 kV coaxial plasma gun for compact toroid injection and transient plasma experiments; (d) A Large Area Plasma Source (LAPS) with capacitively coupled plasma provided uniform coating/etching; (e) Triple-grid Inertial Electrostatic Confinement (IECF) simulations predicted improved ion confinement and longer ion lifetimes; (f) Hydrogen plasma exposure on tungsten (0.205–0.224 MJ/m²) caused blisters, cracks, and residual stress, relevant to mitigated ELMs; (g) Negative hydrogen ions (~2.17 mA) were extracted using Cs-coated tungsten dust; (h) One-dimensional γ-WO_3 nanotendrils and WO_3 nanoparticles produced via He^+ irradiation or plasma electrolysis showed high porosity and photocatalytic activity; (i) Plasma-water interaction in dielectric barrier discharge efficiently generated NH_4^+ (~34 mM) at low energy cost (~0.0054 MJ/mol); (j) Inverse Mirror Plasma Experiment Device (IMPED) produced uniform 2.2 m plasma columns, exciting drift, Rayleigh-Taylor, and Kelvin-Helmholtz instabilities with observed zonal flows and streamers, and (k) High-power microwave experiments (SYMPLE) on over-dense plasma measured fractional absorption consistent with Denisov-like theory.

Extensive theoretical and computational plasma physics research was performed using the ANTYA facility, covering nonlinear plasma phenomena, tokamak and fusion reactor studies, fundamental plasma studies, laser plasma interactions, and dusty/complex plasmas. Artificial Intelligence and Machine Learning methodologies were employed to create DeepCXR software and a Plasma Equilibrium surrogate model for digital twin Tokamak.

In the case of Plasma Based Technologies and Applications, studies funded under DAE projects demonstrated sensitive detection of food adulterant dyes using Surface-Enhanced Raman Spectroscopy (SERS) on nano-rippled silicon and glass substrates coated with silver nanoparticles. Molecules such as Crystal Violet, Rhodamine B, Erythrosine B, Metanil Yellow, and Sudan dyes were detected at concentrations as low as 10^{-7} Moles/litre. Reactive Molecular Dynamics simulations were employed to understand the degradation of the fungicide Carbendazim by Cold Atmospheric Plasma, revealing mechanisms such as hydrogen abstraction, oxidation, and decarbonylation that reduce CBZ toxicity. Copper and copper oxide coatings on polypropylene fabrics were deposited via magnetron sputtering, demonstrating a 4-log reduction of Gram-positive bacteria. The RAUDRA Plasma Pyrolysis plant was successfully tested for biomedical waste treatment, with integration of primary/secondary chambers and gas cleaning systems. Agreements with startups support commercialization for waste-to-energy applications and plasma-activated water for agriculture and dairy. A high-power Helicon Plasma Thruster system was developed for deep-space propulsion, achieving thrust of 5–230 mN with 1–5 kW RF power and 1200 G magnetic field. Integrated automation and control systems using PLC and LabVIEW SCADA enabled coordinated operation. Plasma-based panels for microwave absorption were tested, demonstrating 50–80% absorption of incident power and confirming feasibility for radar signature reduction.

IPR has also been actively participating in two major international mega science projects: ITER and LIGO. ITER-India, which is the domestic agency involved in the collaboration with ITER organization in France, has delivered in-kind components for ITER, including the Cryostat, Torus Cryo-Pump Housing, Cryo-distribution and Cryolines system, and In-wall shielding blocks. Cooling water and cryogenic systems were commissioned, and the Heat Rejection System was made fully operational. Diagnostic Neutral Beam, ICRH, and ECRH systems underwent prototype testing, power supply development, and factory acceptance tests. High-power RF sources, amplifiers, and power supply systems achieved key performance milestones. Integrated Modelling & Analysis Suite (IMAS) was installed and tested on ANTYA cluster facility, INDUCT code adapted and validated, and a free-boundary Grad–Shafranov solver developed. ITER-India's data center was upgraded to Hyper-Converged Infrastructure with enhanced cyber security. Capacity building included CATIA, SEE System Design, and ENOVIA DESA certification. Over 12,000 documents have been archived supporting R&D and prototyping for divertors, blankets, and remote handling. The LI-VISTA facility was established at LIGO Laboratory to validate vacuum system components, achieve ultra-high vacuum ($<1 \times 10^{-9}$ mbar), assess vessel bake-out performance, test gate valve operation, and evaluate cryopump efficiency, providing critical data for LIGO-India vacuum infrastructure.

Technology innovation and its transfer to the Indian industry have been one of the focus areas of IPR through its incubator AIC Plasmatech. AIC Plasmatech is a Section 8 company under DAE, and has supported plasma and allied technology start-ups. Eight start-ups have been incubated and six technology transfer agreements executed with Indian companies/startups. AIC Plasmatech has also hosted colloquia, talks, and training with HBNI Innovation Council to promote start-up awareness and knowledge dissemination.

Additionally, outreach activities continued to cover a large spectrum of schools, colleges, and institutes, including teachers training programs.

DIRECTOR
IPR

ANNUAL REPORT

APRIL 2024 TO MARCH 2025

Considering fusion as an alternative source of energy, the Institute had initiated a programme to study magnetically confined high temperature plasmas in 1984 and built India's first tokamak ADITYA in 1989. Nearly a decade later a steady state tokamak, SST-1 using superconducting magnets is also constructed. Since the inception, the institute has been involved not only on fusion plasma R&D activities but also various plasma physics related fundamental research and its technology developments to address many industrial and societal challenges. To meet large scale computer based design and analysis requirements a High Performance Computing (HPC) facility along with a high capacity GPU cluster has also been established capable of handling 100kW of IT load. Over these years, the institute has trained a large number of man power to pave the way to reach India's "Self-reliant/Atmanirbhar - Vikshit Bharat" goal in the field of plasma science, technology and fusion power. Institute is involved in two international mega science projects, ITER and LIGO; where highly advanced state-of-the-art devices/components to be delivered as in-kind contributions. Many of such technologically challenging items are already delivered successfully. Institute is internationally recognized for its contributions to fundamental as well as applied research in plasma physics and associated technologies.

CHAPTERS

CHAPTER A

SUMMARY OF SCIENTIFIC & TECHNICAL PROGRAMMES

A1. Tokamak R&D and Experiments

Standard discharges of plasma current of ~ 120 kA, duration 300 ms at toroidal magnetic field of ~1.28 T are continued to be achieved in ADITYA-U. Several new diagnostics systems were also commissioned in ADITYA-U including the soft x-ray crystal spectrometer, neutral particle analyzer etc. In SST-1, a new 80K phase separator was setup for cryo-absorber. The following section describes the major developments. Apart from these, design of SST Bharat has also been initiated.

A1.1 ADITYA-Upgrade Tokamak

Following the installation of a Passive Active Multi -junction (PAM) antenna at Radial Port No. 5 for the Lower Hybrid Current Drive (LHCD) system in ADITYA-U, plasma operations utilizing Hydrogen and Deuterium fuel have been conducted. A total of nearly 756 discharges were achieved, providing a range of parameters for various experiments in ADITYA-U. The plasma operations were concluded at the end of January 2025, after which the existing vertical position control coils (BCC) were replaced with new poloidal field coils.

<u>Global Energy Confinement Time (τ_E) Studies for ADITYA-U Discharges:</u> ADITYA-U has achieved notable advancements in the analysis of the energy confinement time (τ_E) in D_2 fuelled discharges. The main objective of this experiment is to improve (τ_E) by utilizing the isotope effect, in comparison to H_2 discharges with similar operational parameters. The scaling of τ_E with density is a critical factor for the advancement of tokamak devices aimed at achieving fusion. An investigation was performed on the relationship between τ_E and density for H_2 and D_2 fuel-assisted discharges in ADITYA-U. To gain insights into the operational limitations of tokomaks with varying parameters, the neo-ALCATOR scaling law was formulated based on plasma discharges from multiple tokamaks. This law is applicable to Ohmically heated plasma discharges at low density ($n_e < 3 \times 10^{19}$ m^{-3}). A comparison between the experimentally measured τ_E and the (τ_E) predicted by the neo-ALCATOR scaling law demonstrates a satisfactory correlation for the Ohmic discharges observed in ADITYA-U data. For high-density ($n_e > 3 \times 10^{19}$ m^{-3}) scenarios, the ITER-89P L-mode confinement scaling law provides the necessary τ_E scaling. Figures A.1.1a and A.1.1b illustrate the comparison of the experimentally determined τ_E for H_2 and D_2 discharges in ADITYA-U, plotted against density (n_e). The τ_E values are derived from actual measurements of density and temperature, taking into account the total Ohmic heating power (P_Ω), after subtracting the radiated power measured using Bolometer, as well as from diamagnetic measurements of stored energy. In contrast, figures A.1.1c and A.1.1d present a comparison between the experimental and the τ_E values obtained through neo-Alcator scaling, also as a function of density (n_e) for the H_2 and D_2 discharges in ADITYA-U. The maximum experimental τ_E in H_2 plasmas in figure A.1.1a is *6.5 ms*, whereas, the maximum experimental τ_E in D_2 plasmas in figure A.1.1b is 11 ms. The maximum value of τ_E estimated through neo-ALCATOR scaling for H_2 plasmas is *7.6 ms* as shown in figure A.1.1c, whereas the τ_E estimated through neo-ALCATOR scaling for D_2 plasmas in figure A.1.1d is 12.5 ms. The analysis depicted in figures A.1.1c for H_2 -assisted discharges indicates that the neo-ALCATOR scaling demonstrated superior τ_E values in comparison to the experimental τ_E values. Whereas, in figures A.1.1d for D_2 assisted discharges indicates that the experimentally obtained τ_E aligns closely with the τ_E values obtained through neo-ALCATOR scaling.

A comparison of the experimentally determined τ_E as a function of electron density (n_e) for D_2 and H_2 -assisted Ohmic discharges in ADITYA-U is presented in figure A.1.2a. In contrast, figure A.1.2b displays the comparison of τ_E values estimated using the ITER-89P L-mode confinement scaling as a function of line-averaged density for both H_2 and D_2 fuels.

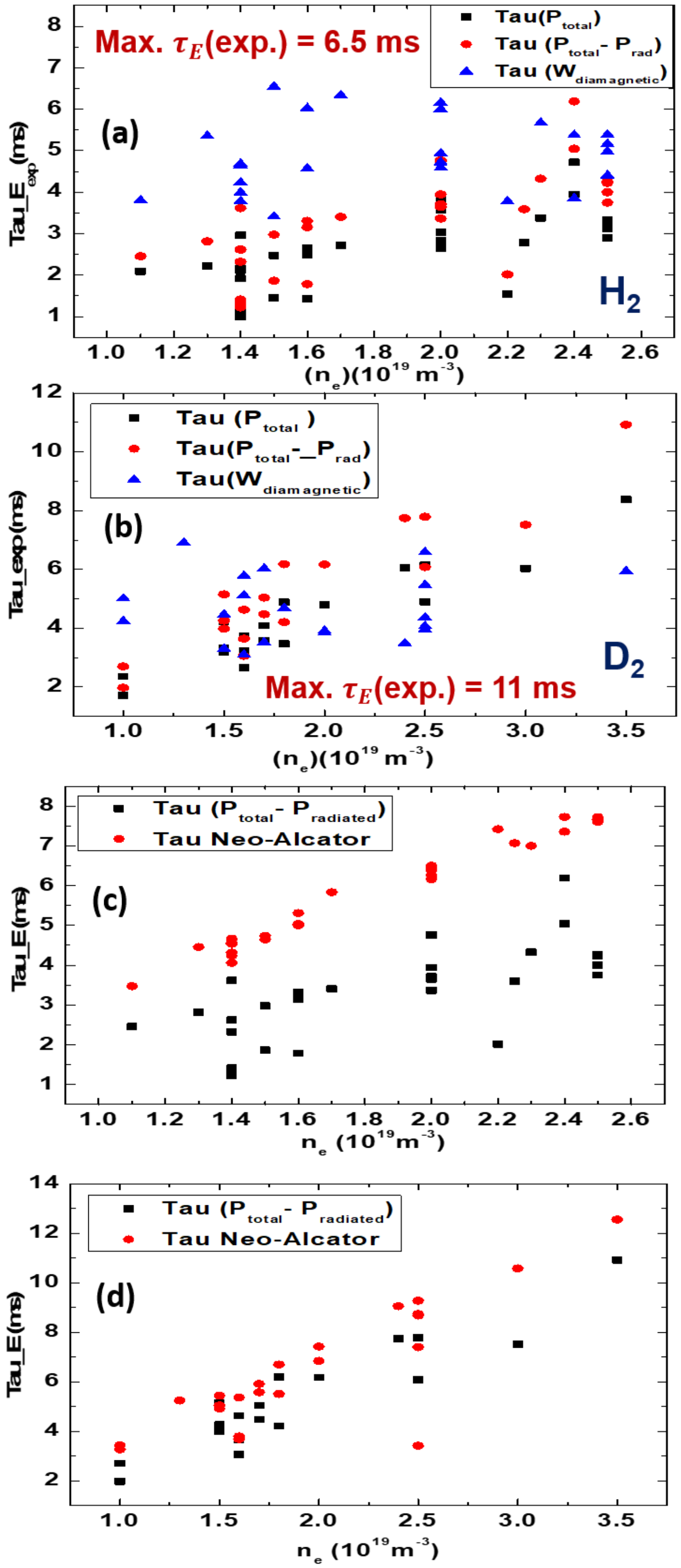


Figure A.1.1: The estimation of τ_E for Ohmically heated ADITYA-U discharges include, (a) τ_E experimental versus density (n_e) with P_{total}, with P_{total} - P_{rad} and with W_{dia} for (a) H_2 and (b) D_2 plasmas, and comparison of τ_E expt. (P_{total} - P_{rad}) and neo-ALCATOR scaling versus density (n_e) for (c) H_2, and (d) D_2 discharges.

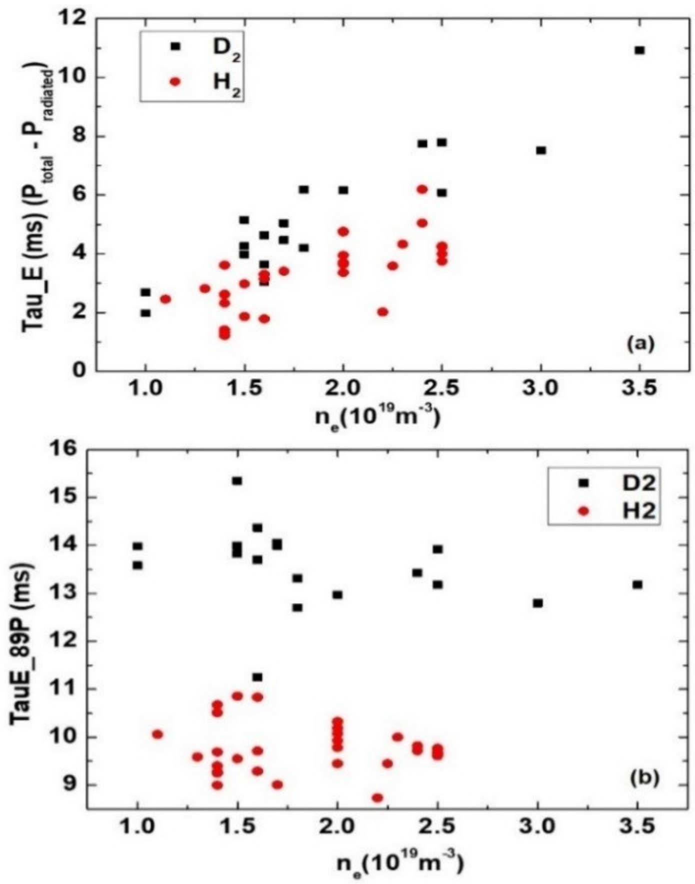


Figure A.1.2: The τ_E scaling related to line average density for H_2 and D_2 Ohmic discharges in ADITYA-U: (a) τ_E experimental, and (b) τ_E according to ITER -89P L-mode confinement scaling law.

The figures indicate that the maximum energy confinement time was achieved in the D_2 discharges of ADITYA-U. When the experimentally obtained τ_E was compared with the neo-Alcator scaling for H_2 and D_2 discharges, a strong correlation was observed. The estimation of τ_E through various scaling laws, including, τ_{Eexp}, $\tau_{Eexp} - \tau_{prad}$, τ_{EWdia} , and ITER-89P L-mode showed a confinement enhancement of ~1.5 times in D_2 plasmas relative to H_2 plasmas.

Real Time Vertical Position Estimation of Plasma Column Using Fast Imaging: Assessing plasma movement is crucial for maintaining equilibrium in a tokomak. Magnetic signals are promising for estimating plasma centroid in real-time, but during formation and ramp-down, plasma current causes transient events that disrupt these diagnostics. Moreover, magnetic diagnostics, positioned close to the plasma, struggle to operate effectively over time in the harsh tokamak environment. Therefore, establishing this optical method as a complementary approach for real -time plasma position detection is beneficial. In ADITYA-U, plasma discharges are recorded using a high-speed camera at 5000 FPS, capturing 504 x 504 pixel frames. The camera operates in triggered mode, and the data is post-processed for complete recording downloads. Sensitive to radiation from 400 nm to 700 nm, it captures visible radiation from the plasma column, especially its periphery, in a wide-angle view.

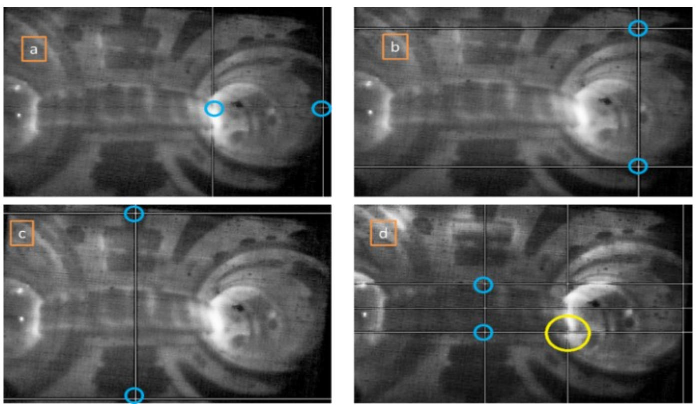


Figure A.1.3: Choosing pixel positions on the recorded frame, shown by intersecting perpendicular lines.

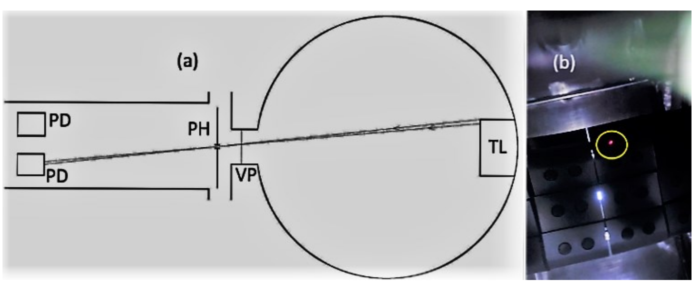


Figure A.1.4: Schematic ray diagram of detector system (a). Deciding location of interest for light collection by back-lighting the pin-hole (b).

The images are analysed to track the plasma's vertical and horizontal movements, identifying specific locations in the vacuum vessel with adequate radiation for tracing the plasma's position. Figure A.1.3 shows the plasma view from the fast camera, with four subplots displaying pixel pairs and their intensity profiles over time to determine plasma movement. Sets (a) and (d) are the best pixel pairs for estimating horizontal and vertical movements, respectively. Using this concept, an optical system based on a photodiode (PD) has been designed, developed, and installed on the tokamak to capture the visible radiation from these areas, as illustrated in figure A.1.3d. The system's schematics are presented in figure A.1.4. The gathered light is subsequently sent to a suitable electronic circuit for the algebraic processing of the signals, and the position signal for the vertical movement of plasma is obtained in the data acquisition system (DAQ). Figure A.1.5 presents findings for standard ADITYA-U discharge #36821. The second panel compiles estimated horizontal positions from the Cosine coil, flux loops, H-alpha measurements, and selected pixel intensities from the fast camera (Figure A.1.3a). The first three methods are well-established in ADITYA-U and are used regularly. The fast camera's consistent measurements validate the post-processing technique. The third panel of figure A.1.5 details the vertical displacement of plasma using the Sine coil, selected pixel intensities from the camera (Figure A.1.3d), and a new real-time photodiode-based optical system. The results during the plasma flat-top confirm the reliability of this new technique. The final estimates show a maximum uncertainty of 7% and have proven effective across various plasma discharges.

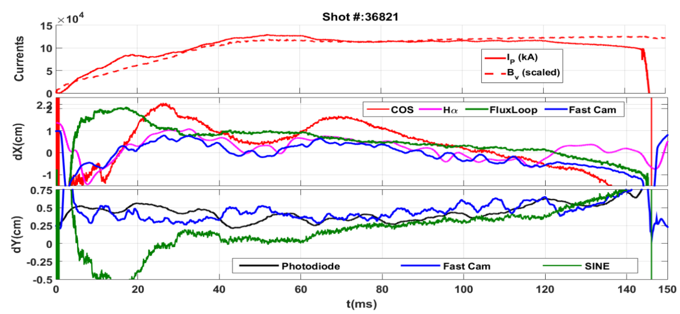


Figure A.1.5: Time traces of currents, horizontal and vertical positions are shown from top to bottom panels.

<u>Upgrade of Existing Vertical Position Control Coils (BCC) with New Poloidal Field Coils:</u> The transformation of the existing correction coil system is a critical step toward enhancing the operational performance of the ADITYA-U tokamak. The redesigned coil system incorporates several optimized parameters, including the feasibility of the coil layout, mechanical handling, alignment tolerances, and the performance of high-current conductors. To meet these requirements, new copper-based correction coils utilizing Continuous Transposed Conductor (CTC) technology have been developed and installed. These coils are designed to withstand higher electromagnetic forces compared to the previous flexible conductor based correction coils (BCC). The upgraded design involves decommissioning the existing coils and implementing a joint-free, double-pancake winding configuration, as illustrated in figure A.1.6. Each double pancake consists of two layers of windings stacked together and electrically connected to form a

complete winding pack. The new coils were integrated within the existing ADITYA-U structural framework with high precision, without the need for dismantling major subsystems. A total of four coil sets have been successfully installed in the ADITYA-U tokamak, with each set capable of functioning at a maximum current of 5 kA.

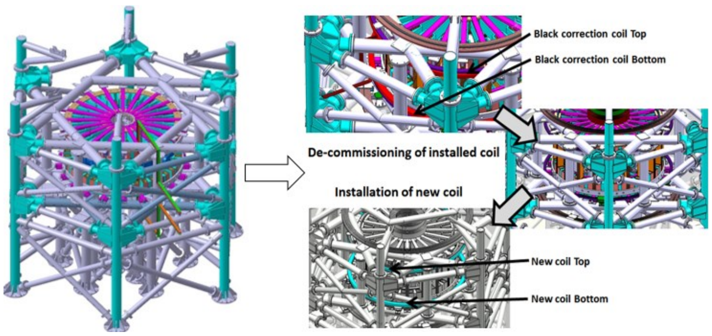


Figure A.1.6: Schematic of upgrading existing vertical position control coils (BCC) with new poloidal field coils.

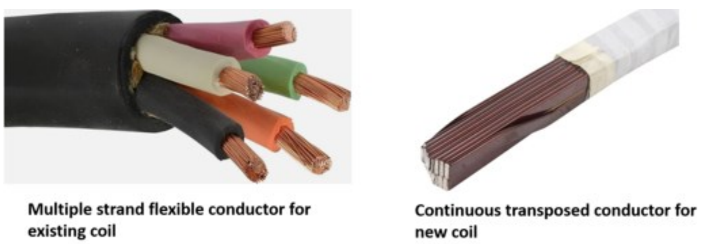


Figure A.1.7. Comparison of conductor configuration for the existing and new poloidal field coils winding.

The environment for coil installation poses considerable challenges regarding spatial limitations and thermal requirements for coil curing. Nevertheless, these conditions are suitable for the application of organic insulating materials and traditional coil manufacturing methods. To maintain stability during high current operations, the coil design incorporates multiple transposed strands arranged in parallel, which helps to alleviate the electromagnetic instabilities commonly linked to non-transposed, monolithic conductor designs. Various conductor configurations that were evaluated during the design process are depicted in figure A.1.7. The effective execution of this design strategy was supported by the technical knowledge and established capabilities of current industrial partners. A significant benefit of the chosen coil concept is its remarkable adaptability, which enables effortless transitions between various coil formations utilizing the same fabrication and installation infrastructure, all while preserving the integrity and performance of the overall coil system.

The strong magnetic coupling in the coil significantly impacts the system's electromagnetic characteristics, especially during high-current operations. Therefore, the coil assembly was rigorously tested for high-voltage insulation and high-current performance before being used in the ADITYA-U plasma discharges. The magnetic coil was successfully connected to the high-current power supply and maintained stable performance under specified electrical and thermal loads during experiments. Notably, the new coil configuration reduced total power consumption by four times compared to the previous system, enhancing overall efficiency.

<u>Improved Horizontal Plasma Position Control Using c-RIO Based Real-time System:</u> Real-time techniques are crucial in tokamaks to stabilize plasma position and achieve longer discharges. ADITYA-U uses real-time feedback control of the equilibrium field to stabilize horizontal plasma position and improve plasma parameters. This innovative control system, developed using the NI-PXI-7831R card in a PXI chassis, featured an integrated PID controller. The PID controller generates control signals for the fast-feedback coils, resulting in successful control of horizontal plasma position.

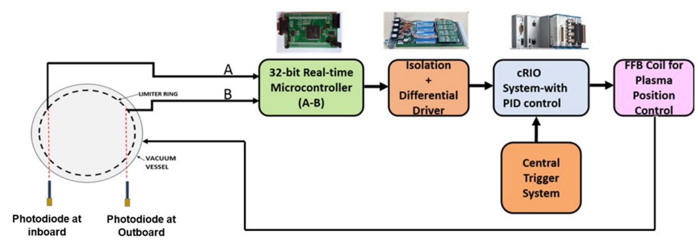


Figure A.1.8: Interconnection of various systems for horizontal plasma position control in ADITYA-U.

However, the initial control system had some limitations. Therefore, it was upgraded using the CompactRIO (c-RIO), for better control and flexibility in adjusting PID parameters. The upgraded system allows longer durations discharge of ~ 400 ms and improved data retrieval capabilities using NI 9147 c-RIO embedded chassis with latest-generation Zynq-7020 FPGA for implementing all the control applications. It is a 4-slot rugged chassis that can add any C-series IO modules. The PID controller parameters are set through a graphical user interface on a Zynq-7020 FPGA. Testing was performed using the power supply for the fast feedback coil in plasma position control in ADITYA-U to determine practical parameter values and assess time response. Figure A.1.8

illustrates the interconnection of the systems involved in position control.

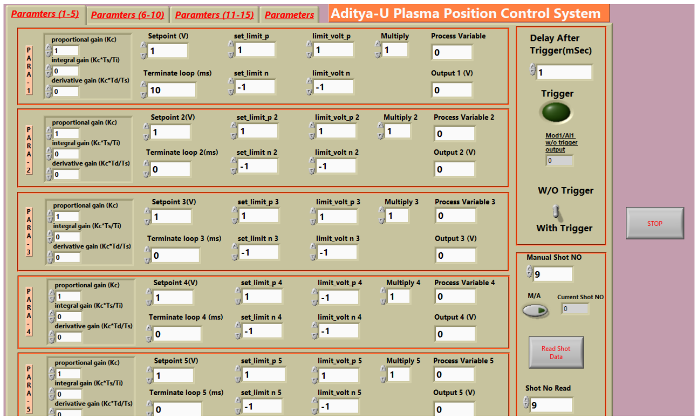


Figure A.1.9: Front Panel view of the Upgraded System with different parameters setting.

The upgraded design accommodates various time-delays and multiple-parameter settings, resulting in a new LabVIEW-based graphical user interface (GUI) that features a total 20 settings displayed on the front panel, with five settings allocated to each tab for the parameters- P, I, D, Set point voltage and loop-time as shown in figure A.1.9. This approach allows for precise and fine tuning of the parameters without compromising the fast feedback power supply, which otherwise can give abrupt transitions and can itself disturb the plasma.

Other than operational aspects and improvements, ADITYA-U has initiated a series of innovative experiments focused on the critical challenges associated with large-scale fusion-grade devices. These experiments encompass non-inductive current drive using lower hybrid (LH) waves, validation and calibration studies of prototype ITER hard X-ray monitor (HXRM) diagnostic, solid boron powder injection using an inductively driven pellet injector, and effect of impurity seeding on edge toroidal rotation. The results of these pioneering experiments are highly promising and could significantly influence the operations of future tokamaks.

<u>*LH Current Drive Experiments Using PAM Launcher in ADITYA-U:*</u> Lower Hybrid Current Drive (LHCD) is a crucial high power heating & current drive (H&CD) system in the modern tokamaks which supports long-pulse, steady-state operation while enhancing plasma performance and stability. Following the installation of Passive Active Multi-junction antenna (PAM) in ADITYA-U, initial LHCD experiment in ADITYA-U has been conducted. Prior to initiation of experiment, the direction of plasma current in ADITYA-U has been reversed to achieve better coupling of LH waves with plasmas. The standard Ohmic discharges in reverse plasma current (I_P) direction have been established. In order to prevent negative loop voltage (Inductive voltage) during the LH pulse launch phase, specific arrangements and modifications have been implemented in the OTPS circuits to achieve zero loop voltage after 70 ms duration.

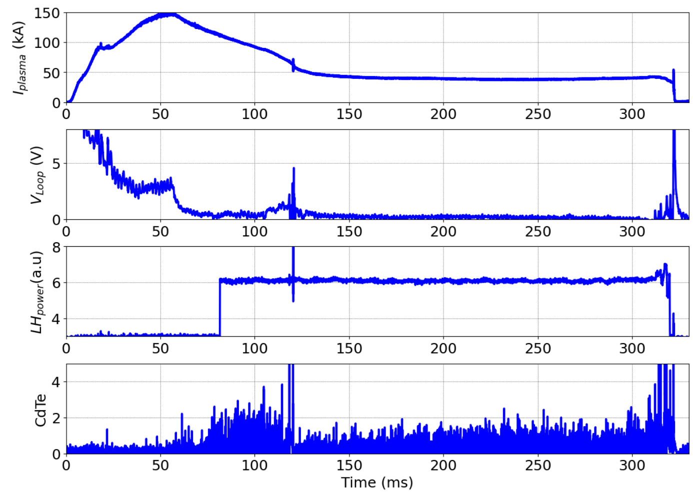


Figure A.1.10: Temporal evolution of (a) Plasma current, (b) Loop voltage, (c) LH power (a.u), and (d) CdTe-HXR signal are shown for the discharge #38781.

During the LHCD experiment (shot #38781), around 100 kW LH power is launched at 3.7 GHz around 80 ms into the discharge with a pulse duration of about 300 ms. During this shot plasma current was sustained for up to 320 ms. In this shot, at around 70 ms, the loop voltage dropped to zero and the plasma current was fully maintained by LH waves. Beyond 70 ms, the loop voltage was maintained at zero by controlling the current in the ohmic power supply ($dI_{OH}(t)/dt \sim 0$)in the positive converter only. A plasma current around 40 kA is sustained up to 320 ms in this discharge. This demonstrate the capability of LHCD to extend the duration of the plasma current in ADITYA-U tokamak. The figure A.1.10 illustrates a recent ADITYA-U LHCD discharge, shows the plasma current, LHCD power, and loop voltage and CdTe signal.

This experimental results on ADITYA-U has significant achievements as for the first time in India, a steady plasma current of approximately 40 kA drives exclusively through lower hybrid waves, without any loop voltage, using a PAM launcher.

Effect of Impurity Seeding on Edge Toroidal Rotation:

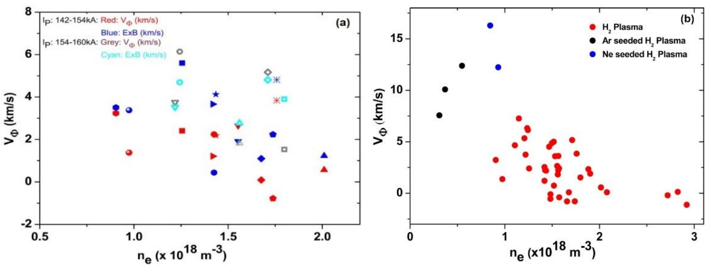


Figure A.1.11. (a) Variation of $E_r \times B_\theta$ flow velocity and edge toroidal rotation velocity as a function of edge density. Simultaneous measurement of V_ϕ and $E_r \times B_\theta$ flow velocity in a discharge is represented by the same symbols in red and blue colors, respectively, for the current range of I_P = 142 – 154 kA and with grey and cyan, respectively, for I_P = 154 – 160 kA. Different symbols represent data from different discharges. (b) Variation of intrinsic rotation with edge density in H_2 plasma (red: without impurity seeding, black: Argon seeded and blue: Neon seeded).

Intrinsic toroidal rotation (V_ϕ) has also been studied explicitly in the edge region of ADITYA-U tokamak as it is well known that the intrinsic toroidal rotation first gets generated in the edge region, and then propagates towards the core. In ADITYA-U, E_r x B_θ drift velocity is found to drive the intrinsic toroidal rotation in the edge region. All the results discussed in this section are having the following plasma parameters: B_T = *1.28 T* (at *R = 75 cm*), reservoir pressure = *2.2 Bar*, central chord-weighted electron density: $n_e \sim 1\text{-}3 \times 10^{19}\ m^{-3}$, central electron temperature: $T_e \sim$ *500—1000 eV*, edge electron density: $n_e \sim 0.5\text{—}3 \times 10^{18}\ m^{-3}$, while the plasma current (I_P) varies between *~120—170 kA*. In the edge region, the presence of radial electric field (E_r) gives rise to the E_r x B_θ flow. This E_r is related to the toroidal rotation velocity V_ϕ as given below:

$$E_r = V_\phi B_\theta - V_\theta B_\phi + (\Delta P / n_e Z) \quad (1)$$

As shown in figure A.1.11a, simultaneous measurements of $E_r \times B_\theta$ drift velocity (using rake Langmuir probe) and edge toroidal rotation V_ϕ (using spectroscopic measurements) at different edge densities, in a purely Hydrogen plasma, suggests that $E_r \times B_\theta$ flows are responsible for generating the intrinsic toroidal rotation in the edge region of ADITYA-U tokamak, indicating that the contributions from the second and the third term on the RHS of equation 1, are negligible. Interestingly, V_ϕ is observed to damp with increase in the edge density. Further, as shown in figure A.1.11b, edge V_ϕ is seen to enhance significantly by ~ 5-15 km/s after neon and argon (medium-Z impurity) seeding inside the Hydrogen plasma, while the edge electron density decreases, as the electrons are consumed in ionizing the injected impurities.

In purely Hydrogen discharges (without impurity seeding) having low plasma current, I_P ~ 120—145 kA, edge V_ϕ is observed to remain in the counter-current direction. This counter-current rotation reverses to co-current direction when the I_P is increased beyond 150 kA. As shown in figure A.1.12a, injecting neon and argon in these discharges enhances the edge rotation V_ϕ in the co-current direction at the same value of plasma current. Impurity seeding seems to provide an external torque to the edge plasma in the toroidal direction which is responsible for this enhancement in the edge toroidal rotation.

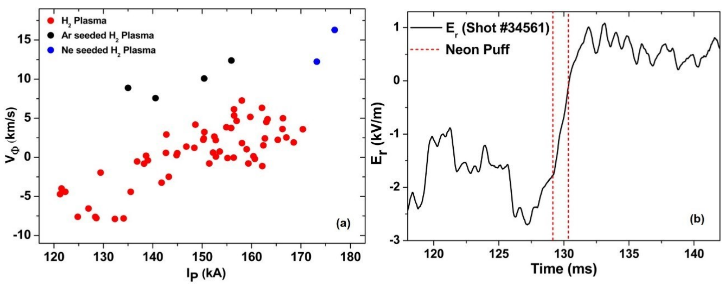


Figure A.1.12. (a) Variation of intrinsic toroidal rotation velocity with I_p in H_2 plasma (red: without impurity seeding, black: argon seeded and blue: neon seeded) (b) Drastic changes observed in E_r (measured at $\rho \sim 0.99$) after neon seeding.

The physical mechanism behind the observed enhancement in the edge V_ϕ can be understood from observation shown in figure A.1.12b. As shown in figure A.1.12b, there is a significant rise in the edge radial electric field, E_r by *~ 1-2 kV/m* , which is capable to enhance the E_r/B_θ flow by *10-20 km/s* in the co-current direction (as $B_\theta \sim$ *0.1 T* in edge region of ADITYA-U).

In addition to experimental advancements, the simulation and modeling of ADITYA-U experiments have been conducted concurrently to deepen the understanding of the underlying physics, which is crucial for improving the precision of predictions related to the performance of fusion reactors. As part of the ongoing experimental efforts on mitigating Runaway Electrons (RE) through local vertical field (LVF) perturbation in ADITYA-U, simulation studies regarding de-confinement in ADITYA tokamak discharges have been conducted.

Numerical Modeling of LVF Assisted REs Deconfinement: Runaway electrons (RE) are relativistic particles ($> MeV$) that emerge during disruptions or intense heating and threaten plasma-facing components in devices from small tokamaks to ITER. Active magnetic techniques, notably resonant magnetic perturbations (RMPs) and local vertical-field (LVF) perturbations, offer a complement path; RMPs have shown mixed success on large machines, whereas LVF experiments are so far confined to VERSATOR -I and ADITYA.

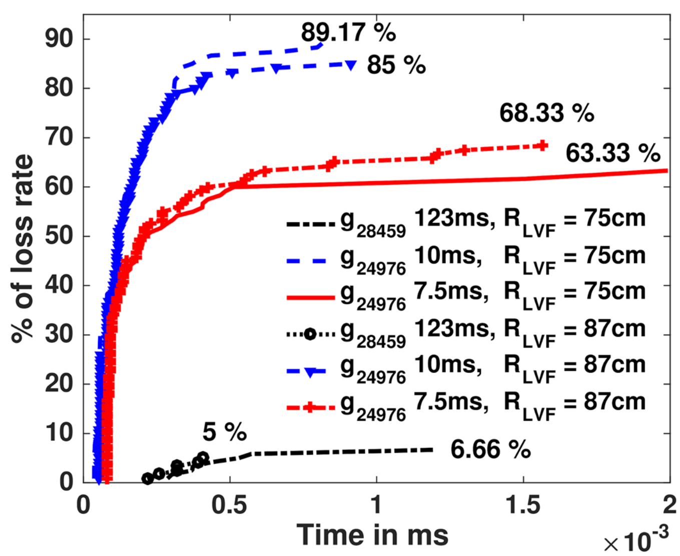


Figure A.1.13: Loss fraction study of 3 MeV REs with negative LVF perturbation generated by 4.3 kA current with two different RLVF positions and for three different plasma equilibrium: shot 24976 at 7.5 ms, shot 24976 at 10 ms and shot 28459 at 123 ms.

In ADITYA, a symmetric pair of Helmholtz-like coils produced *150–260 G* at $R_0 = 0.75\ m$. Applying the LVF during breakdown reduces hard-X-ray emission significantly (*~90%*), without degrading the thermal plasma, demonstrating early-phase RE removal. To interpret these results, a relativistic full orbit-following code was developed from the PARTICLE framework named PARTICLE-3D (P3D). P3D simulations show that an LVF breaks toroidal symmetry, alters guiding-centre drift orbits and can either shrink or expand the RE confinement zone depending on LVF field direction. Positive LVF broadens confinement on the inboard side, whereas negative LVF contracts it, directly expelling edge-born REs ($\Psi_N > 0.7$). The required LVF perturbation strength rises with the energy of the REs.

Further simulation results presented in figure A.1.13, for RE loss fraction studies depicting deconfinement up to 90% of REs in different phases of plasma operation were achieved in agreement with experimental observations from ADITYA tokamak. The study also reveals a strong correlation between the safety factor (q) profile at the plasma edge and the effectiveness of RE deconfinement. REs originating from the plasma edge (Ψ_N >0.7) were more prone to be lost with LVF perturbations, depending on the q-profile and the direction of the perturbation. These results establish LVF perturbations as a flexible, low-disruption tool for RE management. With appropriate scaling, the technique—combined with existing mitigation systems—could form a viable strategy for larger devices such as ITER and DEMO.

Implementation of UEDGE Code to Investigate the Effect of Convective Transport in Edge and Scrape-off-Layer Plasmas of ADITYA-U Tokamak:

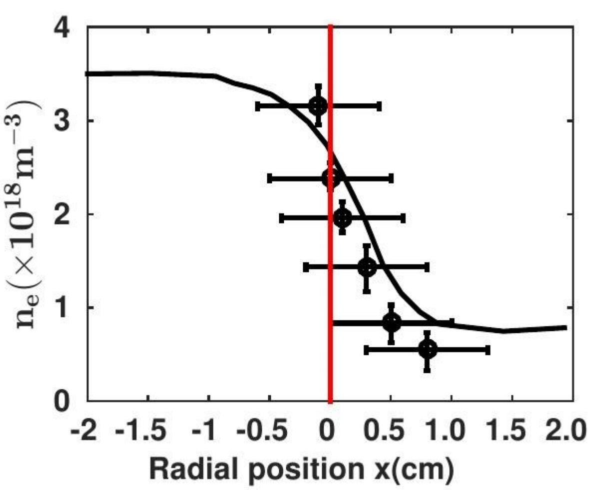


Figure A.1.14: Simulated radial profiles of electron density for diffusion coefficients 0.2 m^2 /s with inward v_{conv} =1.5 m/s. The open circles with error bars are the experimental data for typical discharge of ADITYA-U.

The computational mesh of limiter geometry of ADITYA-U is developed in the UEDGE code through an in-house built routine. It is coupled with the UEDGE code and the measured radial profile of electron density in the edge region is modelled. It is observed that an inward convective velocity, $v_{conv} \sim 1.5\ m/s$ is required in addition to the constant perpendicular diffusion coefficient, $D_{\perp} \sim 0.2\ m^2/s$ to match the measured n_e profile in typical discharges of ADITYA-U. The value of $D_{\perp} \sim 0.2\ m^2/s$ is found to be much less than fluctuation induced diffusivity and lies in-between the estimated neoclassical diffusivity and Bohm diffusivity. Figure A.1.14 shows the simulated radial profile (black solid line) along with the experimental measurements from rake-Langmuir probe.

Investigation of Line Ratio Emitted from Oxygen Ion in ADITYA-U Plasmas Using Spectroscopic Modeling: In the present work, the intensity ratio between two visible spectral lines of the OV ion (650.024 nm and 646.614 nm), corresponding to $1s^2\ 2p$-$1s^2\ 3d$ transitions, is studied in detail. It is found that the experimentally observed line ratio of 650.024 nm and 646.614 nm lines cannot be explained by the conventional corona model. Finally, the collisional-radiative model inside the FAC code is used to explain the experimentally observed line ratio which is around 2. Furthermore, it is also confirmed by the ADAS by evaluating the photon-emissivity coefficients (PEC) from ADAS-208. Figure A.1.15 shows the simulated PEC ratio from FAC code along with the experimental line ratio. Moreover the line ratio is independent of electron temperature.

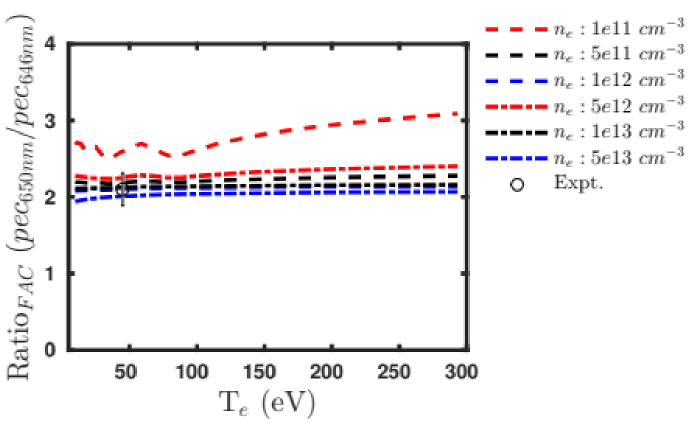


Figure A.1.15: Simulated PEC ratio of 650.024 nm and 646.614 nm. The black circle with error bar represents the experimental line ratio for typical discharge of ADITYA-U.

Lower Hybrid Current Drive System: Initial LH experiments in ADITYA-U with PAM launcher have been done with the plasma current in clockwise direction and the experimental results were encouraging as the plasma current was extended beyond the Ohmic phase. In later stage, LH experiments were carried out while reversing the electric field of the OH system (plasma current in counter clockwise direction) to enhance the current drive performance with the same PAM launcher. Preliminary experiments show encouraging results and further experiments in this direction are underway. The plasma current was sustained for up to 320 ms with the application of lower hybrid waves (LHW). The experiment was carried out with the rf power generation of around 100-120 kW for 300 ms at klystron source end. The recent ADITYA-U shot no. #38781 with the LHCD is shown in figure A.1.16, which shows the result of plasma current, loop voltage and LHCD coupled power. In ADITYA-U, around 70-80kW LHCD power was launched at 3.7 GHz. As shown in figure A.1.16, the LH power was launched at ~80 ms. In this shot, at around 70 ms, the loop voltage dropped nearly to zero and the plasma current was fully maintained by LH waves. This demonstrates the capability of LHCD to extend the duration of the plasma current in ADITYA-U tokamak. Beyond the 70 ms, the loop voltage was maintained nearly to zero by controlling the current in the Ohmic power supply ($dI_{OH}(t)/dt \sim 0$) in the positive converter only. A plasma current around 40kA is sustained up to 320 ms in this discharge.

Along with experimental activities, the regular maintenance of LHCD auxiliary systems was carried out. The LHCD source, namely high-power klystrons were conditioned for both high voltage and high power rf on dummy load for proper functioning. An anode modulator control panel has been developed, tested and integrated with the LHCD anode modulator power supply (AMPS) unit. For the smooth and reliable operation of the LHCD system, a high voltage power supply is required. The maintenance work for the Testing Power Supply (TPS) rated at -70kV, 22A has been carried out. After reviving the power supply, klystron was operated for ADITYA-U LHCD experimental campaign. The calibration for the filament current was carried out while filtering the oil of the klystron tank. The oil filtration work of the AMPS tank has been also carried out. After repair and maintenance of Klystron and AMPS oil tank, standalone low power high voltage test was performed to check the proper functionality of resister bank, Crowbar, AMPS and individual Klystron tube up to -65kV with low power high voltage (LPHV) Tester.

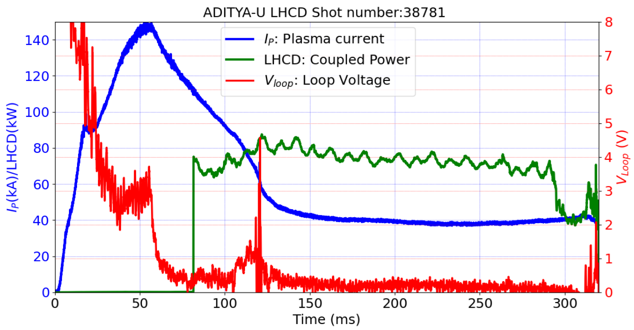


Figure A.1.16: Temporal evolution of (a) Plasma current, (b) Loop voltage and (c) LHCD coupled power are shown for the discharge number-#38781.The plasma current is extended up to 320 ms in a positive converter shot where loop voltage was available up to 70 ms. The maximum duration of such positive converter shots without LHCD pulse is up to ~ 150 ms.

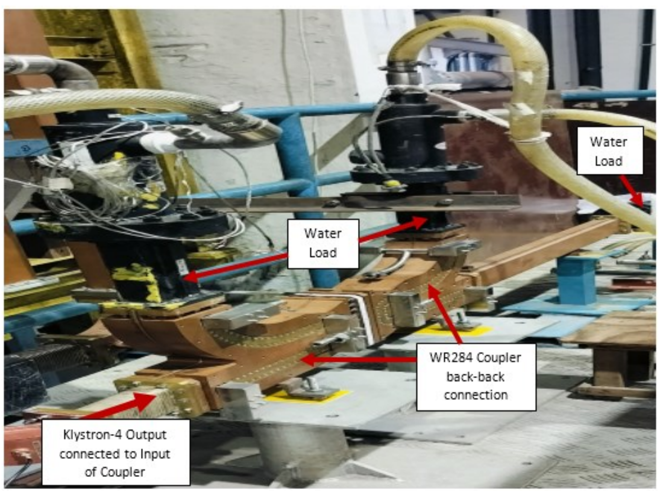


Figure A.1.17: High power test set up for the circulator components. The WR284 couplers are connected back-to-back for the high-power test.

A high power 4-port circulator, 500 kW, 3.7 GHz, CW is being indigenously designed and fabricated. The circulator is composed of 3-dB hybrid coupler, ferrite phase shifter and magic Tee. The successful testing of the circulator at low power rf level has been completed. The circulator components, the WR284 couplers were back-to-back connected and tested for the high-power rf. The input rf power was fed to the input port of the coupler while the remaining three (3) output ports of the assembly were terminated with the water loads. The high-power test set-up is shown in the below figure A.1.17.

The test results are shown in the figure A.1.18. During the testing, the klystron was operated with a beam voltage of around 56 kV and a beam current of 12.3 A. The measured forward power was 140 kW with reflected power having 24 kW for a total duration of 5 sec. The whole assembly of the circulator was tested up to 80 kW, 50 ms. Further improvements to enhance the power level are underway.

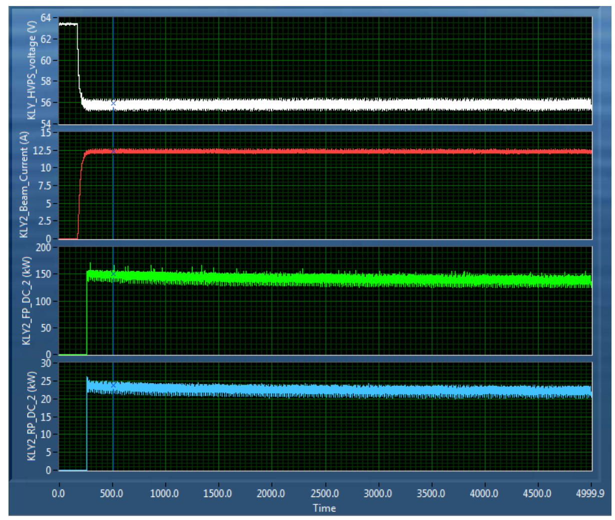


Figure A.1.18: The temporal profile of operating klystron parameters such as beam voltage, beam current, output power (FP, RP) are shown from top panel to bottom panel respectively.

<u>ECRH Heating Experiments on ADITYA-U</u>: Electron Cyclotron resonance Heating (ECRH) has been carried out on tokamak ADITYA-U. The 42GHz ECRH system is used to carry out heating experiments. The operating toroidal magnetic field of tokamak is 0.9T and the second harmonic ECR layer lies outboard side, thus it is second harmonic (X-2) off-axis ECR heating experiment of ADITYA-U Plasma. As shown in figure A.1.19, around 150kW of ECRH power is launched at the flat-top of plasma current. The increase in soft X-ray signal with ECRH power indicates the heating effect of ADITYA-U plasma. This experiment helps to advance fusion research by improving heating efficiency and enhancing plasma performance on the ADITYA-U machine. The ECRH experiments will be continued and the effect of polarization on plasma heating will be observed to generate detail database for ECRH in tokamak.

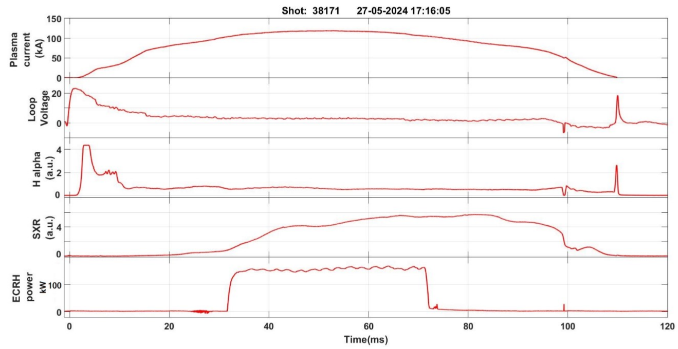


Figure A.1.19: ADITYA-U shot with ECRH power (kW) and other parameters.

__*Prototype SBC Based DAQ System:*__ The development of prototype Single-Board Computer (SBC) based DAQ is aimed to provide compact and low-cost solution for Data Acquisition (DAQ) system. The hardware selection generally depends upon the system complexity and its control requirement (Figure A.1.20).

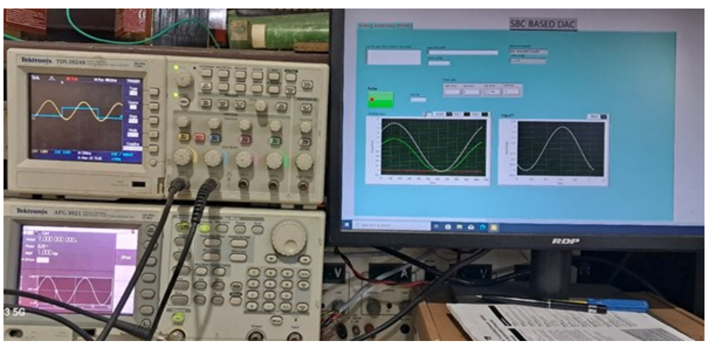


Figure A.1.20: SBC based DAQ system and its validation setup.

__*Development of Compact Interlock System for Gyrotron and High-power Microwave Tube:*__ The ECRH system consists of a high-power microwave (Gyrotron) which operates at megawatt-level high voltage DC (HVDC) power supply. The Gyrotrons are delicate high power microwave tubes that require dedicated protection system. A compact and cost-effective interlock system (figure A.1.21) has been designed and developed, it can operate independently to compare high-voltage and RF parameters, ensuring the safe Gyrotron operation. The prototype interlock system supports monitoring of four analog signals to keep HV parameters within safe limits, three optical channels for arc detection and external digital signals. This compact interlock system provides optically isolated triggers for the crowbar protection system or HVDC power supply. It can identify faults and issue protection triggers within 4µs, ensuring the Gyrotron shuts down safely within the required 10µs timeframe.

Development of prototype DAC application using SBC combining digital and analog conditioning electronics in a single board package has been undertaken. This low-profile system hardware facilitates with inbuilt acquisition hardware. SBC based DAQ system would be effective and budget friendly alternative for DAC requirements of smaller systems. The prototype developed SBC-DAQ system consists of 28 digital and 16 analog channels, and its validation setup is shown in figure A.1.20.

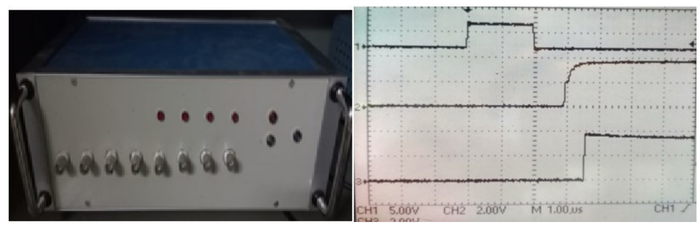


Figure A.1.21: Compact interlock system unit and response time of CILK (Ch-1 input, Ch3-output).

__*High Power Laser Transport Line for ADITYA-U Thomson System:*__ A multi-point Thomson scattering (TS) diagnostic system is being developed for the ADITYA-U tokamak. This system employs the same laser source as the SST-1 TS system. For this purpose, a laser transport line of nearly 65 m has been conceptualized.

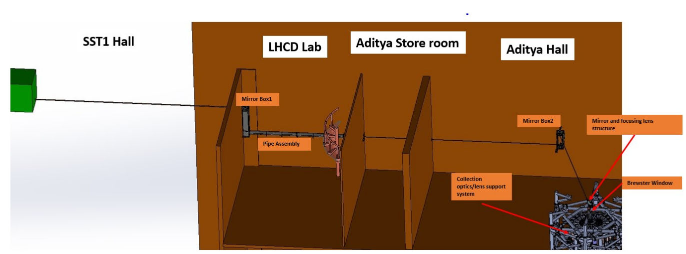


Figure A.1.22: Schematic of the laser transport line.

Figure A.1.22 shows the conceptualized laser transport line for coupling the laser power with ADITYA-U for diagnostics. To reduce the laser beam divergence all the laser beams are expanded 3 times. A cluster of this expanded beam is guided through the laser transport line. The transport line consists of multiple high-precision mirrors of 6 inch diameter for beam steering, safety shutters for controlled operation, and protective enclosures along the beam path. Since the Nd:YAG laser operates as a class IV laser, strict safety protocols must be followed. The beam enclosures are designed for areas with human activity to prevent unintended exposure and interference with surrounding equipment or personnel movement.

Development of a Pump Probe Setup for Laser Melting of Coatings:

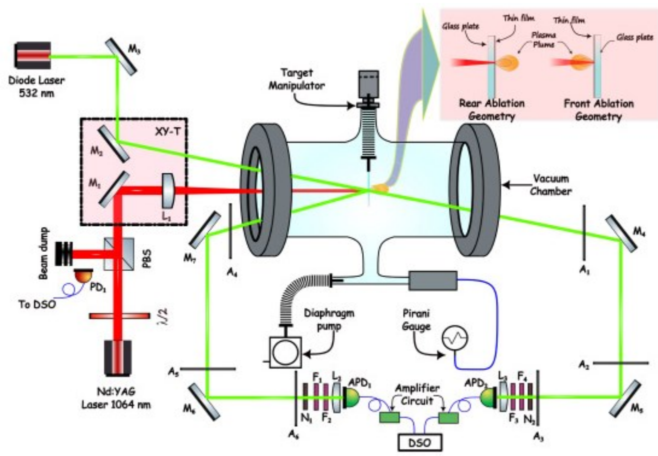


Figure A.1.23: Experimental pump-probe setup for measuring transmittance and reflectance. M-Mirror, A-Aperture, L-Lens, N-Neutral density filter. F-interference filter, APD- Avalanche photodiode, PBS -Polarizing beam splitter, PD-Photodiode, -Half wave plate, XY-T-Automated XY translation stage, DSO-Digital Storage Oscilloscope.

An innovative pump-probe based experimental set up was developed to study the melting, subsequent evaporation, plasma formation and re-deposition in a thin film coated on a glass substrate under different ambient conditions and laser fluences. The ambient conditions restrict the expansion of the plasma plume. The experimental set up helps in the identification of multiple processes and their temporal evolutions during the melting, expansion and re-deposition stages. The ambient conditions affect the plasma plume formed upon ablation, thus modulating the transmission of probe laser pulses, which provides information about the plume dynamics. The experiment can provide valuable insights into the laser-based ablation of thin film coatings, which will have implications in situ cleaning of view ports on large experimental facilities such as tokamaks and other systems e.g. coating units, pulsed laser deposition, Laser induced forward transfer, Laser surface structuring, etc. Figure A.1.23 shows the schematic of the experimental set up developed.

Study of Anisotropy in Laser Produced Plasma and its Consequences on LIBS Analysis:

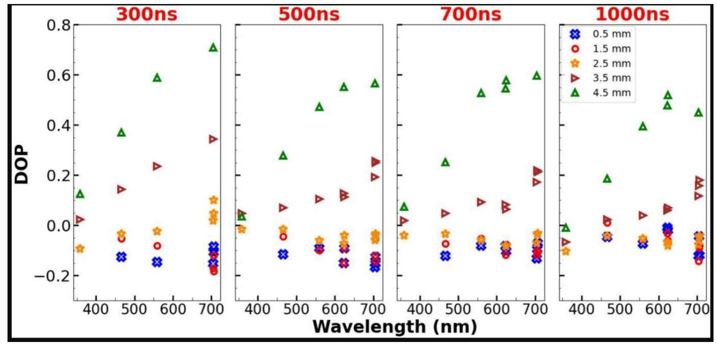


Figure A.1.24: Variation of DOP with emission wavelength at different times after the laser ablation. Different points represents various locations within the plasma. The maximum error in the estimated DOP is expected to be around 10 %.

In the present study, we demonstrate the effect of polarization on electron density and temperature for different polarizations estimated from optical emission spectroscopy (OES). Electron density remains same irrespective of polarization of the emission, as the line width remains the same. On the other hand, estimated electron temperature from Boltzmann plot method shows large variation with polarization, particularly depending on the wavelength of lines used for estimating it. Temperature estimated from the line intensity ratio of two successive charge states appears to show less variation with polarization. The likely reason for this phenomenon appears to be deviation from the Maxwell-Boltzmann distribution of the energy states involved in the transition. This deviation suggests that the population of these energy states does not follow the expected thermal equilibrium distribution. The present study will have important implications in exploiting PRLIBS in elemental analysis. Figure A.1.24 shows the wavelength dependence of Degree of Polarization (DOP) of Al II emissions lines from different locations within the plasma plume generated using a high power Nd:YAG laser, at various time delays. At larger distances (3.5 mm and 4.5 mm), the DOP of emission lines shows a substantial wavelength dependence in comparison to the locations nearer to the sample.

Design and Fabrication of the Lens Reducer for Soft X-ray Diagnostics: A lens reducer is needed to increase the efficiency of the total light collection on the camera sensor. Hence, a lens assembly is designed and optimized in ZEMAX software. The holding assembly is being made by 3D printing from the remote handling division of the institute.

<u>Development of Visible Imaging Diagnostics for SSST Tokamak</u>: The conceptual design of the diagnostics has been prepared. It will be mounted on the tangential port of the machine. A schematic Diagram is shown in the figure A.1.25. A solid angle is projected from the port to the inner and outer limiter. The Field of View (FOV) of the port is 51 degrees. The diagnostics will be used to capture and record the images of poloidal cross-section of the tokamak plasma.

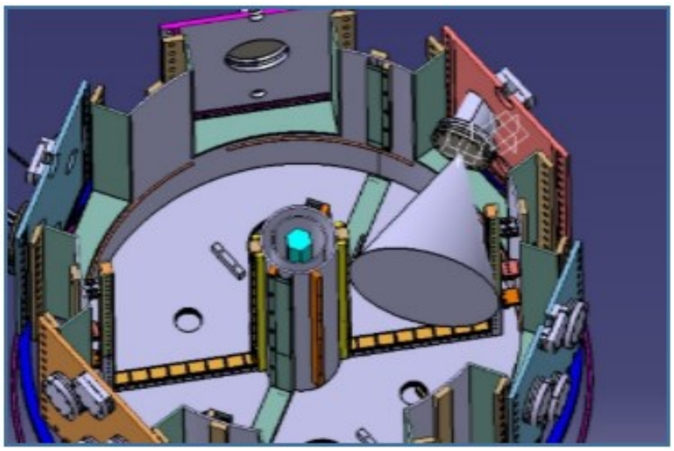


Figure A.1.25: The tangential port and its projected solid angle cone.

<u>90 GHz W-band Trans-receiver Sub-system:</u> Characterization and testing of the system have been completed and documented. A millimetre wave (MMW) W-band transceiver system has been developed (Figure A.1.26) for measuring relative displacement or vibration of a target from a distance.

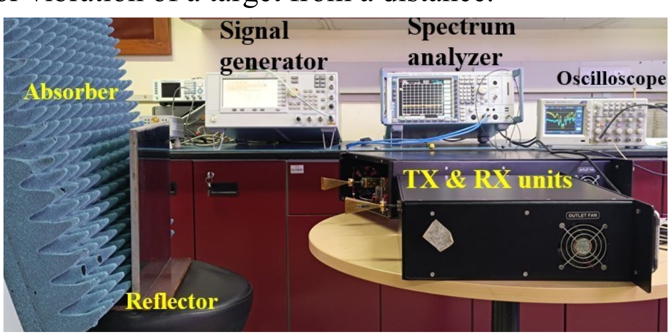


Figure A.1.26: In-lab Characterization set-up for developed W-band trans-receiver unit.

The setup consists of two integrated units — a transmitter (TX) and a receiver (RX). It operates at frequencies of 90 GHz and 90.6 GHz, with both TX and RX units delivering a minimum output power of +15 dBm. The transceiver provides a quadrature (I/Q) output, enabling accurate phase measurements. The receiver offers a low noise figure of around 11dB, a dynamic range of 30dB, and the overall system gain exceeds 40dB. The system is currently deployed for plasma density diagnostics on the ADITYA-U tokamak.

<u>Investigation on Pitch Angle Scattering (PAS) Events Observed & Reported for the First Time at ADITYA-U Tokamak Using the ECE Radiometer Diagnostic:</u>

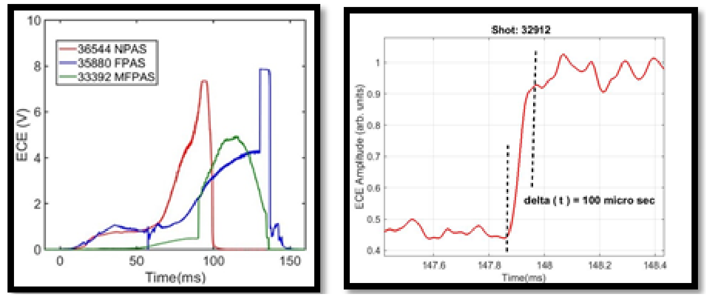


Figure A.1.27: Fast jump of few μs observed in the ECE radiometer signals due to PAS at ADITYA-U tokamak.

The findings concerning the impact of kinetic instabilities on electron cyclotron emission (ECE) from runaway electrons (REs) are investigated at the ADITYA-Upgrade (ADITYA-U) tokamak. For the first time at ADITYA-U, a sudden 20-40% rise in the ECE radiometer signal amplitude is observed within a few μs along with few step-like modulations specifically for the low density ($n_e \leq 1x10^{19}m^{-3}$) plasma discharges. This is expected to result due to wave particle interaction resulting between the Doppler shifted cyclotron frequencies (or its harmonics) with the excited LH waves that arise due to the Anomalous Doppler Resonance (ADR) instability occurring during low density discharges at ADITYA-U tokamak. The experimental findings were supported simulations using PREDICT code (Figure A.1.27).

<u>The Generation of Density Profile for ADITYA-U Plasma:</u> The density profile code has been developed for the generation of density profile from the data of Multichannel interferometer system. The preliminary density profile has been generated for some plasma shots, figure A.1.28. An analysis is conducted on the percentage of ionization during the avalanche and burn-through phase of Ohmic discharges in the absence of pre-ionization in the ADITYA-U tokamak. The impact of error fields on the percentage of ionization is evaluated by adjusting the pre-fill pressure, applied loop voltage and the vertical magnetic field. It has been noted that the percentage of ionization is highly influenced by the applied vertical magnetic field, which counteracts the error fields during the breakdown phase.

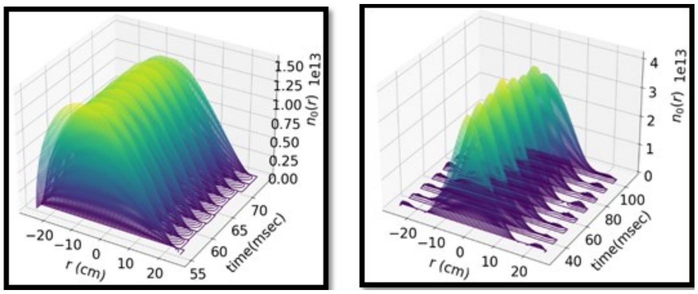


Figure A.1.28: Density profile generation from the experimental data. Analysis of the start-up phase of the plasma.

<u>*First Results from Testing of the Prototype ITER Hard X-Ray Monitor (HXRM) on ADITYA-Upgrade Tokamak:*</u> Runaway electrons (REs) pose a significant risk in high-plasma-current tokamaks like ITER, where their localized energy deposition can damage in-vessel components. The ITER Hard X-Ray Monitor (HXRM) has been specifically designed to detect bremsstrahlung emissions from REs under extreme environmental conditions expected during ITER operations, particularly in the non-nuclear phase. Unlike conventional HXR diagnostic systems used in current tokamaks, the ITER HXRM adopts a unique design wherein the scintillator crystal is decoupled from the photomultiplier tube (PMT), and scintillation photons are relayed via optical components to the PMTs located remotely in the port-cell area as shown in figure A.1.29. This arrangement enables the system to withstand environmental conditions while ensuring high sensitivity and broad dynamic range in RE energy and current measurements.

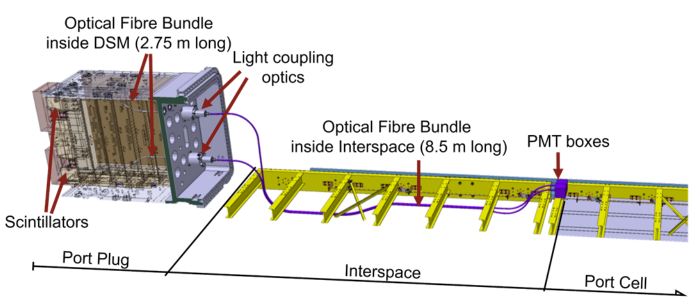


Figure A.1.29: Schematic layout of the designed HXR Monitor for the ITER Tokamak, to be located in Equatorial Port Plug #12.

Under the framework of Task Agreement, between ITER-International Organization (France) and ITER-India, the full prototype of the ITER HXRM system was successfully tested in a real tokamak environment for the first time. Figure A.1.30 shows a schematic layout of the prototype ITER HXRM diagnostic system installed on the ADITYA-Upgrade tokamak and figure A.1.31 shows corresponding photographs. The experimental campaign was conducted on the ADITYA-Upgrade tokamak. This collaborative effort marks a significant milestone in the validation of the ITER HXRM system beyond laboratory conditions.

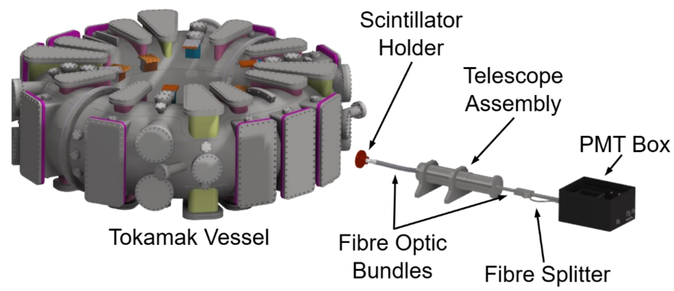


Figure A.1.30: Visualisation of the ADITYA-U tokamak with the ITER HXRM prototype components at its installation location just outside the tokamak.

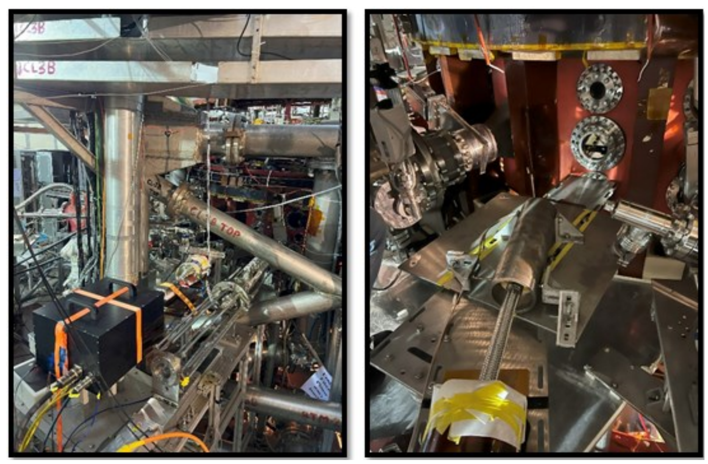


Figure A.1.31: Photographs of the prototype ITER HXRM installed on the ADITYA-Upgrade tokamak.

Initial design validations, including low-count-rate radioactive source tests and I&C development, were performed at Lodz University of Technology (TUL-DMCS), Poland. However, the ADITYA-U tokamak offered an extremely useful platform to test the system's functionality under real plasma discharge conditions, including high-count-rate RE events, thereby simulating key aspects of ITER's operational scenarios particularly during the startup phase where low RE energy and current levels are expected.

The system demonstrated reliable performance during multiple plasma discharges. Both counting-mode and current-mode PMTs were validated, showing consistent results with conventional HXRM systems as shown in figure A.1.32 and A.1.33 respectively.

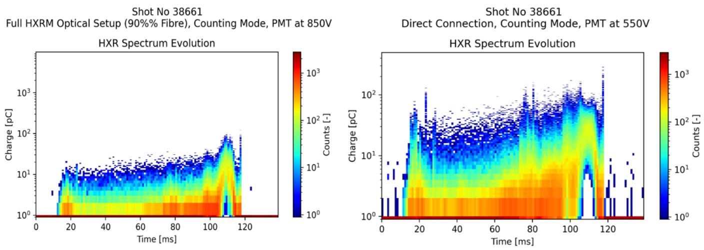


Figure A.1.32: Time and energy resolved count rate registered by the HXRM systems during a plasma discharge #38661 with the prototype ITER HXRM as shown in the left plot and results obtained using conventional HXRM configuration are shown in the right side plot.

Various plasma scenarios were tested to study the effects of plasma density, gas puffing, and MHD activities on HXR signal behavior. Different configurations, including a conventional direct-coupled PMT setup and the prototype optical relay configuration, were evaluated side-by-side. The prototype HXRM achieved a counting capability of ~2 MHz and provided spectral and temporal measurements of HXRs.

The successful execution of this project reflects strong collaboration between ITER-IO, ITER-India, and various teams within the institute. The ADITYA-Upgrade tokomaks' flexibility allowed rapid system installation and tuning between discharges, playing a vital role in this milestone achievement. The insights and data gathered from this experimental campaign significantly advance the qualification of the ITER HXRM system for eventual deployment in ITER tokamak. *(Disclaimer: This is a collaborative work between IO and the institute and the observations on ADITYA –U tokamak has been reported).*

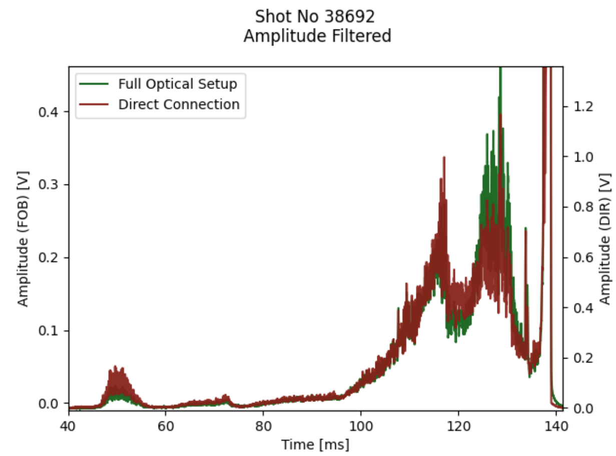


Figure A.1.33: The output signals of the PMTs operated in the current mode operation shows the waveform for the channel working in the direct connection (conventional HXRM) and for the channel working with the full optical setup (prototype ITER-HXRM) is consistent and comparable.

A1.2 Steadystate Superconducting Tokamak (SST-1)

ICRF Wall Conditioning System Development in SST-1: Ion Cyclotron Resonance Heating (ICRH) system on SST1/Aditya-U tokamak designed for *35-65 MHz*. It consists of more than *150* meters of Aluminium / Copper based rigid coaxial straight transmission lines, matching networks, Pre-matching stub near antenna feeder, Vacuum Transmission Line (VTL) system, centre-fed single strap antenna system and high-power RF source chain (Figure A.1.34). The system is used to perform experiment on SST-1.

A critical aspect of controlled tokamak operation is managing plasma wall interaction, which significantly impact plasma stability, confinement and core plasma impurity accumulation. Wall Conditioning (WC) and wall coating in tokamaks and other fusion machines is an effective tool to control particle recycling, plasma wall interactions, impurity contamination from fast wall and has been proved to influence plasma burn-through and current ramp up phase to produce reproducible discharge. The standard WC and coating technique employs glow discharge conditioning (GDC) which is not effective in superconducting machines like SST-1. ICRF based WC, which is independent of magnetic field has been experimented for SST-1 with a new antenna and feeder system that is developed and integrated to the machine. Preliminary experiments have been performed exploring various operational parameters like fill pressure, RF power, duration etc. Neutral breakdown and sustained plasma in front of antenna has been produced for short pulse and long pulse (up to 50s) conditions in less than 30 kW of power. Various diagnostics like spectroscopy, fast visible camera, pressure measurement etc. are used to monitor the plasma production in front of the antenna. These are

Figure A.1.34: Newly installed Aluminium transmission line and matching network at SST-1.

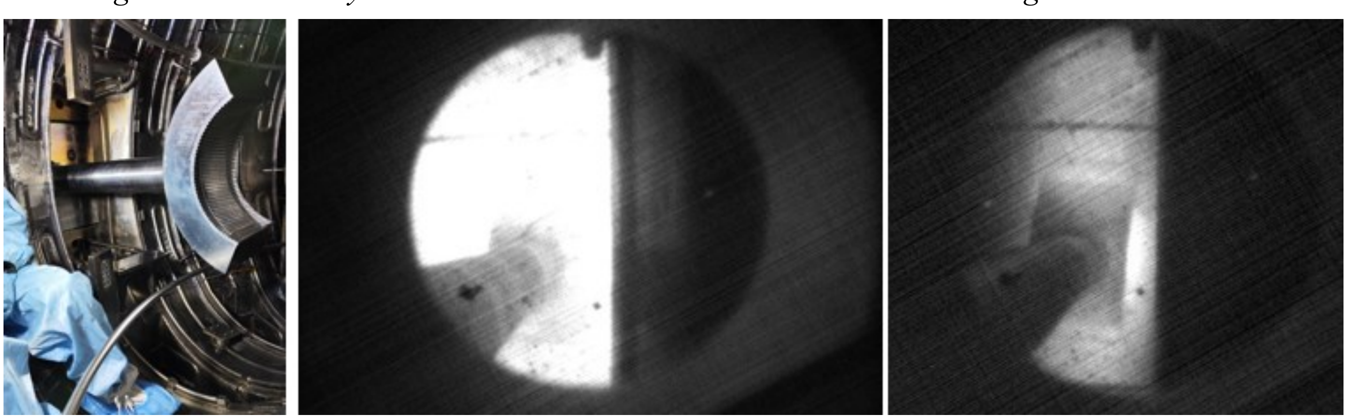


Figure A.1.35: A view of installed antenna in SST-1 and snapshot of plasma production by visible camera.

used to optimize the RF power, pulse and fill pressure parameters to obtain the best condition of plasma production (Figure A.1.35).

Design and Development of a 5 kV, 25 A Series IGBT Switch for Pulsed HVDC Output: To support ECR-based plasma experiments, a 5 kV, 25 A solid-state IGBT series switch has been indigenously developed (Figure A.1.36). This switch enhances the performance of a 1 kW, 2.45 MHz magnetron, which requires a -4.2 kV, 1 A DC bias in both continuous and pulsed modes, with pulse durations from microseconds to several seconds. The existing HVDC power supply lacked the capability to generate fast-rise, adjustable-width pulses. By integrating the IGBT-based switch at the HVDC output, pulsed DC up to ~5 kV with microsecond-scale rise times has been successfully achieved, enabling precise control for plasma physics experiments.

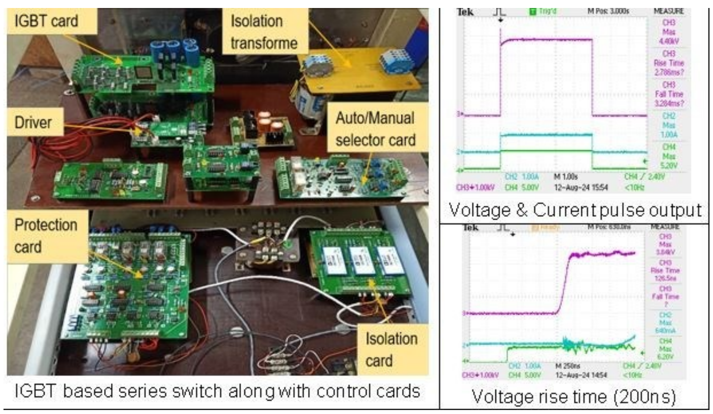


Figure A.1.36: A view of 5 kV, 25 A solid state switch and test result waveform.

Design and Development of Transmission Line Phase Shifter (TL-PS) for the ICRH System of Tokomak: The design and development of the Transmission Line Phase Shifter (TL-PS) for the ICRH system of the Tokamak has been successfully carried out. It is a crucial component of the ICRH system, providing a variable phase shift essential for matching the plasma load impedance. This directly affects how efficiently power is delivered to the plasma.

The TL-PS primarily comprises a support assembly, a movable plunger, and precision electronic controls as shown in figure A.1.37. Key research challenges arose due to discontinuities—mainly at transitions from the cavity to the coaxial transmission line, the movable joint, and the inner support structure. These discontinuities have been compensated and optimized to achieve the desired performance. The developed TL-PS has been integrated with the ICRH system of the Aditya Tokamak, and commissioning activities are currently underway. Provision has also been made for its deployment in the SST-1 system, contingent upon successful commissioning in Aditya.

The system is designed to handle power levels up to 1.5 MW, deliver a phase shift ranging from 50° to 110° within the 40–60 MHz frequency range, maintain a VSWR below 1.2, and achieve a return loss better than 25 dB. It is equipped with precision control electronics that enable plunger movement along the full 1500 mm length with a step resolution of 1.0 mm.

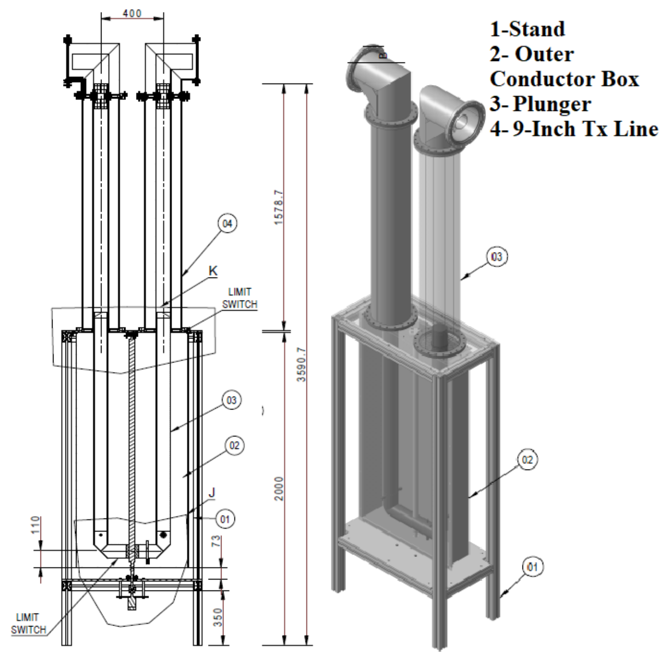


Figure A.1.37: Assembly Drawing of Transmission line Phase Shifter.

SST-1 Cryogenics: SST-1 Cryogenics Division caters to the various cryogenic flow and cooling requirements in SST-1 (Steady State Superconducting Tokamak) in a smooth and efficient manner.

Assessment for System Improvements: Plasma operation campaigns in SST-1 have been carried out regularly, with gradual progress in controlling plasma for better experimental results. Alongside this, efforts were made from time to time to improve cooling of the superconducting magnets. Among all the Poloidal Field (PF) superconducting coils, only the two PF3 coils (top and bottom) were selected for cooling and current charging, since they had comparatively lower flow resistance and heat load. However, during the past last campaign, attempts to cool and charge the PF3 coils were unsuccessful. The bus bar temperatures at certain points remained significantly high (around 15 K), well above the required superconducting state. In addition, the cooling and current charging of the Toroidal Field (TF) coils were found to be worse than earlier campaigns—especially after the introduction of PF3 current leads and larger vacuum barriers. This indicated that one of the major challenges was excessive cryogenic heat load. A helium leak was also detected in the PF4 coil during operation. Considering these issues, it was decided that major system improvements were needed. Various proposals were discussed, and task force teams were formed to study feasibility, cost, and timelines. One proposal suggested removing all PF coils and replacing them with copper coils cooled by liquid nitrogen, while keeping the TF superconducting coils cooled by helium at ~4.5 K. However, this approach required significant time and budget, and there were concerns about whether the TF coils could still be cooled and charged to design levels. An SST-1 Assessment Committee (SSTAC) formed to review and recommend improvements identified opportunities for significant upgrades in the cryogenic and superconducting systems without major modifications inside the cryostat. It recommended improvements mainly in systems outside the cryostat, such as enhanced thermal shielding and measures to reduce heat loads on the 4.5 K refrigeration system, better flow path arrangements for improved cooling of bus bars and magnet coils, optimized vacuum barriers for bus bars, increased 4.5 K cooling capacity using existing helium plants at the institute (both indigenous and imported NBI plants), replacement of conventional current leads with High Temperature Superconducting (HTS) current leads etc some of which are detailed below:

High Heat Load on 4.5 K Cryogenic System of SST-1: Recent analysis of SST-1 operation data shows that the external heat load on the system, which must be removed by the 4.5 K cryoplant, is about 4–5 times higher than the design value of 400 W at 4.5 K. In addition, liquefaction power is required to cool the current leads. When all 10 pairs of current leads are connected to power supplies, about 7 g/s of liquid helium (200 liters/hour, equivalent to ~700 W at 4.5 K) is needed. In recent operations, both PF3 and TF coil current leads were cooled to 4.5 K, but the PF3 coils could not be charged due to high bus bar temperatures. Heat load estimates also showed variability between operations, which is not unusual at cryogenic temperatures. A detailed review revealed that some temperature measurements had significant errors, which led to inaccurate heat load calculations. Because it is difficult to bring all PF and TF coils to ~4.5 K simultaneously, the PF coils are typically cooled only to ~10 K during each campaign. This allows more helium flow to be directed to the TF coils so that they can at least reach the superconducting state. However, this strategy results in unsteady and non-uniform temperatures, contributing to variations in heat load from campaign to campaign. Further analysis identified several sources of direct radiation heat load from room temperature surfaces (~300 K) to the cold mass. Radiation from a 300 K surface is nearly 200 times higher than from a liquid nitrogen cooled thermal shield at 80 K (since heat radiation is proportional to 4th power of temperature). Major contributors include: 14 manhole ports of the cryostat (out of 32), sections of helium transfer lines, parts of bus ducts, portions of the Current Feeder System (CFS) and Integrated Flow Distribution and Control System (IFDCS), cryostat support columns. Additionally, tubes and cables for magnet parameter measurements enter the cryostat without proper thermal intercepts, introducing conduction-assisted radiation heat load to the 4.5 K system. Some of these issues (such as unshielded ports and transfer lines) are outside the cryostat (Figure A.1.38) and accessible for improvements. However, others (like incomplete thermal shielding, contact between 80 K shields and the cold mass, or gaps in shield coverage inside the cryostat) are harder to access and modify. A thorough experiment to measure these heat loads more accurately are needed.

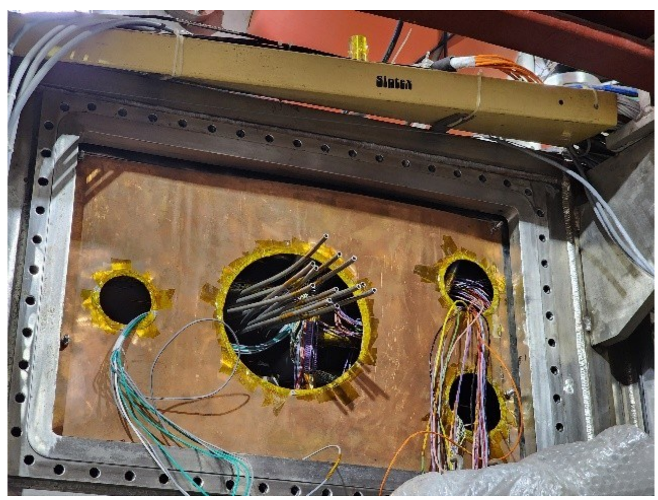


Figure A.1.38: Cryostat ports without thermal shielding.

Possible Ways and Plan to Reduce 4.5 K Heat Loads: Before planning improvements, it is essential to measure the heat loads on each component, subsystem, and the overall system separately. This helps identify which areas contribute most to the problem and where reductions are both easier and more effective. Measuring heat loads at cryogenic temperatures is challenging, especially in a complex machine like a tokamak. To reduce uncertainty, errors in temperature and flow rate measurements must be minimized. In past SST-1 campaigns, some temperature sensors showed errors greater than 0.5 K, while the target is to keep errors within ±0.2 K. The main causes were poor sensor installation and improper use of multi-layer insulation (MLI). Where accessible, sensors can be re-fixed with better thermal anchoring and proper MLI wrapping. In some cases, correction is possible during operation by using two-phase flows, since their temperature can be derived from the local fluid pressure. Flow meters will also be calibrated at both cryogenic and room temperatures using known flow rates to improve accuracy. Together, these steps will allow more reliable and quantitative understanding of the sources of heat load.

Figure A.1.39: CFS chamber with room temperature radiation components inside the chamber.

A major contributor to high heat load is thermal radiation from warm (300 K) surfaces. About 14 of the 32 cryostat manhole ports lack 80 K cooling, making them significant sources of unwanted heat. Equipment entering through these ports must be provided with actively cooled thermal shields ("bubble panels") and proper thermal anchoring, which also reduces conduction-assisted radiation heat loads. Other unshielded areas include the entire 3S–2R helium transfer line, parts of the 3S–3R transfer line, and sections of bus ducts carrying superconducting bus bars. Openings around cryogenic valves in the IFDCS also allow direct line-of-sight from room temperature surfaces to the 4.5 K system; these can be sealed. Inside the thermal shields of the CFS chamber, several components & surfaces having higher temperature (Figure A.1.39) and directly "see" the 4.5 K parts, adding more heat load. Since these areas are accessible, modifications can be made so that no surface hotter than 100 K is visible to the 4.5 K cold mass. Altogether, these corrective measures are expected to reduce the heat load on the 4.5 K system by 400–800 W.

Possible Ways to Increase 4.5 K Cooling Power: The existing Helium Refrigeration and Liquefaction (HRL) plant of SST-1 has a cooling capacity equivalent to 1.3 kW at 4.5 K when operated in mixed mode (providing about 650 W of refrigeration at 4.5 K along with 200 liters per hour of liquid helium). When run in refrigeration-only mode, it can deliver about 1180 W at 4.5 K, as confirmed during commissioning tests in 2001. At present, the plant is mainly used in refrigeration mode. By carefully adjusting process parameters of different plant components, it may be possible to take advantage of design margins and improve cooling performance. The exact extent of improvement, however, can only be confirmed through plant operation. As an alternative, the indigenous helium plant developed by the LCPC (Large Cryogenic Plant and Cryosystem) Division can also be used. Its current tested capacity is 200 W at 4.5 K, but it has the potential to be upgraded. Given budget constraints, the plan is to first enhance its capacity to about 450 W, and eventually to around 1 kW, depending on available funding.

A1.3 SST Bharat

SST-Bharat: Gateway to India's Fusion Program: India's pursuit of sustainable and self-reliant fusion energy has reached a defining moment with the plan of the SST-Bharat reactor. As fully indigenous steady-state tokamak platform, SST-Bharat represents a major step forward in translating fusion research into practical reactor technologies. It is strategically positioned to bridge the gap between current experimental devices and future commercial reactors such as DEMO. SST-Bharat builds upon the technological foundation established by Aditya-U and SST-1, and integrating the knowledge gained from India's participation in ITER. By enabling steady-state operation and reactor-relevant testing under Indian conditions, SST-Bharat will serve as a critical platform for maturing fusion technologies and advancing India's long-term fusion goal.

Currently, institute is leading the design activities related to SST-Bharat. SST-Bharat is planned to be a tokamak fusion device with roughly two third the size of ITER tokamak with a power gain, Q > 2. The success of SST-Bharat depends on a strong collaboration between the institute, BARC, and other national research labs, each bringing complementary strengths to the project.

A2. Fusion and Related Technologies

In continuation to the last years progress, several new technologies related to fusion science and technology have been developed. A brief about the newly developed technologies under various heads are high-lighted in the following subsections.

A2.1 Magnet Technologies

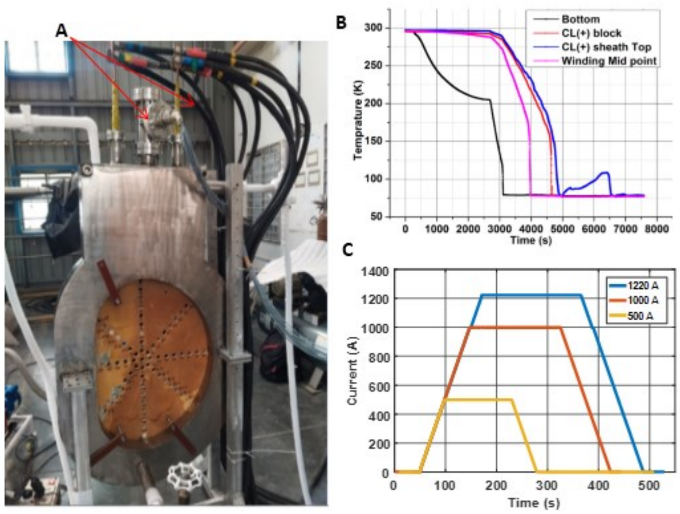


Figure A.2.1: A) D-Shape magnet, B) Cool down curves, and C) Current wave forms.

Significant progress has been made on the R&D for high temperature superconducting (HTS) magnet technology and test facility development for high magnetic field generation using liquid nitrogen as coolant. Various milestones of superconducting magnets DPR viz. the design, fabrication, and testing of a D-shaped HTS magnet with dimensions of 1.1 m in height and 0.7 m in width, were also undertaken for the assessment of winding, insulation, casing and interfacing with current leads. The design of this magnet has been derived from a toroidal magnetic confinement model of plasma consisting of eight D-shaped toroidal field (TF), a central solenoid (CS) and four poloidal field (PF) magnets. The winding pack of D-shaped magnet employs a double pancake configuration with 12 turns of stacked rare earth barium copper oxide (REBCO) cable, insulated with dry FRP tapes. The winding pack fabrication of this magnet was done in-house, utilizing the bottom section of an LN_2 casing as a mandrel to achieve the precise D-shaped geometry. After cable winding, the winding pack was encapsulated by the welding of the bottom section of LN_2 casing, and enclosing it in a D-shaped vacuum chamber with a volume of 0.05 m^3. This magnet was then successfully cooled down to 77 K and charged up to 1.22 kA with a current ramp rate of 10 A/s, producing magnetic field of 0.1 T. The test results of this magnet are shown in figure A.2.1.

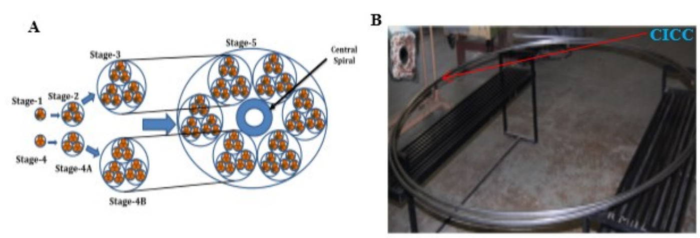


Figure A.2.2: A) Cabling pattern, B) Cross-sectional view and 15 m long NbTi CICC.

As a continuous part of development on Low Temperature Superconducting (LTS) high current conductors, which includes the cabling of 0.81 mm diameter NbTi strands and the jacketing of 15 m long 10 kA NbTi cable to form a Cable-In-Conduit Conductor (CICC) of size 15.2 mm x 15.2 mm with a central cooling channel, has been successfully completed by the institute and Atomic Fuel Division (AFD) of BARC. The cabling pattern and the cross-sectional view of NbTi CICC and a loop of 15 m long CICC are shown in figure A.2.2A and A.2.2B.

A2.2 High Temperature Technologies

Piping connection between High Heat Flux Test Facility (HHFTF) and Experimental Helium Cooling Loop (EHCL) has been completed. The welded joints passed the Radiography Tests. Pressure test carried successfully at 110 bar. Insulation of the pipe spools is completed and enclosure of the piping is done (Figure A.2.3).

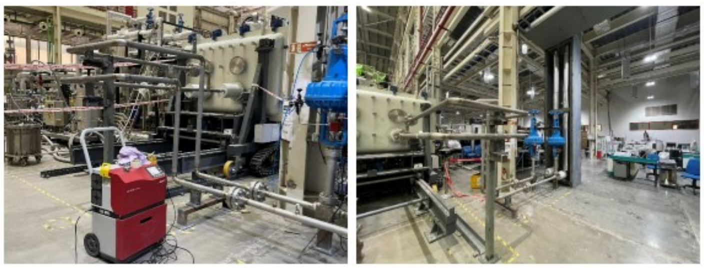


Figure A.2.3: Piping connection between High Heat Flux Test Facility (HHFTF) and Experimental Helium Cooling Loop (EHCL) has been completed. Thermal insulation of the entire piping connections (not shown above) is also completed.

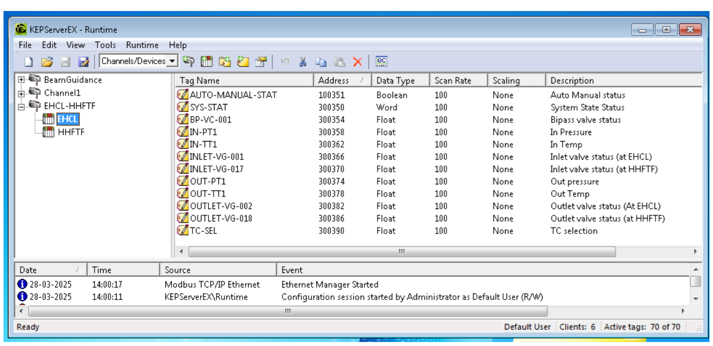


Figure A.2.4: Snapshot of KEP Server OPC with configuration of EHCL variables.

Regarding the establishment of connectivity between High Heat Flux Test Facility (HHFTF) and Experimental Helium Cooling Loop (EHCL) for data acquisition, the interface topology and various tags (variables) to be exchanged between these two systems were finalized. The exchange of all tags over OPC has been successfully tested for both - read and write – operations. The OPC interface between HHFTF and EHCL is found to working satisfactorily. Hardware and key safety interlocks have been finalized, and hardwired connectivity will be established for them. Screenshot of the Kepware OPC Server GUI (Figure A.2.4), which is configured for the HHFTF and EHCL tags, is shown.

High heat flux testing of finger-type test (Figure A.2.5) mock-up made of copper (Type-1) is performed for absorbed heat flux in the range 1.18 MW/m^2 to 1.82MW/m^2 applied over time period in the range 80 s to 120 s in the High Heat Flux Test Facility (HHFTF). Pressurized nitrogen gas at room temperature is circulated through the test mock-up at flow rate in the range 40-55 g/s at pressure inside test mock-up in the range 5bar to 8bar during the heat transfer experiments. Water cooled copper mask surrounding the test mock-up is used for calorimetry to estimate the absorbed heat flux. Following figure shows the test mock-up mounted on the HHFTF for heat flux testing.

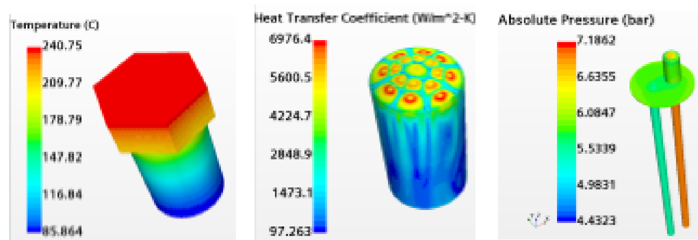


Figure A.2.5: Finger-type copper test mock-up with copper mask assembled in HHFTF for high heat flux testing. Typical surface temperatures on mock-up is in the range 170-330 °C.

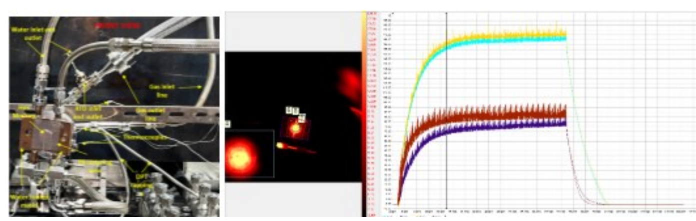


Figure A.2.6: Heat transfer simulation of finger type test mock-up. Experimental parameters are used as input parameters for the CFD simulation.

Simulations for heat transfer studies on copper made finger-type test mock-up are performed using following experimental parameters: (a) Inlet gas temperature: 24.2 ºC; (b) Mass flow rate of nitrogen: 38 g/s; (c) Inlet gas pressure: 7 bar; (d) Absorbed heat flux: 1 MW/m^2. Realizable k-e model coupled solver is used for the CFD analysis. Maximum surface temperature of 240ºC which was estimated from this CFD simulation is found to be slightly lower than the experimentally observed value of 250 ºC (Figure A.2.6). Shear-punch experiments are performed on tungsten samples (8 mm dia. x 0.5 mm thick) in temperature range 600 ºC to 700ºC using newly fabricated tungsten-carbide fixtures and Gleeble 3800 system (Figure A.2.7 & A.2.8). During these experiments, temperature and heating rate remains stable.

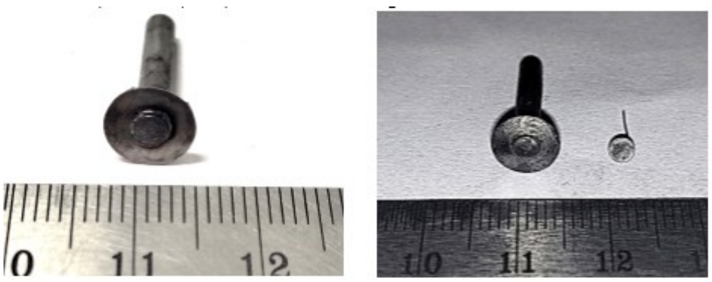


Figure A.2.7: Shear punched tungsten sample at 600 °C (left) and 700 °C (right).

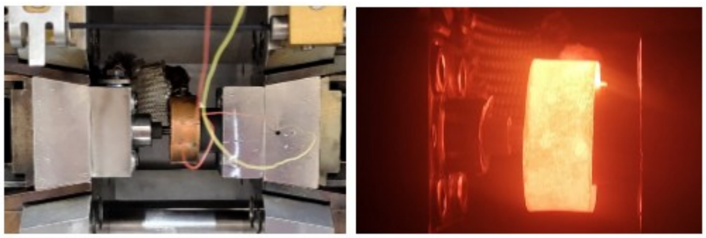


Figure A.2.8: Shear punch testing of tungsten sample performed at 700 °C in Gleeble-3800 system.

<u>*Tungsten Fiber Tungsten Composite (W/Wf) Material Development:*</u> Phase-2 of the MoU between the institute and ARCI (Hyderabad) has been completed. Tensile tests are performed using cylindrical sample at MIDHANI. At 500 °C temperature, UTS for W/Wf samples are found in the range of 250 MPa-300 MPa elongation is found in the range of 2.1-2.5%. Fracture toughness tests are performed using indentation method called "Anstis". Fracture toughness values are found to be 4.2 MPa√m for pure tungsten samples, 5.9 MPa√m for W/W_f composite samples with uncoated fibers and 12.1 MPa√m for W/W_f composite samples with Erbium Oxide coated fibers.

<u>*Tin-Lithium (Sn-Li) Liquid Metal Alloy Production Facility:*</u>

Figure A.2.9: Steady-state thermal analysis of Tin-Lithium Loop (Left). PID based temperature controller is energized and ready for integration with Tin-Lithium Loop (Right).

Engineering analysis of Sn-Li loop was performed based on the drawings received from the vendor (Figure A.2.9). Static structural and thermo-structural analysis of different parts of the loop was done. Manufacturing drawings and tender specification documents submitted by the vendor are approved by the tender processing committee. Fabrication of the facility is in progress at vendor's site.

A2.3 Fusion Blanket Technologies

<u>*Development of Cold Trap for Pb-16Li Purification:*</u>

During the operation of the Pb-16Li breeding blanket system, structural materials like RAFMS and austenitic steel are susceptible to corrosion from molten Pb-16Li, particularly in the high temperature regions of the system (Figure A.2.10). As the molten Pb-16Li circulates during blanket operation, impurities generated in the high temperature regions precipitate in the colder regions of the system, due to their lower solubility at lower temperatures. Oxide impurities such as PbO and Li_2O are present in the molten Pb-16Li that precipitates during system operation. The accumulation of these impurities in the colder regions can result in plugging of those sections, which adversely impact the performance and safety of the blanket system.

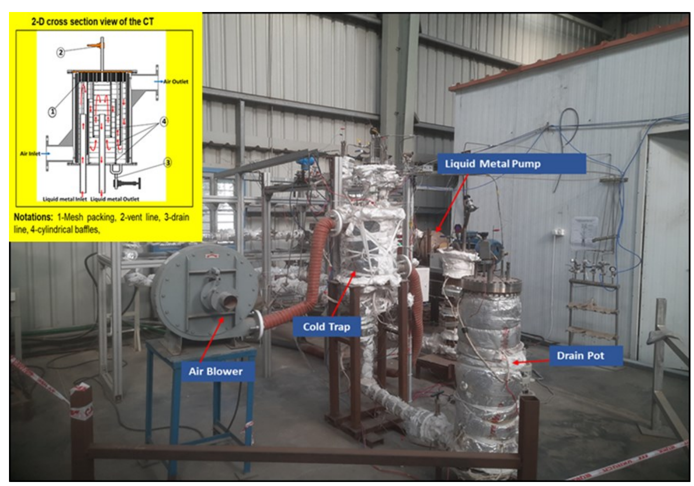


Figure A.2.10: Pb-16Li purification loop . Schematic of CT internal flow configuration is shown at the top corner.

To address this issue, a purification component known as the "Cold Trap" (CT) is essential for removal of impurities from the Pb-16Li system. A new variant of the CT with annular geometry (2-D schematic of CT internals indicating the Pb-16Li flow path is shown in top left corner of figure A.2.10) has been tested in the bypass line of the Pb-16Li purification loop. The present CT design increases the residence time for impurity precipitation due to multiple annular paths, thus enhancing the effectiveness of CT. The purification loop has been operated continuously for ~5,000 hours to extract impurities from the molten Pb-16Li and trap them inside the Cold Trap. During the operation Pb-16Li flow rate of about 0.125 kg/s and a uniform temperature of approximately 270 ± 5 °C has been maintained within the Cold Trap to facilitate the precipitation of impurities.

Design & Fabrication of Lithium Injector and its Performance Testing: The Lead Lithium Eutectic Alloy (Pb-16Li) has been considered as a tritium breeder, neutron multiplier, and coolant in various liquid metal breeding blanket systems (Figure A.2.11). As a part of R&D activities for Pb-16Li component development, it is imperative to develop Pb-16Li alloy itself as a process fluids for operation of Pb-Li loops. Institute has already demonstrated production of this alloy using MHD stirring technique. Lithium injector is one of the important components for injecting lithium into the molten lead in a dispersed spray pattern. The design and fabrication of lithium injector has been taken up at the institute using a Swagelok make needle valve and its preliminary testing has been performed using petroleum ether to demonstrate the dispersive spray pattern of the fluid during the injection process. The high temperature (~ 400 ^{o}C) testing of lithium injector has also been performed successfully.

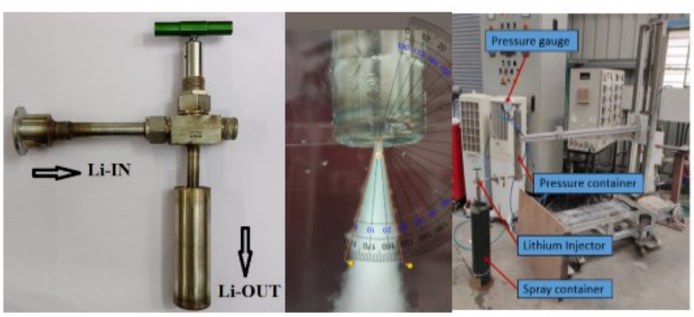


Figure A.2.11: (a) Fabricated and assembled lithium (b) Test setup for spray testing of the lithium injector (c) Testing of Li injector to demonstrate dispersed spray pattern

MHD Experimental Studies in LLMHD Facility: The integrated liquid lead lithium MHD (LLMHD) experimental facility has been developed at the institute to perform Pb-Li isothermal as well as thermo-fluid MHD experimental studies in different flow configurations, relevant to the liquid breeder fusion blankets and is under operation.

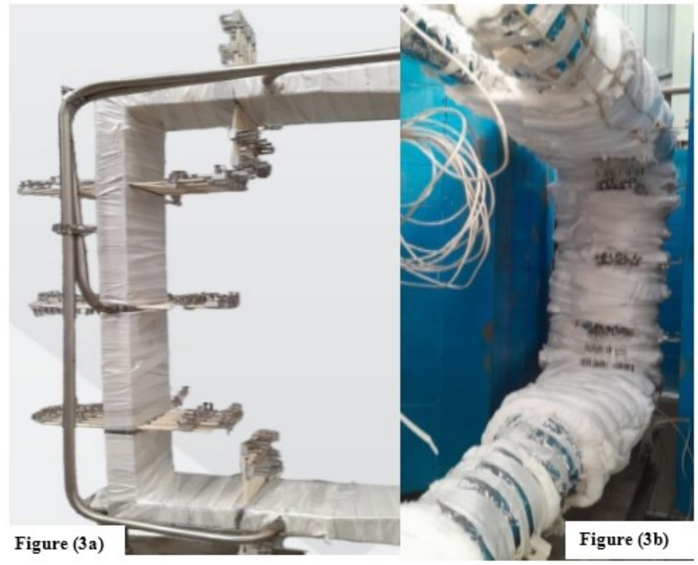


Figure A.2.12. (a) Picture of the rectangular test mock up (b) Mock-up integrated with the LLMHD loop inside the pole gap of electromagnet.

Recently, isothermal MHD experiments have been performed with a rectangular U-bend test mock up (Figure A.2.12) in presence of a uniform transverse magnetic field up to 1.0 T. The operational Pb-Li temperature is kept at 320 °C and mass flow rate ranges from 5 – 7 kg/s. The test mock up consists of a large number of potential pins (145 Nos.) and three pressure ports for induced wall electric potential and liquid metal pressure measurement, respectively. To measure the Pb-Li temperature, several thermocouples were spot welded on the outer wall surface of the test mock up. The experimental data analysis is under progress.

High Temperature Calibration of a MHD Flow Meter Using First Principle: Institute has developed a permanent magnet based MHD flow meter for high temperature liquid metal applications (> 300 ^{o}C) using an optimised arrangement of permanent magnets [Indian Patent no: 455892, (2023)]. Usually, the high temperature flow meters are calibrated using analytical expression or numerical simulation or using surrogate low temperature (< 100 ^{o}C) fluids. The best way to calibrate a flow meter would be to use the first principle i.e. to measure the weight of the liquid transferred per unit time through the flow meter and at the same time recording the flow meter signal. The correlation between these two parameters provides the calibration factor for the flow meter. Based upon this principle, a high temperature liquid metal loop set up has been fabricated having a storage tank, a collector tank, flow meter, actuator-controlled valves, weighing balance etc. (Figure A.2.13).

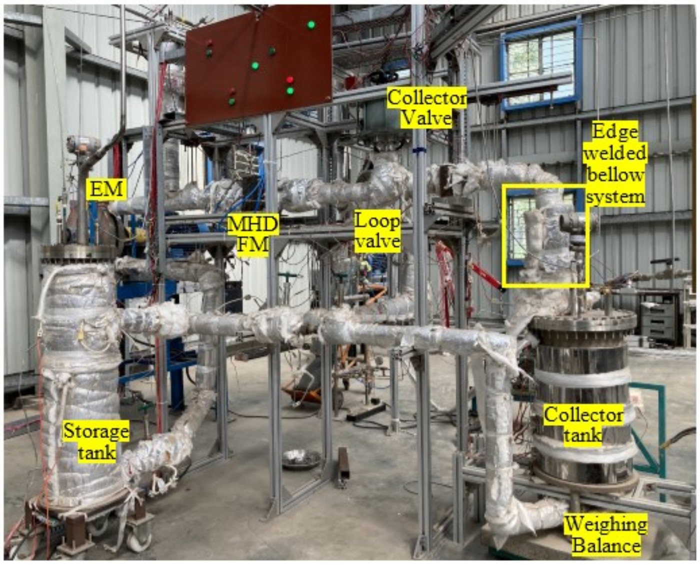


Figure A.2.13: Experimental set up for the high temperature calibration of MHD flow meter using Pb-Li as the working fluid.

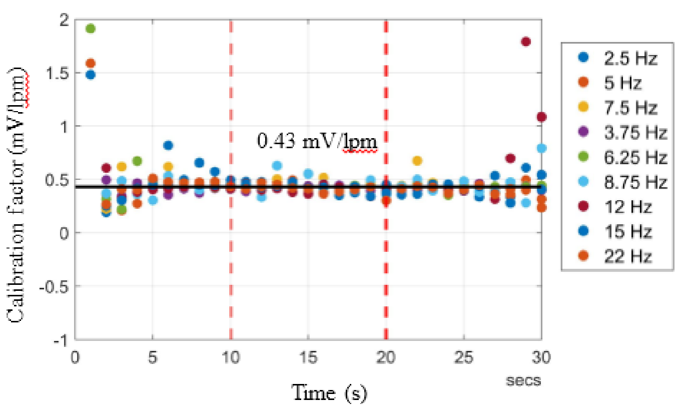


Figure A.2.14: Estimation of calibration factor for the 30 seconds of Pb-Li weight collected in the collector tank.

A novel isolation system has also been designed, using an edge welded bellow that isolates the reaction forces between the collector tank and the rest of the setup. This, enabled the accurate weight measurements of Pb-Li collected in the collector tank and the calibration of the MHD flow meter could be done successfully. During operation the molten Pb-Li (at 300°C) is transferred from the storage tank to the collector tank via the flow meter using an electromagnetic pump (EMP). Meanwhile, the weight of the Pb-Li collected per unit time is measured by a weighing balance placed below the collector tank and the calibration is done as mentioned earlier. Figure A.2.14 shows the estimated calibration factor of the developed flow meter for different pumping speed through collection of Pb-Li in the collector tank for 30 seconds.

<u>*Development of Gas Chromatographic Columns for the Rapid Resolution of Hydrogen Isotopes in Helium Gas:*</u> Developed and tested gas chromatographic (GC) columns with a focus on improving the separation efficiency and retention times for the rapid analysis of trace levels of hydrogen isotopologues in helium gas at 77.4 K. Two different activation techniques were employed to assess their effect on the performance of the GC stationary phase: thermal activation and plasma activation. The GC columns were externally mounted in a cryogenic stainless steel dewar with 1/8" inch stainless steel inlet/outlet connections. A commercial GC system (Model: Gowmac GC Series 580 DID) was customized for this application (Figure A.2.15a) and the data acquisition was performed using Clarity Lite software. Prior to cryogenic separation, the gas samples, carrier and discharge gases was purified using Pd-based purifiers at 623 K. Column stationary phases were prepared using neutral grade activated alumina (80–120 mesh), followed by either thermal or argon plasma activation (13.56 MHz, 50 W, 15 min, 100 Pa Ar). The plasma reactor was a cylindrical SS-316 RF -powered chamber with a glass petri dish used to hold samples on the powered electrode (Figure A.2.15b). Post-activation, alumina was impregnated with $MnCl_2$ and $NiCl_2$ salts for transition metal modification. GC testing was carried out using an equimolar mixture of H_2 and D_2 (1000 ppm each) in He, with 2 mL injection volumes at varying carrier flow rates (60–120 mL/min).

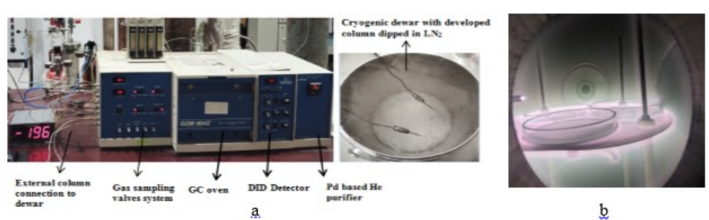


Figure A.2.15: (a) Experimental installation of the GC system with DID under operation. The column for hydrogen isotopes analysis is connected externally to a dewar filled with liquid nitrogen; (b) Ar plasma treatment of the alumina samples.

When the sample injection volume is 2 mL, the maximum peak resolution of 2.73 was observed at 75 mL/min for spin isomer separation on plasma-activated (PA) Al_2O_3,(Figure A.2.16a) while a resolution of 2.97 was achieved at 60 mL/min on $NiCl_2$ impregnated thermally activated (TA) Al_2O_3 at 77.4 K. Peak symmetry was preserved in $MnCl_2$ modified columns, while slight tailing was observed for $NiCl_2$ - treated samples, attributed to stronger D_2 interaction with Ni sites (Figure A.2.17b). The system also demonstrated potential for resolving spin isomers and isotopologues including HD, DT, HT, and T_2, based on retention time shifts predicted from reduced mass correlations. Detector response showed linearity in the 10–1000 ppm range, with total separation achieved in under 7 minutes. Overall, transition metal -impregnated alumina columns demonstrated enhanced performance and stability, offering a viable, low-cost alternative to spectroscopic, RGA or micro-GC methods for real-time hydrogen isotope monitoring in fusion fuel cycle and hydrogen energy systems.

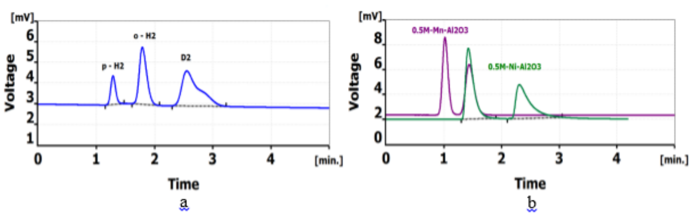


Figure A.2.16: (a) Mixture of 1000 ppm H_2 -1000 ppm D_2 in He gas on PA Al_2O_3; (b)Comparison of Ni and Mn impregnated TA Al_2O_3 at 77.4 K.

<u>*Indigenous Development of Er Metal Organic Solution as an Alternate to Import for TPB Coating:*</u> Er_2O_3 is one of the leading materials as hydrogen isotope permeation barrier coating because of its favourable properties like high temperature stability, high permeation reduction factor and high resistivity. Dip coating technique is attractive to deposit the same due to its simplicity, scalability and cost-effectiveness. It has shown good results in our previous studies with metal-organic decomposing solution available commercially. Specifically, for Er_2O_3, high cost and import of the commercial solution is a limitation in up-scaling the process. So, for development of an economical Er_2O_3 dip coating solution, experiments are conducted by making solution of $Er(NO_3)_3{\cdot}5H_2O$ as a precursor dissolved in ethylene glycol methyl ether (2 Methoxy-ethanol) mixed with different viscosity adjusters in varying concentration. The study investigates the suitability of viscosity adjusters like Ethanolamine, Poly (ethylene glycol) bis-(amine) (PEGBA) and Di-ethanolamine and their concentration on the properties of the solution and coating. Based on the crystalline phases, surface and cross-section morphology and elemental composition of the coatings deposited on fused silica, 3% of Poly-(ethylene glycol) bis-(amine) as viscosity adjuster gives better and comparable results to commercial solution (Figure A.2.17). This study is a step towards indigenising economical dip-coating Er_2O_3 solution synthesis to pave the way to upscale the dip-coating process.

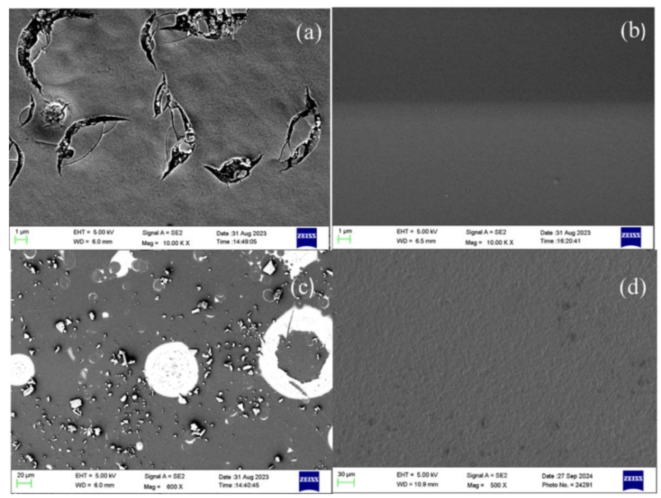


Figure A.2.17. SEM images of Er_2O_3 coating with (a) 0.1% PEGBA solution at 10K magnification, (b) imported solution at 10K magnification, (c) 0.1 % PEGBA solution and (d) 3 % PEGBA solution, at lower magnifications.

<u>*Development and Testing of Getter Bed for Solid State Hydrogen Isotope Storage:*</u> Lanthanum Nickel ($LaNi_5$) based solid state hydrogen storage getter bed system has been developed and tested at the institute (Figure A.2.18a). Getter bed serves as a crucial component of tritium extraction system for regulating hydrogen isotope uptake and release rates, ensuring optimal performance and safety. Operational testing of the getter bed has been conducted to evaluate its hydrogen storage capabilities. Experiments were carried out to assess the impact of heat transfer on the storage capacity of the getter bed. A helical coil heat exchanger, made from SS316L and copper, was used for heat transfer within the getter bed. Figure A.2.18b displays the results for hydrogen absorption per kilogram of getter material, both with and without heat transfer. With an effective heat transfer arrangement, approximately 6.5 grams of hydrogen

storage per kilogram of getter material has been achieved.

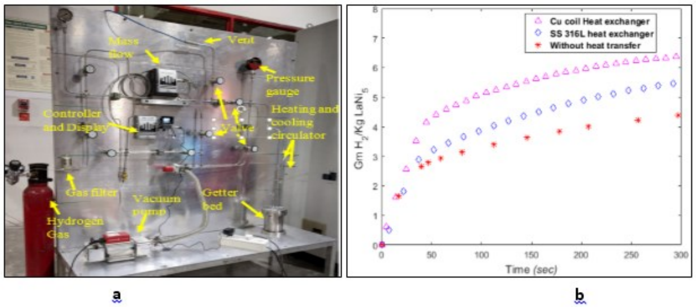


Figure A.2.18. (a) A photograph of Getter bed system for hydrogen isotope storage (b) Hydrogen absorption evolution for $LaNi_5$ with and without heat transfer.

Design of Annular Getter Bed Vessel for Hydrogen Isotope Storage System in Neutron Generator: Based on the experience gained from La-Ni getter bed, an annular getter bed vessel employing ZrCo as the getter material has been designed and optimized for the hydrogen isotope handling system of the institute's neutron generator. The ZrCo getter bed design involved estimating the required quantity of ZrCo to store 20 grams of hydrogen isotopes, based on its theoretical absorption capacity, which guided the sizing of both the primary and secondary vessels.

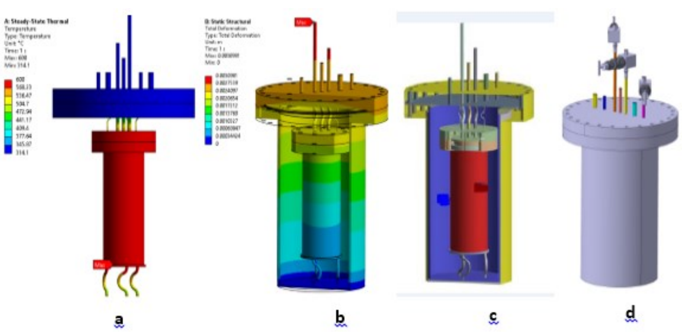


Figure A.2.19: (a) Thermal analysis result (b) Structural analysis result (c) Internal view of primary and secondary vessel with support and tube arrangement (d) Complete vessel isometric view.

Thermal and mechanical analyses were performed to ensure mechanical integrity under operating conditions of 650 °C and 30 bar gas pressure. The internal support structure and tubing were also optimized accordingly, leading to the finalization of the design. The final design was concluded based on these parameters. Figure A.2.19 shows the final results of thermal and mechanical analysis, internal view of primary vessel with support and isometric view of complete vessel.

Interfacing of Experimental Helium Cooling Loop with High Heat Flux Test Facility: A high pressure (10 MPa) high temperature (450°C) Experimental Helium Cooling Loop (EHCL) is in operational. The system is continuously operated at its nominal conditions of 300 °C, 80 bar conditions. Figure A.2.20a shows the actual photograph of developed EHCL system.

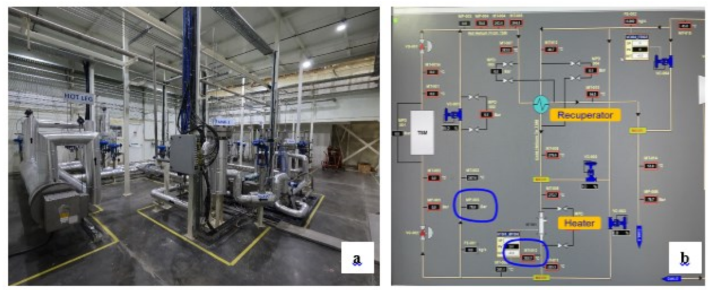


Figure A.2.20: a) Photograph of EHCL system b) Hot testing results of EHCL at 300°C, 80 bar conditions.

Figure A.2.20b shows the results obtained from hot testing of EHCL at 300 °C, 80 bar conditions. One of the important objective of EHCL is to test helium cooled blanket and divertor mock-ups using the existing electron gun system of the High Heat Flux Test Facility (HHFTF). To facilitate the same, an interconnecting system of ~120 m overall length was installed to connect the EHCL and HHFTF systems.

Figure A.2.21: Actual site photographs of interconnecting piping system a) Termination to HHFTF b) Origin of pipes from EHCL.

The piping system shall carry hot helium (300-400 °C) at high pressure (8 MPa) from EHCL pipes to the D-shape chamber of HHFTF system where an electron gun will shower heat on the test mock-ups. These experiments from the test mock-ups shall enable to gather database on heat transfer studies and also make understanding of relevant off-normal / accidental scenarios so as to simulate actual heat extraction of the incident heat coming from a fusion reactor. Figure A.2.21a shows the termination of interconnecting piping system to HHFTF system and figure A.2.21b shows the interconnecting piping system from EHCL side.

Measurements of Effective Thermal Conductivity of Pebble Beds: The effective thermal conductivity of lithium titanate pebble beds has been measured as a function of uniaxial compressive stress (upto 6 MPa), temperature (up to 800 °C) and also with the helium gas pressure (up to 1 bar). The functioning of experimental setup (Figure A.2.22) is based on the transient hot-wire techniques. The temperature of hot-wire was obtained using the four-wire method rather than employing an additional temperature sensor. The estimated error associated with the hot-wire system was below ± 1.0 % and the uncertainty value in effective thermal conductivity was found to be below 1.5 %.

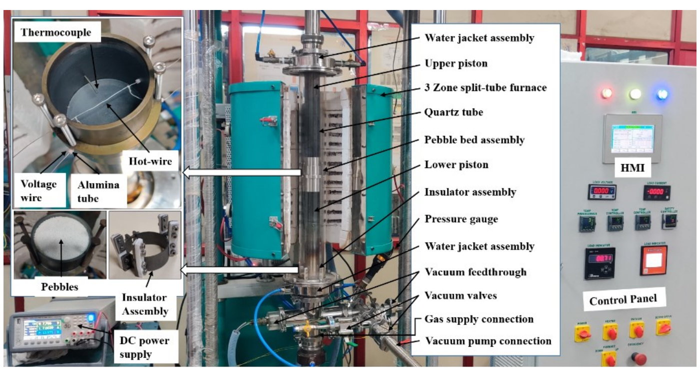


Figure A.2.22: Experimental setup for effective thermal conductivity measurements of pebble beds.

Simulations to Study Packing and Heat Transfer in Spherical and Ellipsoidal Shaped Pebbles:

Packing characteristics of different size variations of spherical and ellipsoidal shaped lithium titanate pebbles have been studied using discrete element method and their effective thermal conductivities were obtained using finite element simulations. The pebbles are generated at the top of the funnel and are allowed to fall under the influence of gravity (Figure A.2.23) in three different cases: (i) 0 Hz, (ii) 20 Hz vibration in the X-direction, (iii) 20 Hz vibration in the Z-direction (direction of gravity).

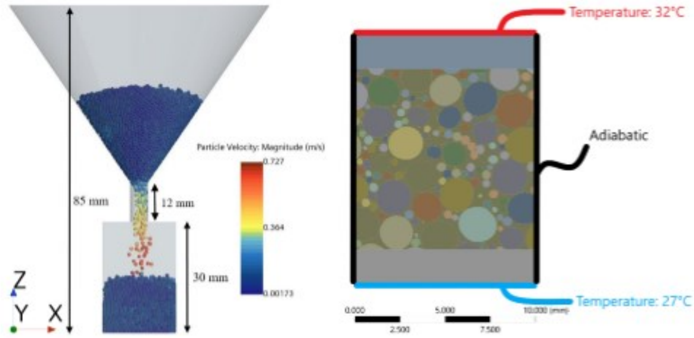


Figure A.2.23: DEM simulation & Boundary condition for thermal simulation of pebble bed.

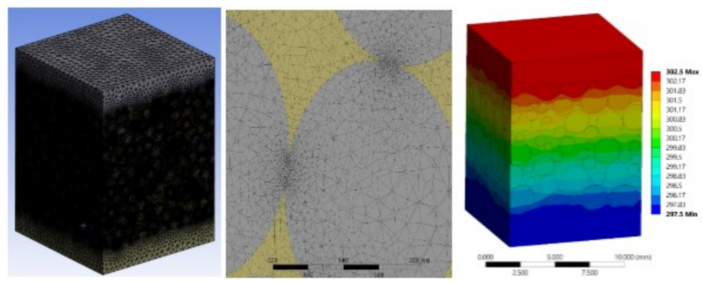


Figure A.2.24: Meshed model & temperature contours of ellipsoidal shaped pebble bed.

The pebbles were allowed to settle down until the total kinetic energy of the bed reached below 10^{-10} J. Steady-state thermal simulations have been conducted for the pebble beds generated by discrete element method (Figure A.2.24) and the results are benchmarked with experiments on the similar type of pebble bed.

Chemical Compatibility Experiments Between Li_2TiO_3 and IN-RAFM Steel: The Fusion blanket comprise of two key materials: Lithium titanate (Li_2TiO_3) as the tritium breeding material and Indian Reduced Activation Ferritic Martensitic (IN-RAFM) steel as the structural material. During blanket operation, Li_2TiO_3 pebbles remain in direct contact with IN RAFM steel and at elevated temperatures, interaction between the elements of the lithium titanate and steel can lead to the formation of various reaction products. Over a period of time, these interactions may result in the development of complex oxide layers. Understanding the nature, composition, and growth kinetics of these oxides is essential for accurate life-cycle assessment and reliable blanket design. To investigate the chemical compatibility between Li_2TiO_3 and IN-RAFM steel, an experimental (Figure A.2.25) setup has been developed. High-temperature interaction studies are being conducted at 550 °C under controlled helium and (0.1% H_2 with helium).

Figure A.2.25: Chemical compatibility experimental setup installed in Fusion Blanket Division.

Initial observations and microstructural analyses, including SEM and EDX, have been performed on samples exposed for 50 hours (Figure A.2.26).

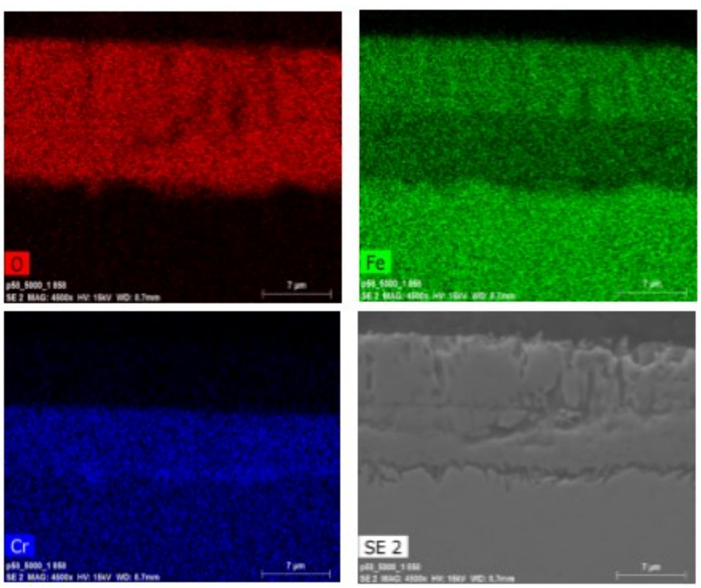


Figure A.2.26: SEM-EDS image of oxide layer after 50 h of experiment.

<u>*Development of Dissimilar Welding of IN-RAFM/SS316LN Steel:*</u> Dissimilar welding was developed using an in-house Tungsten Inert Gas (TIG) welding method to achieve a high-quality weld between IN-RAFM and SS316LN materials. The welding process involved fabricating a dissimilar weld coupon by various interlayer buttering materials and filler wire i.e. S316L and INCONEL-82 to enhance weld-ability and mechanical performance (Figure A.2.27). Investigations also were carried out with and without buttering layers and subsequent followed by post-weld heat treatment (PWHT).

Figure A.2.27: Dissimilar weld joints of IN-RAFMS – SS 316LN using INCONEL-82 filler wire.

A2.4 Large Volume Cryoplant Technologies

<u>*Helium Refrigerator-cum-Liquefier (HRL) Plant Re-installation Activity:*</u> The HRL plant developed at the institute was dismantled in the components were shifted to new allotted space at new R & D Lab. The over all system and sub-system layout were modified according to the space available at new Lab. Several new items for the purpose of reinstallation and commissioning purpose have been procured. Pipe layout work, fabrication of platform in the compressor room, oil removal system, etc. are in progress.

<u>*Improvements in Performance and Reliability of HRL Plant for Possible use in SST-1:*</u> The test operation of the indigenous HRL plant and various previous tests at different levels like, component, sub-system, system and plant have been done with the aim of improving the plant performance. In the compressor system, improvements in secondary oil removal system to have oil content < 2 PPB (parts per billion) is planned for long duration operation (few weeks) of the compressor system. More number of room temperature and low temperature control valves in the plant cycle can improve control of flow rate and pressure, and it can lead to higher efficiency of the plant. Better operational software for Gas Chromatographs for measurement of online and continuous impurities at the strategic points of the plant cycle will improve reliability of the plant. More numbers of heat exchangers and of higher fin density (780 fins/m) can be included in the cold box to increase the efficiency of the plant. Some of these have been procured and some are in progress.

Development Activities to Make the Plant Fully Indigenous: The developed HRL plant at the institute has about 90 % indigenous content. Except turbines and cryogenic valves, all other critical items have been made indigenously and further improvements in reliability and efficiencies of these are in progress.

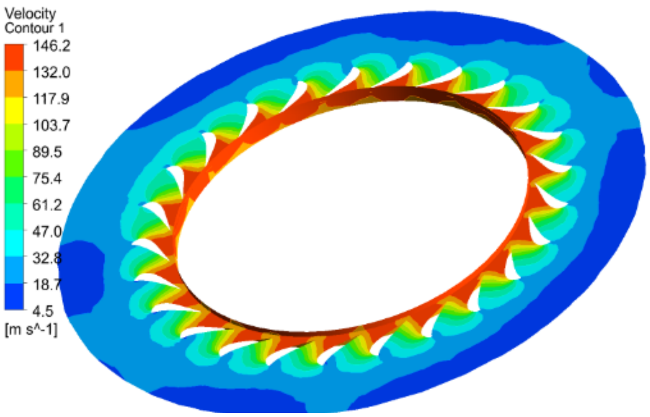


Figure A.2.28: Velocity field around nozzles of helium turbine.

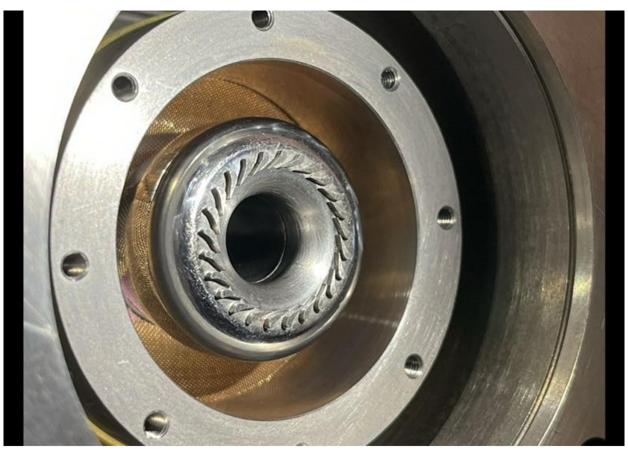


Figure A.2.29: Fabricated LTS of helium turbine.

Turbines, cryogenic valves and temperature sensors below 80 K are also under development. Recently the low temperature sub-assembly (LTS) which houses nozzles with complex heat in-leak reduction mechanism has been manufactured successfully as a trial piece with tolerance of ±20 micro for the helium turbine, whose nominal rotational speed is 1.6 lakhs RPM (Rotations per minute), cooling power of this turbine is ~1 kW, nominal operating temperature range is 15 to 10 K. Figure A.2.28 shows the velocity field variation around the nozzle as per CFD analysis and Figure A.2.29 shows the fabricated nozzles by the AIC of C V Raman Global University, Bhubaneswar.

The cryogenic valve development is being done by industry and R&D organizations within India. For 4.5 K, low heat in-leak and helium leak tightness with bellow-sealing are necessary. Improvements in these directions have been made through a Indian valve supplier. Figure A.2.30a shows the manufactured long stem valve with thermal intercept and low cross -sectional area to reduce heat in-leak. Temperature sensors, both Silicon diode and Cernox type have been developed recently as shown in figure A.2.30b. The temperature sensor calibration set up down to 2.8 K and accuracy up to ±10 mK could be made and shown in the figure A.2.30c.

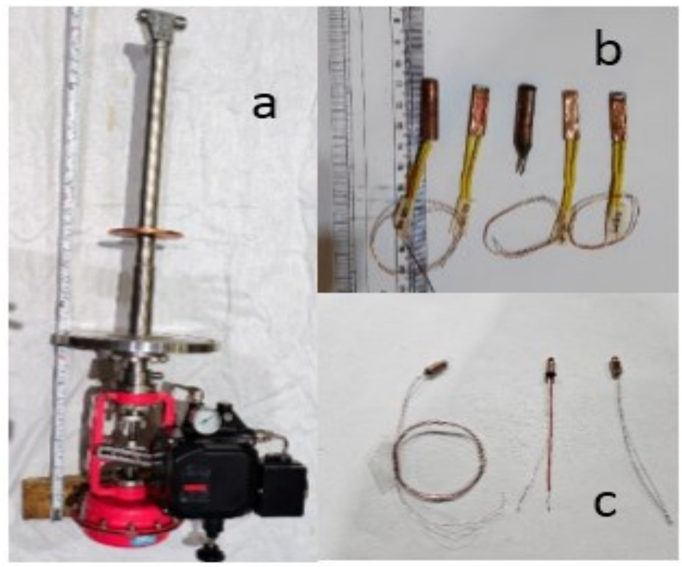


Figure A.2.30: a) Indigenous cryogenic long stem control valve, b) Silicon Diode temperature sensors. and c) *Zirconium nitride (cernox) temperature sensor.*

Development of 65 K Pressurized Helium Circulation System: Based on the successful development of pressurized 80 K helium circulation system, a new 65 K pressurized helium circulation system is being developed. In this system, LN_2 precooling heat exchanger will be used with a vacuum pump to reduce the boiling pressure and boiling temperature of nitrogen. It is planned for a smaller helium flow rate of ~10 g/s and operating pressure ~14 bar. This cooling concept can be useful for HTS (high temperature superconducting) magnet cooling and cryosorption pump cooling. Design and analysis of component layout has been completed for this system.

A2.5 Remote Handling and Robotic Technologies

Dual Arm Manipulator (DAM): A 12-DOF DAM System has been developed and successfully demonstrated as shown in figure A.2.31. DAM can perform operations like picking, placing, manoeuvring, manipulating (minor assembly or disassembly) of components. Each arm of DAM is having six degrees of freedom and has ~5 kg payload, reach of ~1m length. DAM actuator system consist of modular rotary joints with integrated Brushless Direct Current, BLDC motor, gearbox, incremental and absolute encoders, holding brake and motor drive. The system also has head and hand cameras. The DAM system is demonstrated for integrated system functionality with Tool Centre Point (TCP) alignment within a 5 mm cube. Also, a central winch has been developed with lifting payload of 50 Kg. The integration of winch system with DAM is being planned.

Figure A.2.31: Dual Arm Manipulator.

<u>Haptic force feedback arm:</u> To execute dynamic RH tasks safely, a 'man-in-loop' architecture is typically followed. A 6 DOF haptic master arm with force feedback has been developed and successfully tested. Tele-manipulation experiments with virtual reality integration are being planned.

<u>Hyper-Redundant Inspection System (Hy-RIS):</u> HyRIS is a tendon driven long reach arm, having dexterity similar to an elephant trunk deployable in narrow spaces, challenging environments etc. An 18 axes HyRIS system with linear translation has been developed and is shown in figure A.2.32. The control system integration & testing for simultaneous motion of the 18 actuators has been completed and initial trials successfully completed synchronized motion. The system is being programmed and tested for various motion scenarios.

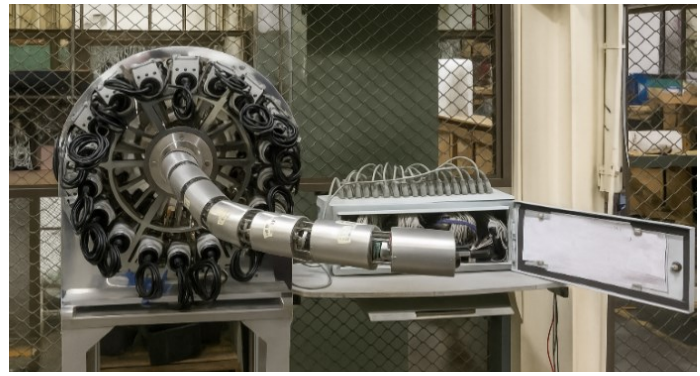


Figure A.2.32: HyRIS System.

<u>Prototype Gravity Compensation (GC) System:</u> A gravity compensated robotic joint has been developed and is shown in figure A.2.33. By integrating gravity compensation, the robotic arm can retain position or carry out precise motions safely with less strain on actuators. In haptic applications, the gravity compensation aids in better accuracy and force rendering for master-slave tele manipulation.

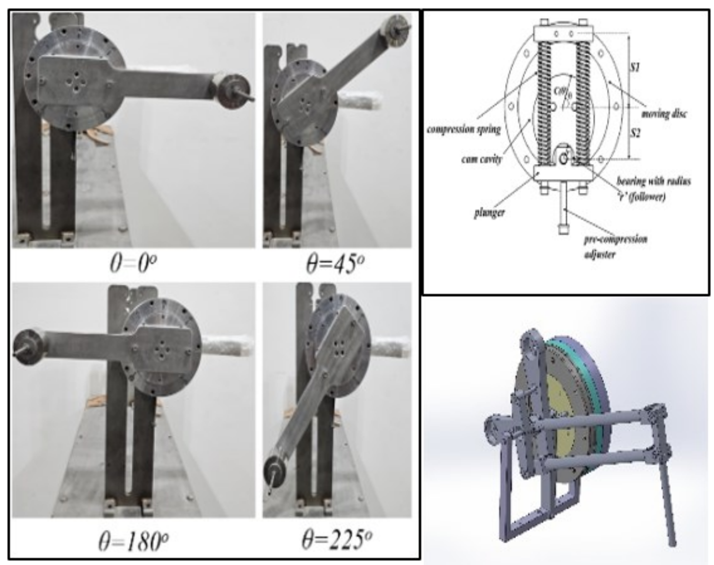


Figure A.2.33: Gravity compensated joint.

<u>Vacuum Automation System:</u> The tendon driven vacuum automation system has been developed (Figure A.2.34) for a sample tile rotation inside vacuum vessel (10^{-7} mbar) and successfully tested for motion under vacuum. In this process tile will be retracted back around up to 200 mm and then it will be rotated by 180 degrees to provide the clear view of the tile for diagnostic/characterization purpose. The Major components include actuation system, vacuum feed-through, vacuum chamber, support structure, vacuum pumps and gauges. The actuation system consist of

three linear actuators which are independently being controlled by three DC servo motors and the linear actuator consist of ball screw and nut, linear motion rail and block, end peripherals etc. Virtual Reality, VR integration of the system is ongoing.

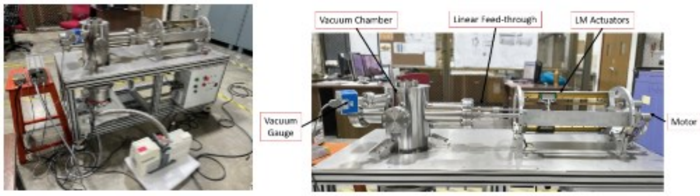


Figure A.2.34: Vacuum automation system.

A2.6 Negative Ion Neutral Beam Technologies

Negative Ion Beam Experimental Setups: Two negative ion sources are in operation: (1) TWIN, and (2) ROBIN. TWIN source has two RF drivers powered by a 180 kW, 1 MHz RF generator. Coupling of 75 kW of RF power is achieved to generate hydrogen plasma at a pressure of 0.9 Pa, with a power factor of more than 0.8. Figure A.2.35 shows the TWIN source setup, plasma formation, and a typical characteristic discharge waveforms. The hydrogen plasma density of the order of 10^{17} m^{-3} has been achieved. TWIN source has also been successfully operated at a low pressure of 0.3 Pa. During operation, precise tuning of variable capacitors in the impedance matching circuit is needed to maximize RF power coupling with the plasma. A graphical user interface (GUI) based control program is developed to adjust the multiple stepper motors using TWIN DACS for impedance matching remotely. Beyond 75 kW, coil breakdown is observed, which motivates measuring the voltages across the RF coils. The measurements, using Rogowski coil and high-voltage probes, confirmed that the voltage values are in the range of 19 to 21 kV (peak-to-peak) and are responsible for coil breakdowns.

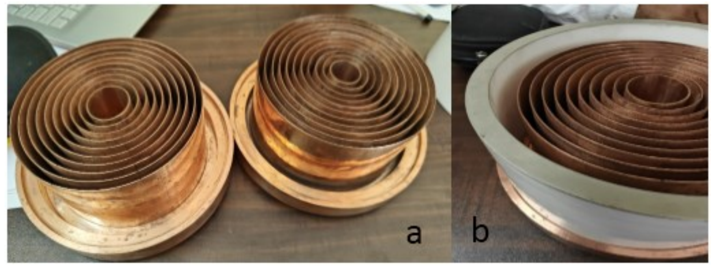


Figure A.2.36. (a) Photograph of the ERID high voltage feedthrough and schematic of the ERID set-up. (b) Voltage and current profile of -13kV, 2A DC power supply during neutral beam experiments of ROBIN.

The ROBIN setup was upgraded with new Electrostatic Residual Ion Dump (ERID) high voltage feedthroughs (>20 kV) and a new HV power supply (13 kV, 2 A) to facilitate high-energy (> 35 keV) neutral beam operations. To enhance the overall performance and reliability of the neutral beam system, the HV power supply is integrated with ROBIN DACS to allow automated, remote, and safe operation. The present ERID high voltage feedthroughs (04 Nos.) are designed, fabricated, assembled, tested, and implemented in ROBIN. Figure A.2.36 shows a picture of a HV feedthrough with its integration scheme with the ERID plates, and a typical waveform of the integrated HV power supply. The new design allows changing the gap (*in situ*) between the ERID plates in ROBIN. The neutral beam experiments were restarted without any fresh Caesium injection into the source and gas into the neutralizer, and around 450 mA (at >25 keV) neutral equivalent current from 690 mA accelerated negative hydrogen current was obtained in ROBIN, having 65% neutralization efficiency.

Figure A.2.35: (a) TWIN Source Test Bed (b) TWIN source Plasma; (c) Typical high RF power coupling plasma shots.

Indigenous Manufacturing and Technology Development:

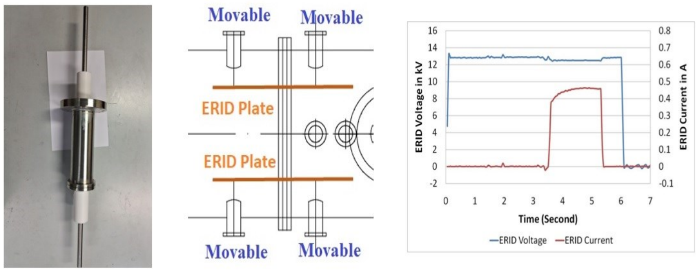


Figure A.2.37: (a) Machined copper parts have circular fins for the capacitor's top and bottom electrodes, (b) Partially Cu-Ceramic brazed assembly.

An electro-deposited ITER DNB-type grid has been successfully manufactured at RRCAT under a collaborative agreement between the institute and RRCAT. This marks the first indigenous development of its kind, aimed at reducing reliance on foreign suppliers. It is also a significant step towards gaining comprehensive process knowledge and ensuring readiness for future components needed for ITER and domestic fusion applications. The initial machining of open cooling channels is done at NFTDC, Hyderabad, followed by chemical cleaning, waxing, and preparation of the electrolyte bath. The electro-deposition, up to a thickness of 3 mm, was carried out at RRCAT. The final aperture machining is performed at NFTDC. Significant progress has been made in another indigenous import-substitute development of fixed vacuum capacitors for high voltage RF applications. Vacuum brazing using a copper-silver brazing alloy is being explored to join the ceramic to the copper parts (Figure A.2.37).

The grid system for the TWIN source and its supporting HV insulated grid holder box and flange are manufactured and received for the negative ion beam operation phase. The manufacturing process meets the required dimensional tolerances according to ISO 2768 mK standards. The flatness and parallelism were also maintained within the specified limit of 500 microns. Given the high-vacuum application, surface roughness was carefully controlled, achieving a final roughness of 0.6 microns (Ra value).

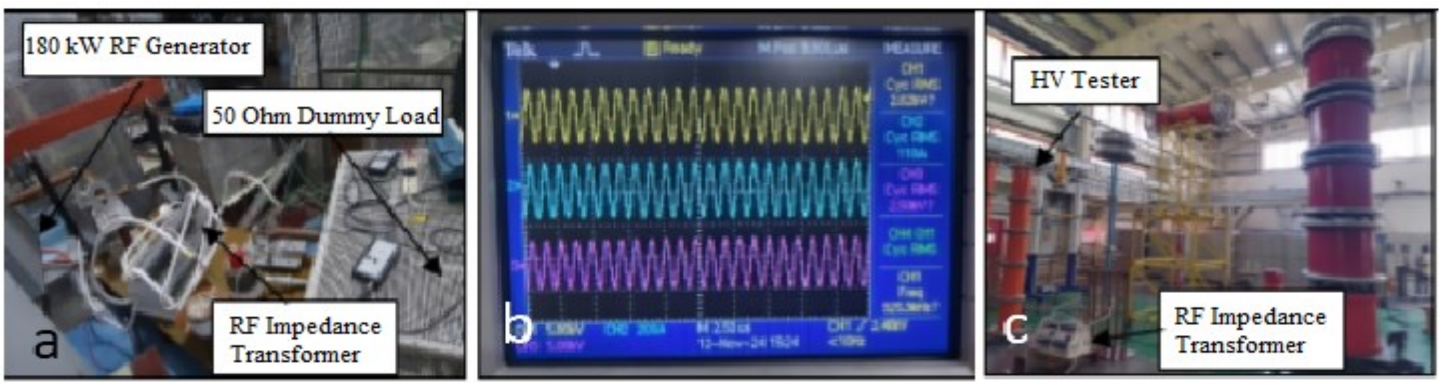


Figure A.2.38: (a) Experimental test setup of RF Transformer using 180kW, 1MHz RF generator & 50Ω RF dummy load. (b) The voltage and current waveforms during the testing of the transformer at 150kW. Transformer input Voltage (pink: 1V in scope = 1V actual), output voltage (yellow: 1V in scope = 1V in actual) & output current (blue: 1A in scope = 0.5A actual). (c) HV isolation testing between primary and secondary of the transformer at 150kV in UHVPS Facility.

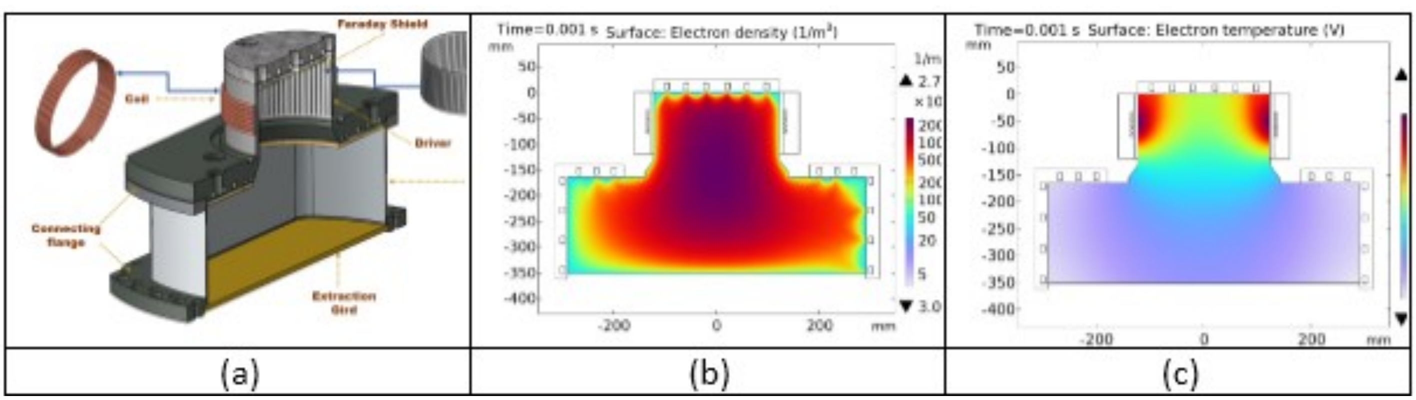


Figure A.2.39. COMSOL data: (a) A 3D cross-sectional view of the ROBIN ion source and its essential components used for modeling. (b) Plasma density profile, and (c) plasma temperature profile at 0.3Pa, 50kW RF power.

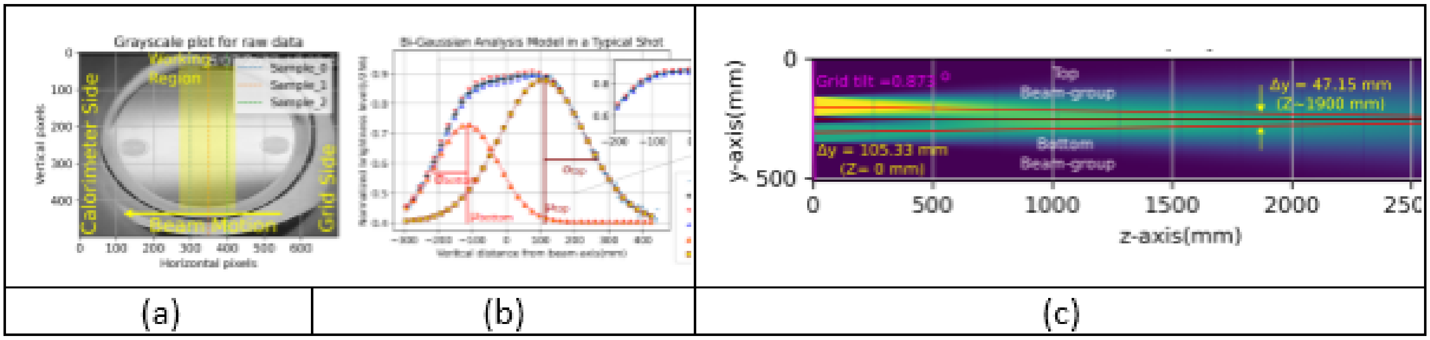


Figure A.2.40:. Beam modelling: (a) Experimental data from the CCD, (b) Superposition of top-bottom beam groups, (c) Schematic representation of top-bottom beam group merging along the downstream.

A high-power RF impedance transformer of rating 150 kW, 1 MHz, and 150 kV DC isolation has been successfully developed for use during the high-power TWIN source experiment. It was a DPR proposal and part of the "DAE 100-day target". The transformer has been developed using Toroidal Ferrite cores, RF-compatible cables, and supports (Figure A.2.38).

Simulation/Modeling Activities: A finite-element-based simulation using COMSOL Multiphysics software has been started to study the plasma dynamics in the ROBIN ion source plasma chamber for different pressures, RF power, and magnetic field configurations (Figure A.2.39).

The ion beam emerging from the ROBIN source was experimentally characterized using a CCD camera mounted transversely to the beam axis at a position 1900 mm downstream of the grid assembly's grounded grid. The CCD's pixel array derived the total beam's vertical intensity profile. To characterize the beam quantitatively and to understand its dynamics for different operational parameters, a numerical modelling technique is applied to the experimental data, which exhibits a superposition of two vertically merging beam groups from the top and bottom grid sections (Figure A.2.40).

A2.7 Neutron Irradiation Activities

Neutron Irradiation of Electronic Components:

In harsh environments like nuclear reactors, particle accelerators and outer space research, electronic components are exposed to high-intensity of ionizing radiation and possibly fast neutrons. These electric systems should be tested for their resilience to such exposure and associated degradation of material over time. Neutrons of high energy can cause atomic displacement in the material, resulting in material defects leading to change in conductivity and equipment failure. Such experiments are conducted for the electronic devices like, opto-couplers, field effect transistors, static random access memory, analog to digital converters, and instrumentation amplifiers.

In these experiments (Figure A.2.41), the functionality of the system was tested before radiation exposure. The experiment was conducted with periodic exposure to fast neutron flux and the cumulative damage was recorded. Performance evaluations after each step of irradiation showed the opto-coupler partially damaged at 5.31×10^{11} n/cm² and completely damaged at 1.77×10^{12} n/cm².

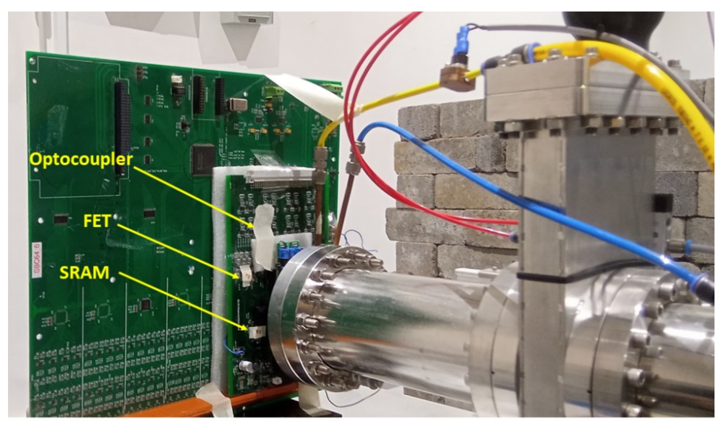


Figure A.2.41: Experimental setup for testing of electronics components.

Medical Radioisotope Production:

The demand of medical isotopes is increasing day by day and the scientific community is working to find innovative methods to produce and deploy them. Institute's 14 MeV neutron generator facility can be utilized to explore nuclear reaction channels that have a high neutron absorption threshold, and are not possible in thermal nuclear reactors.

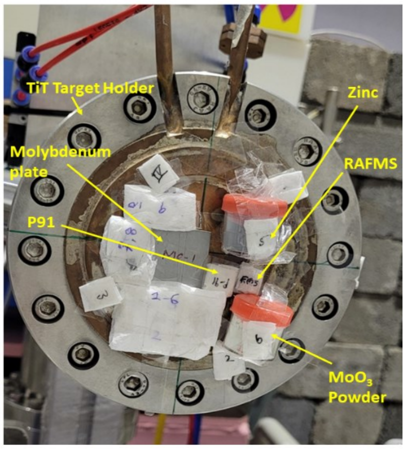
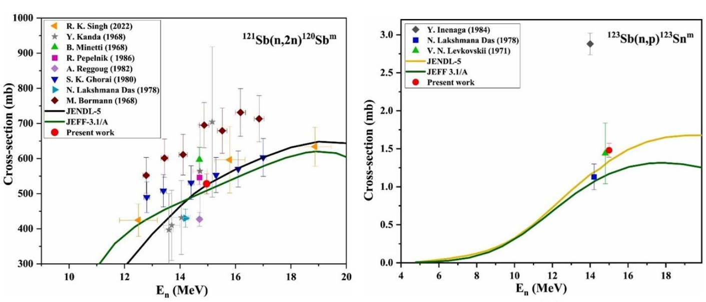


Figure A.2.42: Experimental setup for testing of Samples for medical isotopes electronics components.

At present diagnostic and the anostic medical radioisotopes production experiment has successfully been conducted for Mo-99, Cu-64 and Cu-67. Mo-99 is used to produce Tc-99m, which is in turn used for more than 80% diagnostic procedures worldwide. In the experiment molybdenum metal plate and molybdenum trioxide powder samples were used. Cu-64 and Cu-67 are used for various scan and therapeutic purposes (Figure A.2.42). During the experiment, these isotopes were produced from natural zinc. Neutron irradiation of molybdenum metal plates and MoO_3 powder has generated Mo-99 with specific activities of 48 kBq/gm and 0.24 kBq/gm, respectively. Similarly, zinc metal powder irradiation produced Cu-64 and Cu-67 with specific activities of 34.76 kBq/gm and 0.21 kBq/gm.

<u>*Neutron Induced Reactions Cross-section Measurement:*</u>

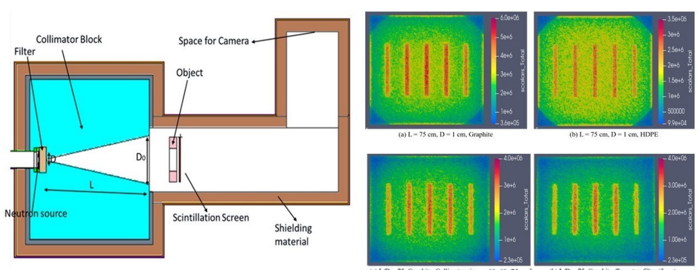


(a) (b)

Figure A.2.43: Comparison of measured cross-section of with existing experimental data and evaluated libraries with ENDF (a) $^{121}Sb(n,2n)^{120}Sb^{m}$ (b) $^{131}Sb(n,p)^{123}Sb^{m}$.

Experiments were performed to investigate the reaction cross sections of the reactions: ^{121}Sb(n,2n) ^{120}Sb^{m}, ^{123}Sb(n,p)^{123}Sn^{m}, ^{90}Zr(n,p)^{90m}Y and ^{90}Zr(n,α) ^{87m}Sr. In the experiment, mono-energetic neutron of 14.96 ±0.03 MeV were used for sample activation followed by offline gamma ray spectroscopy. HPGe detector was used to determine the activity generated during the experiment. Later, the data analysis includes covariance study of experimental data for fast neutron induced reaction (Figure A.2.43).

<u>*Design of Neutron Radiography System:*</u> Fast neutron radiography is a non-destructive tool in which an object is exposed to high energy neutrons and estimate the elemental composition and structure of thick and dense objects. Conventional techniques like x-ray radiography are applicable only for low density material. On the other hand, fast neutron radiography uses the high penetration power of fast neutrons to analyse the internal structure and elemental composition of the sample.



(a) (b)

Figure A.2.44: (a) Proposed neutron radiography system and (b) Radiography image.

Simulation studies are carried out to make use of the 14 MeV neutron generator facility for fast neutron radiography on large samples. Various parameters like L/D ratio, moderator and reflector thickness, sample size and distance are optimized to get high quality image. A uniformity of 78% was achieved between the center and the end of collimator with a scattering ratio of 6%. A high neutron to gamma ratio of 6.05×10^{6} n/cm2 mR^{-1} will be available at the object (Figure A.2.44). The simulation study also includes the thermalization of the neutrons for high image resolution due to low scattering. However, in that case the penetration depth of the neutrons is low, effecting the sample thickness. Simulation results shows that 75.5% of neutrons had the energy of 1 eV or below with a total flux of 10^{5} n/cm2, ensuring high quality images.

A2.8 Fusion Related Diagnostics

<u>*Prototype of view dump for Vertical Electron Cyclotron Emission (VECE) diagnostics:*</u> A prototype of the view dump, designed using different materials and geometries, was simulated in CST Studio Suite and the results have been documented (Figure A.2.45). The electromagnetic (EM) response of various geometrical configurations — including slabs, pyramids, and inverted cones — was analyzed across the microwave to millimetre-wave frequency range (60–180 GHz), using materials such as Boron Carbide (B_4C), Silicon Carbide (SiC), and MACOR. Based on the simulations, prototype structures were fabricated in MACOR to experimentally validate the EM performance. The experimental characterization of the slab, pyramid, and inverted cone geometries is presented below.

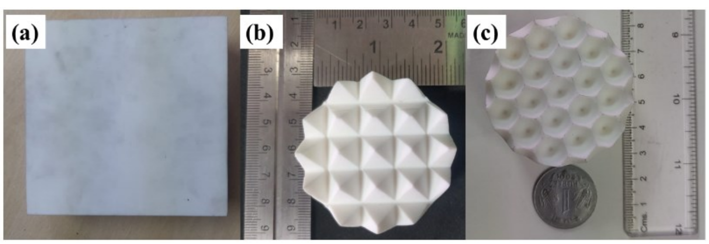


Figure A.2.45: Fabricated prototype geometry made of MACOR: (a) slab, (b) pyramid, and (c) inverted cone.

<u>*Nano DAQ Characterization:*</u>

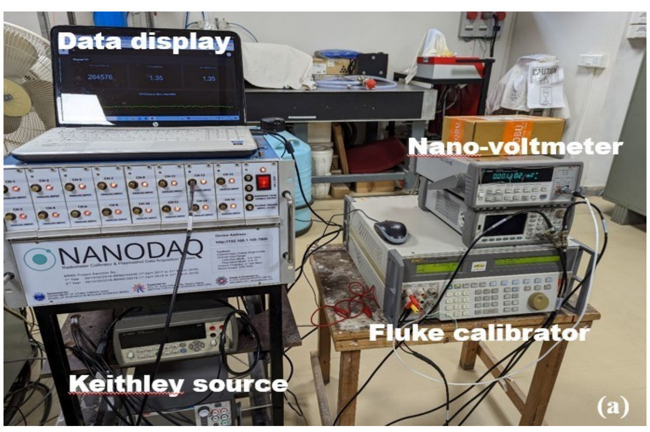


Figure A.2.46: Set-up for in-lab characterization of newly developed instrument – NanoDAQ.

A 16-channel low voltage data logger cum data acquisition device developed under BRNS to be used for Radiometer diagnostic calibration. The instrument was initially characterised in-lab (Figure A.2.46) using low voltage input from Keithly meter (source) and a fluke calibrator. The data was simultaneously detected on the Nano DAQ and on the Agilent make, single channel, Nano voltmeter for comparison. The results matched reasonably. Further, the device was characterised at EQDC, Gandhinagar for its performance at different temperature & humidity conditions.

<u>*Investigating the ECE Radiometer Diagnostics Measurements in the Presence of Electron Cyclotron Resonance Heating (ECRH):*</u> Besides furnishing localized spatial and temporal electron temperature measurements, Electron Cyclotron Emission (ECE) diagnostics are routinely employed across various tokamaks for diverse physics investigations, encompassing MHD localizations, transport studies, and fluctuation measurements (Figure A.2.47).

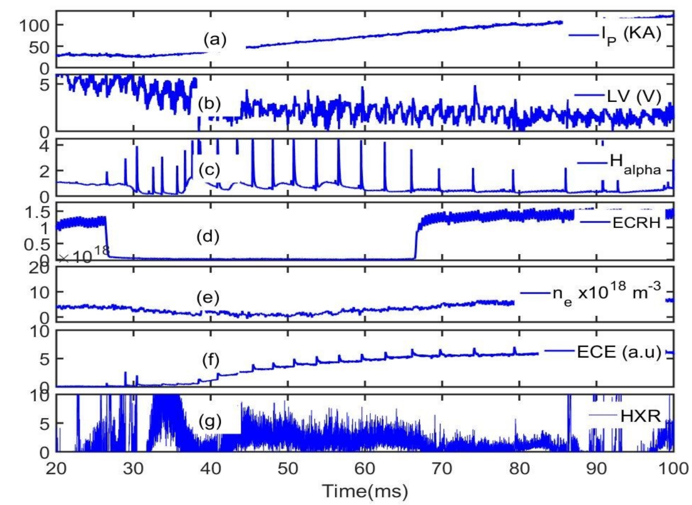


Figure A.2.47: Temporal evolution of various plasma parameters a) Plasma current (IP) b) Loop voltage c) H-alpha d) ECRH pulse e) plasma electron density f) Central ECE ch.amplitude and, g) HXR (Hard X-ray.

Variations in the bulk of the electron distribution function manifest as alterations in ECE signatures, often attributable to the presence of fast electrons induced by auxiliary heating mechanisms such as Electron Cyclotron Resonance Heating (ECRH). Further, the impact of ECRH application, including preionization and heating, resulting in ECE signal saturation and an expected rise in electron temperature (T_e) respectively. Furthermore, the discourse explores instabilities potentially induced by high-energy electrons stemming from ECRH, focusing initial observations on runaway discharges characterized by relaxation oscillations in ECE, Soft X-ray (SXR), CIII, and H_α emissions.

Reflectometry Diagnostics and Computational Simulations for Tokamak Edge Physics: A new diagnostic FMCW reflectometry which measured for the first time the edge density profiles has been established. Several publications on hardware design and testing, signal processing methods employed are made and advanced signal processing codes under development. Indigenization of IF section hardware for the microwave detection with comprehensive performance validation in lab. Timing and driver electronics for the frequency source have also been indigenized, custom hardware design for the same is now complete and ready for fabrication.

Analysis code also developed in-house has been completely documented, presented in International Reflectometry Workshop and extensively peer reviewed by top international experts in reflectometry. To mitigate the noisy tokamak environment, software methods like Empirical Mode Decomposition and Wavelet based MOPDWPT followed by the standard spectrogram method are being developed. Multiple advanced methods to extract localized information in both time and frequency domains were also investigated extensively. A parallelized computational code was deployed on the HPC Antya. The measured edge density profiles from FMCW reflectometry were used as input and edge turbulence model was solved (Figure A.2.48). The results obtained match qualitatively the expected physics in tokamak edge

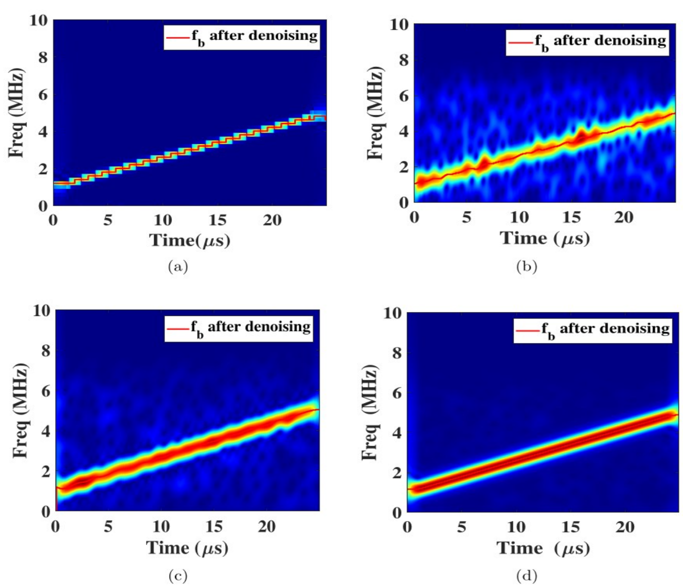


Figure A.2.48: Estimated signal frequencies after denoising using wavelet method for complex linear chirp for different time-frequency analysis methods being considered a) FSST b) PCT c) SCT and d) GWT.

The Design and Development of PLL Source for Microwave Interferometer System: For Interferometer system the high frequency stable sources are required because as high the frequency stability the phase measurement will be more accurate. The design and development of prototype PLL source for lower frequency (7GHz-8Ghz) has been done (Figure A.2.49).

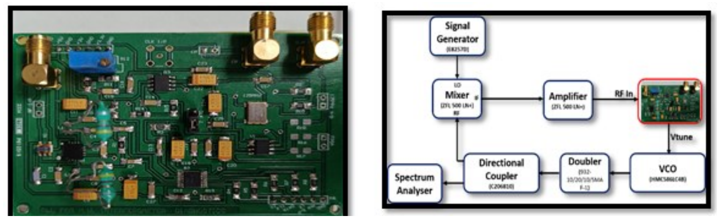


Figure A.2.49: Actual photograph of PCB designed with measurement set up.

The PLL design is simulated in sim PLL software for the desired frequency and different type of loop bandwidth. A characterization and calibration of PLL source has been done on spectrum analyser.

Numerical Design and Experimental Characterization of Reconfigurable Leaky Wave Plasma Antenna:

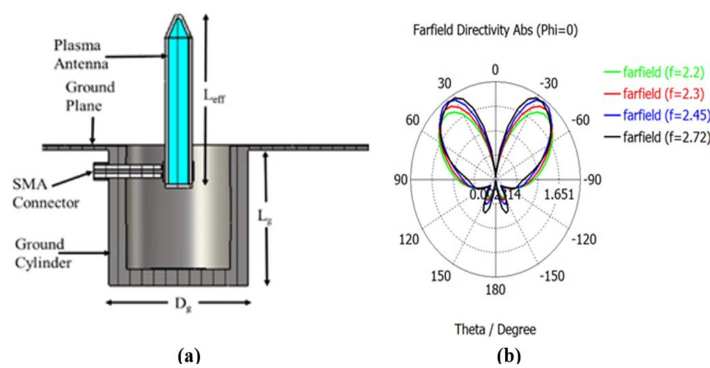
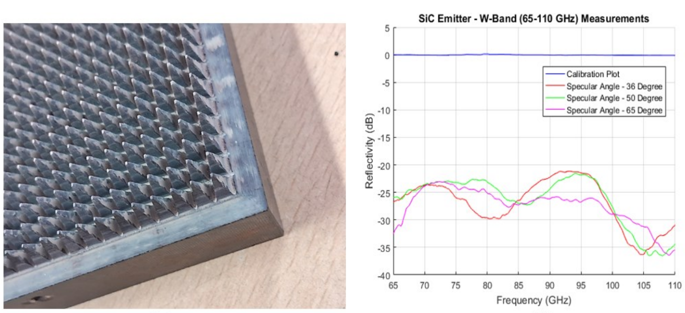


Figure A.2.50: (a) Plasma Antenna, (b) 2D Polar Plot of the Plasma Antenna.

The design, development and characterization of a leaky wave plasma antenna at 2.45 GHz has been done which has potential application in military Wi-Fi, in areas where a continuous change in frequency is required. The design of the cylindrical plasma antenna is optimized by varying the plasma tube and ground cylinder dimensions to achieve better impedance matching (S11) of the antenna. Furthermore, the axial length of the plasma generated inside the tube is directly proportional to the input excitation power, which also determines the plasma resonant frequency, making it possible to fine-tune the resonant frequency.

The novelty of this work lies in two key achievements that surpass previously reported results. First, this designed antenna achieves an enhanced directivity of 4.31 dBi, coupled with a broad bandwidth of 441 MHz at 2.45 GHz. This represents a substantial improvement over prior designs. Second, and most notably, the antenna attains a high radiation efficiency of 73.8%, a benchmark not reached in earlier studies. These advancements underscore significant contributions to the field of plasma antenna technology. The designed plasma antenna (Figure A.2.50*)* is fabricated and characterized experimentally to determine its resonant frequency and scattering parameters. A 10 KHz AC power supply is used for plasma generation inside the tube. The experimental results obtained are consistent with the simulation results.

Design, Development and Characterization of Indigenously Developed High Temperature Black Body Source for Calibration of ECE Diagnostics: The design, development, and characterization of a Silicon Carbide (SiC) based high-temperature black body source at 600 ºC for Electron Cyclotron Emission (ECE) measurements has been done (Figure A.2.51). The design has been optimized for higher emissivity performance in 65-140 GHz frequency range using CST Microwave Studio. The innovative design features a pyramid-based structure, incorporating a heater and emitter surface, integrated with an electrical control system.

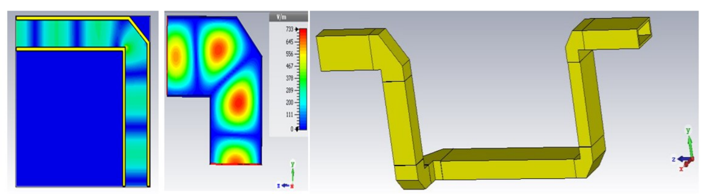


(a) (b)

Figure A.2.51: (a) Fabricated Emitter Plate, (b) W-Band Characterization Results.

The improvement in emissivity with variation in pyramid slant angle was analyzed. The design was refined to ensure surface temperature consistency within a range of ± 15 ºC and rapid heating, taking less than 60 minutes to reach 600 ºC from room temperature. The developed black body calibration source was thermally characterized using IR camera for different set of temperatures and mean temperature distribution was determined. The microwave characterization of the calibration source has been performed in 65–220 GHz frequency range using Vector Network Analyzer (VNA) and reflectivity of more than 20 dB has been obtained. The results highlight the synergy between advanced design methodologies, and precise engineering, leading to the development of an efficient SiC-based black body source. This research work not only contributes significantly to the field of engineering but also paves the way for enhanced accuracy and reliability in ECE measurements.

Design, Simulation and Testing of Wave Collection and Transport System for Michelson Interferometer Diagnostic: A Wave Collection and Transport System (WCTS) has been designed and simulated using CST Microwave Studio to transport electromagnetic waves from tokamak hall to the Michelson interferometer (MI) system (Figure A.2.52). The MI system is the diagnostic used for plasma electron temperature profile measurement on the tokamak. Simulations were carried out in the frequency range 70-170 GHz range for the transmission line components using CST microwave studio. To minimize propagation losses, oversized waveguides were chosen instead of fundamental.



(a) (b)

Figure A.2.52: (a) E-field pattern for E and H plane mitre bend, (b) Geometry of an Oversized WCTS.

For selection of suitable oversized waveguide, simulations were performed in S, X and Ka band and best performing band was selected for WCTS. These oversized waveguides not only reduce propagation losses but also decrease the group delay of the propagating wave as compared to fundamental waveguide. The primary components of the oversized WCTS include waveguides, miter bends in both E and H planes, and wire-grid polarizers (WGP) to select the polarization of electromagnetic waves from the plasma. While the use of oversized waveguides significantly reduces the overall transmission line losses, it also introduces the issue of higher-order modes. The transmission line components have been designed, simulated, and experimentally validated in the laboratory, and the results have been presented.

Operation of Positive Neutral Beam Using Cryo-

sorption Pump:

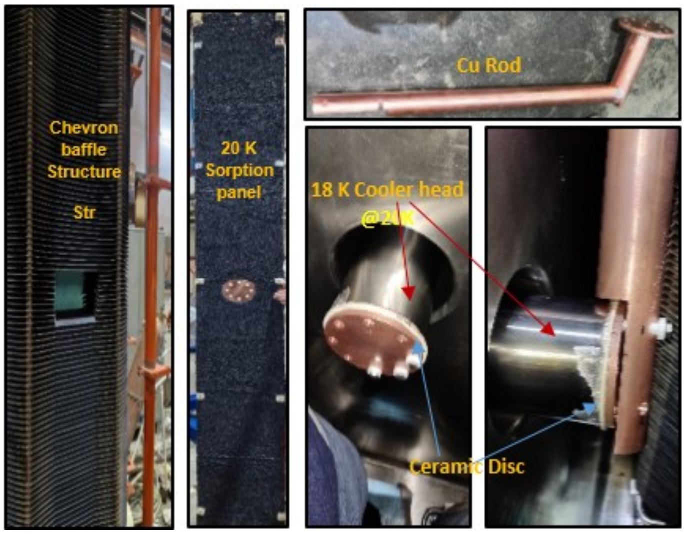


Figure A.2.53: Positive neutral beam assembly using cryo-sorption pump.

Normally in Positive Neutral beam (PNB) System, beam is extracted using 4 K Cryo-condensation pumps because of the requirement of high gas throughput (H_2) of 30 Torr l/s upto higher throughput of ~100 Torr l/s to maintain background pressure of ~10^{-5} mbar along the beam propagation path. Four Cryo-condensation pumps were operating at 4 K using a Helium Refrigerator Plant. Presently, a charcoal coated Cryo-sorption pump using a 20 K Cryo-cooler was proposed for beam operation in the PNB test stand. Cryo-sorption pump with an area of 1.8 m^2 has been characterized for Hydrogen gas with different gas throughputs ranging from 5 Torr l/s to 40 Torr l/s, tests conducted in PNB vacuum vessel of 20 m^3. The setup was consisting of a Cryocooler @20 K, connecting Cu rod and a Sorption panel enclosed within the Chevrons baffles @80 K as shown in the figures A.2.53. The pumping speed observed was ~1.7 x 10^5 l/s at 1.4 x 10^{-4} mbar with gas feeds upto 40 Torr l/s. However, using such pump with a Cryocooler in harsh electrical/electro-magnetic environment during PNB operation is a challenge. Idea of using an Alumina disc in the thermal path between the cold head (18 K) and Copper rod connected to sorption panel was devised to protect the Cryocooler electronics/electrical components. Tests were conducted for electrical isolation using a hi-pot @500 V, 1 MΩ.

Thermal performance and pumping performance tests were conducted. Subsequently, beam operation was conducted upto 30 kV, 20 A for 3 days with a maximum gas throughput of 25 Torr l/s (Figure A.2.54). The vessel pressure was stable at ~1.4 × 10^{-4} mbar. The Cryocooler worked without any issues/ interruption during the beam operation (figure A.2.55). The objective of using a sorption pump (in place of condensation pump) with a Cryocooler has been achieved successfully and Beam operation in test stand mode was simplified without operating the Helium Plant.

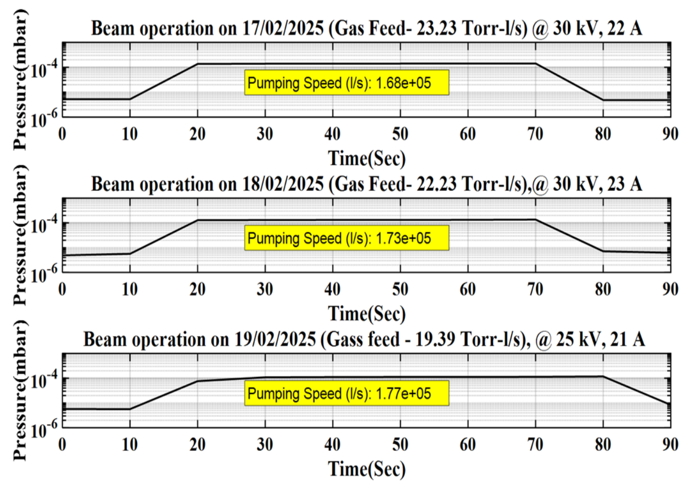


Figure A.2.54: Positive neutral beam operation with cryo-sorption pump.

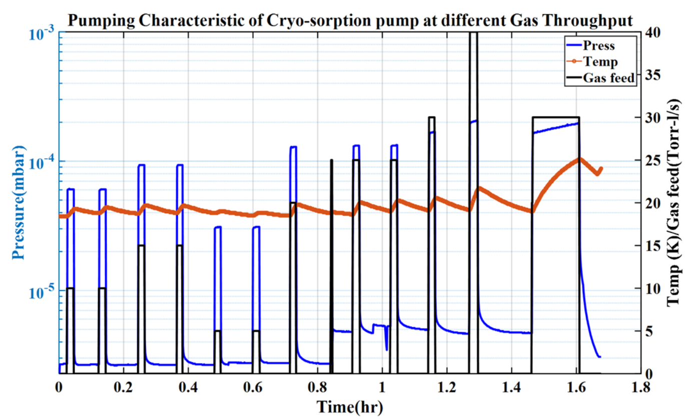


Figure A.2.55: Pumping of cryo-cooler using gas feed.

Spectroscopy Diagnostics: Upgraded space resolved visible spectroscopy diagnostic has been operated on the Aditya-U tokamak (minor radius 25 cm) for measuring the temporal evolution of spatial profile of the visible spectral lines. The upgraded system is having capability to record 15 no. of tracks on the sCMOS detector coupled with 1 m long high resolution spectrometer.

The spectral resolution of the system is 0.026 nm at 50 mm entrance slit width. With this system, the measurement of spectral line emissions from high field and low field sides of ADITYA-U tokamak has been carried out as shown in figure A.2.56 for investigating poloidal asymmetries in neutral and ion temperatures and impurity transport. The spectrum contains the spatial profiles of H_α (656.28 nm) and C^{1+} (657.81 and 658.29 nm) lines. The measurement covers the outboard half of the poloidal plasma cross-section (r = 0 cm to r = +22 cm) and the inboard half of the poloidal plasma cross-section (r = 0 cm to r = −18 cm) viewed through the 20 lines of sights. Here, the data from two similar discharges have been utilized to cover the entire plasma cross section due to the limited number (12) of relaying fibers (20 m long) transferring light from the tokamak to the spectrometer.

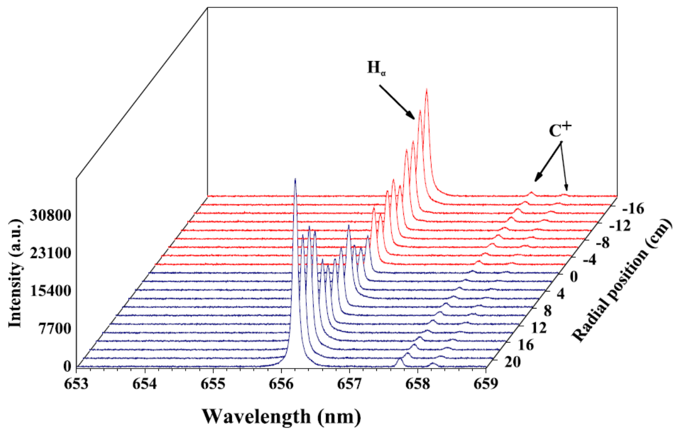


Figure A.2.56: Space-resolved spectra having Hα and C1+ lines spanning over the entire plasma poloidal cross-section of the ADITYA-U tokamak plasma.

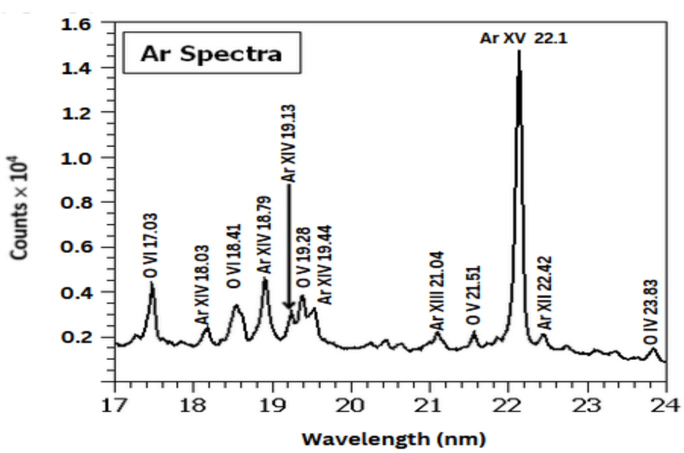


Figure A.2.57: VUV spectra with Ar gas puffing into the Aditya-U plasma recorded by VUV survey spectroscopy system showing Ar spectral lines.

An anomaly in the intensities of VUV spectrum of Ar^{13+} recorded from Aditya-U tokamak has been noticed as shown in figure A.2.57. It has been seen that the intensity of the resonance line at 18.03 nm ($2s2p^2\ ^2P_{3/2}$ - $2s^22p\ ^2P_{1/2}$) VUV line is smaller than the line at 18.79 nm ($2s^2\ 2p\ ^2P_{3/2}$ - $2s2p^2\ ^2P_{3/2}$) of the same ions. This observed anomaly has been explained through the theoretical estimation of intensities of those VUV lines. The theoretical calculation has been done through the generation photon emissivity coefficient using ADAS database and by obtaining the Ar^{13+} ion density through the modelling of observed visible spectral lines of Ar^{1+} ions and VUV spectral lines of Ar^{13+} and Ar^{14+} ions. It has been found that this variance can be explained using the absorption oscillator strengths associated with these transitions of Ar^{13+} ion.

<u>*Progress in Pellet Injector Technology Development for Fueling and Plasma Control:*</u> Fueling and plasma control are critical aspects of the successful operation of magnetically confined fusion devices, especially tokamaks. Ice pellets, created from various gases at cryogenic temperatures, have advantages over traditional gas puffing due to their ability to penetrate deeper into the plasma and provide increased efficiency. While ice pellets made from hydrogen and its isotopes are used as fuel, pellets made from gases such as argon, neon, and hydrogen, or their mixtures, are utilized for plasma control.

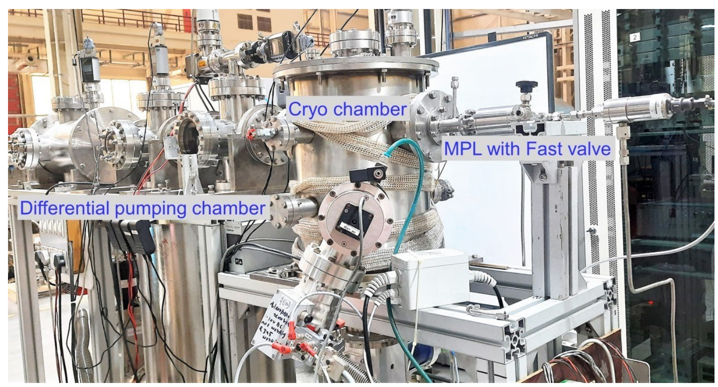


Figure A.2.58: Image of the complete pellet injector setup with its various sub-systems.

As part of the pellet injector development project, a novel cryostat configuration has been designed to operate over a wide temperature range of 4 K to 70 K, allowing for the freezing of high-Z gases (Figure A.2.58). The complete injector setup includes a GM cryo-cooler, which helps achieve low temperatures in the cryo- chamber, and a gas feed system capable of managing both low-pressure fueling gas and high-pressure helium gas. Additionally, it features a multi-stage differential pumping system for propellant removal and a fast camera for diagnosing the injected pellet. Various components of the cryostat have been successfully tested. A cool down study of the cryostat has been conducted, demonstrating effective temperature control over the application head within the specified range using the newly proposed cryostat configuration and suitable heaters. Hydrogen and argon pellets have been successfully frozen. Pellet launching experiments were conducted using two different systems: a solenoid-based pneumatic gas gun and a fast valve-assisted mechanical pellet launching system (MPL). In these experiments, cylindrical hydrogen pellets with a diameter of 4.2 mm were used, with lengths ranging from 1 to 1.5 times their diameter (l/d = 1 to 1.5). The pellets were injected at speeds between 100 and 600 m/s (Figure A.2.59). Also, a study on pellet shattering was performed to support disruption mitigation applications in plasma. This involved injecting intact pellets onto a shattering plate inclined at an angle to the pellet injection direction.

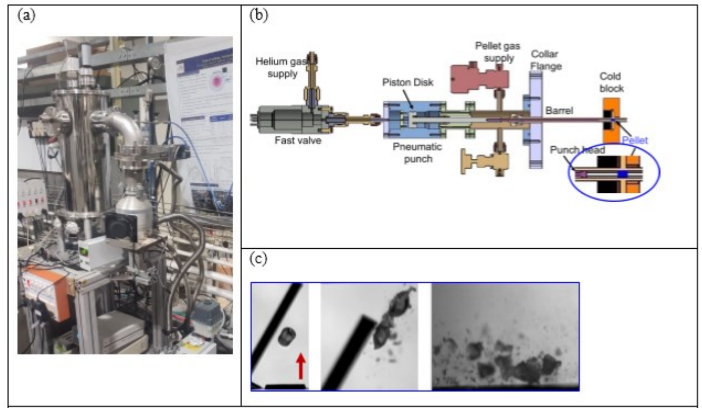


Figure A.2.59: (a) Photograph showing the test setup for the cryostat configuration optimization and Argon pellet formation experiment, (b) the mechanical pellet launcher used to inject hydrogen pellets, (c) Left to right: Interaction of a solid hydrogen ice with shattering plate and its fragmentation.

A3. Fundamental Plasma Physics

Studies of fundamental plasmas naturally occurring whether in laboratory, in earth's magnetosphere plasma or solar environment of our universe is of great interest to the plasma community because of their dynamicity and interaction with mankind directly or indirectly in our day to day life. Plasma created in laboratories is characterized under various experimental conditions to explore its fundamental nature and proprieties which not only lead to a better understanding of the various areas of physics interest but also can be exploited for several applications of importance to the society, industry and power plants. The following section describes experimental devices at the institute working in the field of fundamental plasma physics..

A3.1 Large Volume Plasma Device (LVPD) - Upgrade

Plasma Density Depletion: Plasma transport across magnetic fields is a fundamental phenomenon that influences a range of applications, from space plasmas to laboratory plasmas to controlled thermonuclear fusion experiments.

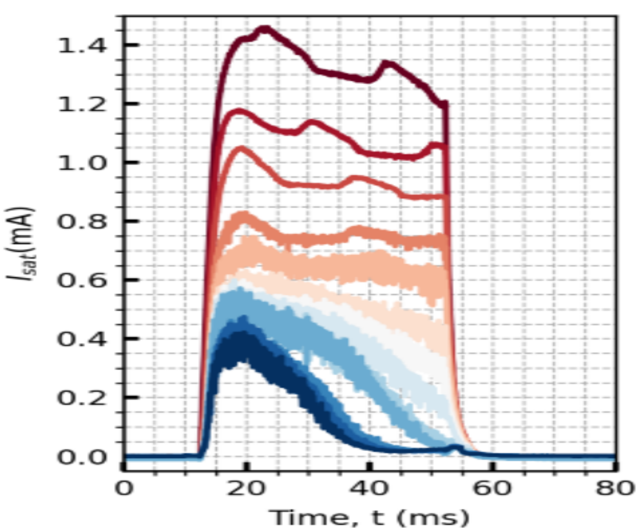


Figure A.3.1: Ion saturation current decrease and depletion with increasing of screening magnetic (maroon to dark blue color) field in target plasma of LVPD.

We have reported a unique experimental observation for a pulsed ($\Delta t \sim 50$ ms) moderately dense, low temperature, partially magnetized plasma diffusing across a magnetic screen produced by the electron energy filter magnetic field, showing finite-time dependencies on the diffused plasma density during the pulse. The time dependence is estimated from the evolution of the ion saturation current proportional to the plasma density, and its decay rate is found to be a function of the strength of the applied screening magnetic field.

An analytical expression has been derived for the time dependence of the plasma decay rate and is found to have a nonlinear relationship. This decay typically exhibits a two-stage behavior with screening magnetic field strength: an initial slow decline followed by a steeper phase. The latter, being less affected by transients or plasma buildup, more accurately reflects the dominant diffusion dynamics. These findings provide additional insight into the role of turbulence-driven transport in low-temperature plasmas and their potential applications in other plasma systems such as negative ion sources. Figure A.3.1 shows the ion saturation current decrease and depletion in steps as we increase the screening magnetic field.

Whistler Induced Particle Flux: The electrostatic particle flux is measured in the presence of obliquely propagating quasi-longitudinal (QL) whistler turbulence ($\omega_{ci} < \omega_{LH} \sim \omega < \omega_{ce}$) in the plasma system. The QL whistler is observed with frequency band between 40 kHz and 100 kHz, and the characteristic wave numbers $k_{\parallel} << k_{\perp}$ are excited by the reflected energetic electrons via loss cone (localized mirror type magnetic geometry) formation in the presence of a transverse magnetic field ($B_{EEF}(x)$) of electron energy filter and axial magnetic field of LVPD ($B_0(z)$). The effect of mirror strength on radial particle flux is explored by changing the B_{EEF} as this variation changes the excited QL-whistler turbulence. We observed that the increase in QL-whistler turbulence level, the radial particle transport, i.e., the radial particle flux subsides, is accompanied by particle flux direction reversal from radially inward to outward. This is a significant observation and the reason may be the presence of electromagnetic fluctuations, which may contribute to the generation of more ambipolar particle flux rather than directional which, in turn, has reduced the net radially outward electrostatic particle fluxes. It is observed that the particles are transported radial inward when, $B_{EEF} = 0$ G, having a flux magnitude, $\Gamma_x \sim 1.5 \times 10^{19}\, m^{-2}s^{-1}$ and , the magnitude of inward particle flux decreases and beyond $B_{EEF} = 0$ G, the direction of particle flux reverses and becomes radially outward (þx) direction and gets saturated to a value $\Gamma_x \sim 1.5 \times 10^{19}\, m^{-2}s^{-1}$. Figure A.3.2 shows the estimated particle flux at different EEF magnetic fields.

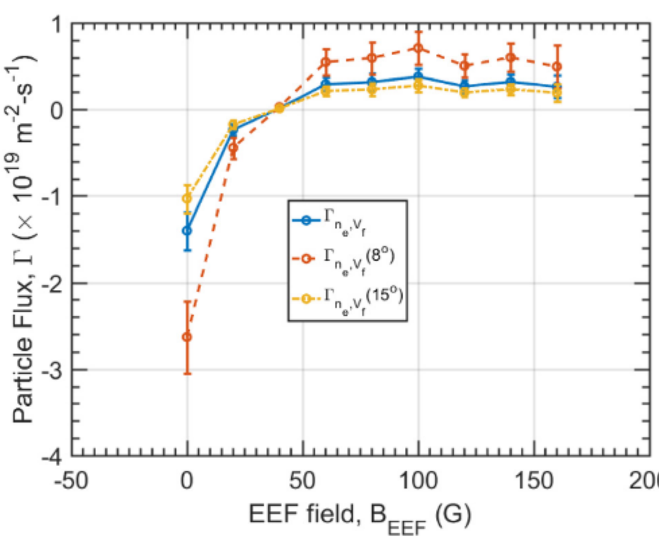


Figure A.3.2: Estimate particle flux at different magnetic field in presence of QL whistlers.

__Electromagnetic Wave Excitation and Detection:__ Electromagnetic waves in the range of whistler frequency were excited in the plasma by a loop antenna using a capacitor bank based pulse forming network (PFN) discharge. The exciter pumps a fundamental wave of frequency 50kHz in the plasma and the wave signatures were detected at an axial distance of 37.5cm from the antenna center using a 3-axis magnet probe. The experimental setup made is a combination of a loop antenna, a Helmholtz coil and a radially movable 3- axis magnet probe having a flat response in the range of 1 kHz—10 MHz. The Helmholtz coils (d = 45 cm) is charged to produce a i) magnetic null region at the center of it by cancelling the background magnetic field ($B_0 \sim 6.2$ G) of LVPD, ii) a magnetic field 20 G along the direction of B_0 and iii) 20 G magnetic field opposite to the direction of B_0 for experiment and measurement calibration. The measurements were carried out in a moderate density ($n_e \sim 5 \times 10^{17} m^{-3}$), low temperature (2 eV—5 eV) plasma in the presence of a background uniform magnetic field. We could successfully detected the electromagnetic waves in the experiment with a peculiarity of wave propagation goes out of Helmholtz field configuration when magnetic null field is produced apart from this high frequency modes are detected of the order of ~ 150 kHz in other two Helmholtz field configurations. A suitable 2D magnetic field code is prepared to simulate the Helmholtz magnetic field for different experimental configurations. Figure A.3.3 shows the wave detection signatures during the magnetic null field scenarios.

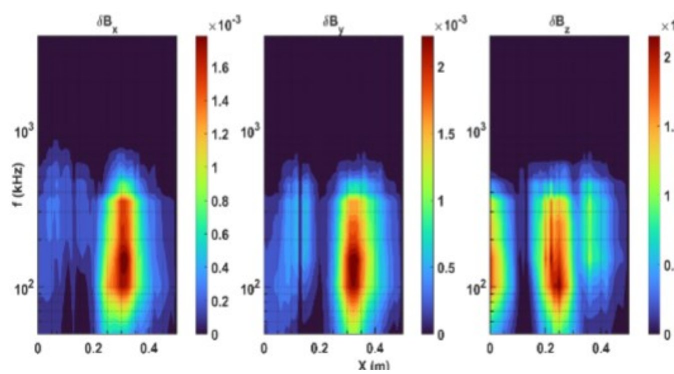


Figure A.3.3: Detection of electromagnetic wave component of ($\delta B_x, \delta B_y$) outside the Helmholtz coil setup with magnetic null region at the center.

__Diagnostics for Magnetic Mirror Experiment:__ Preliminary design and fabrication of differently shaped solenoid systems were done for producing variable magnetic mirror fields (Figure A.3.4). The diagnostics were prepared to mimic the earth like magnetic field configurations within the LVPD plasma. The diagnostics are fabricated in-house and its magnetic field simulations are done using AMPERE electromagnetic software.

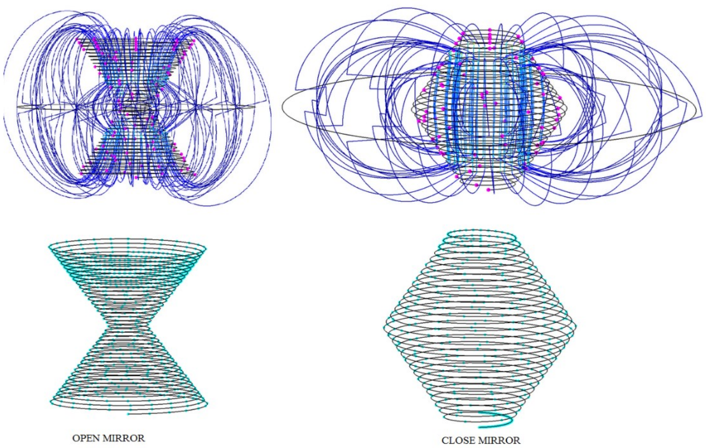


Figure A.3.4. Simulated open and closed mirror solenoids.

A3.2 Non-Neutral Plasma Device (SMARTEX-C)

Development of Diagnostics: Electron plasma in partial toroidal trap SMARTEX-C have been confined exceeding 100 seconds, to understand the responsible transport mechanism, various diagnostics are being developed, tested and implemented.

A) Charge collector diagnostics to measure the total stored charge in the trap has been upgraded by improving the Signal to Nosie Ratio (SNR) by nearly two orders of magnitude and measurements have been made possible to measure the stored charge till 30 seconds of hold-time.

B) To measure the electron plasma temperature, evaporative dump method has been developed based on the principle of retarded-field energy analyser. Single stage dump method has been developed by measuring the number of trapped electrons energetic enough to escape past the confinement potentials of collector grid. The charge collector (collector grid + collector shield) voltage is ramped up slowly to ground (V = 0 in 2 μs) and the current is measured due to charges falling on the charge collector. By integrating the current signal, number of charges that escape is obtained as a function of the potential barrier. If the distribution is assumed Maxwellian, then parallel temperature of the electron cloud can be estimated. Estimation lies within a range of 3 to 6 eV with an error-bar of 1 to 1.5 eV. Two stage charge collection method to diagnose the temperature with the necessary correction factor, conversion of potential energy to kinetic energy during estimation of temperature, has been carried out and conservation of charge in two stage dump is experimentally verified as shown in figure A.3.5.

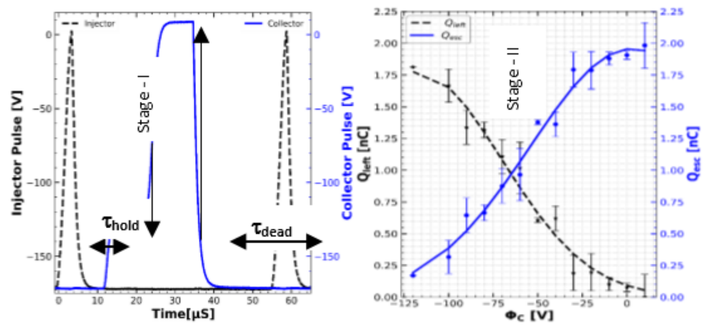


Figure A.3.5: (left) Injector and Collector pulses in multiple -plasma shots, where collector is dumped in two stages, here stage I is at -120 V & stage II is at +5 V, and τ_{dead} is the dead-time between two shots. (right) Charges measured in two stages for different values of two stages in steps of 20 V. In any shot, the total stored charge is conserved to approximately 2nC.

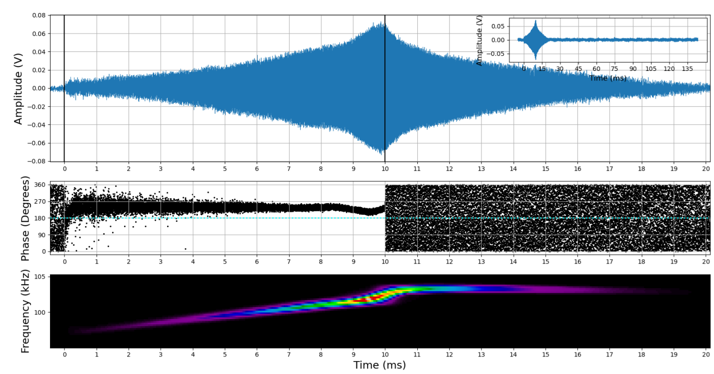


Figure A.3.6: (a) Excitation of m – 2 diocotron mode, zoomed detected probe signals, (Inset) complete evolution of the probe signal, (b) Evolution of cross-phase between launched signal and detected signal and spectrogram of the detected signal on the capacitive probe, showing the launch of the m = 2 eigenmode of the system.

m = 2 Diocotron Mode Launch: To estimate the plasma parameters like, plasma density, self-rotation frequency, and plasma radius one can launch the m = 2 diocotron mode in toroidal non-neutral plasma using combination of a probe pairs. The mode is observed to be in phase for two oppositely mounted probes. Using the frequency of the launched mode and assuming cylindrical dispersion relation of diocotron instability valid for toroidal geometry, one can evaluate the above-mentioned plasma parameters. Additionally, if proper chirp rate and launch parameters are selected, one may get the resonant excitation of the m – 2 diocotron modes as shown in figure A.3.6 (right). Plasma parameters obtained are in the following range, n_e – 2 x 10^6 cm^{-3}, plasma radius r_p approximately 4.0 cm.

<u>*Cylindrical Non-Neutral Plasma Trap:*</u> A linear non-neutral plasma trap is developed, and electron plasma is confined for few hundred milli-seconds in a uniform magnetic field of few hundred Gauss. Trap consists of five cylindrical ring electrodes and end-grids and tungsten filament as an electron source. This system is used as a test-bench setup for development and testing of novel diagnostics planned for SMARTEX-C a toroidal experimental setup. Following experiments have been carried out; formation of electron plasma, observation of unstable diocotron modes on capacitive probe, identification of m-1 diocotron mode, scaling of diocotron mode frequency with electron injection energy, magnetic field, controlling of instability at lower pressure and higher B – field, launching of m - 1 diocotron mode, measurement of confinement time using diocotron wave launch, m -2 diocotron mode launch, excellent reproducibility of plasma production (repeatability < ± 1%) and initial experiments on phosphor screen imaging of electron plasma. Figure A.3.7 shows the trap setup along with photograph and figure A.3.8 shows the images obtained from phosphor screen imaging diagnostics.

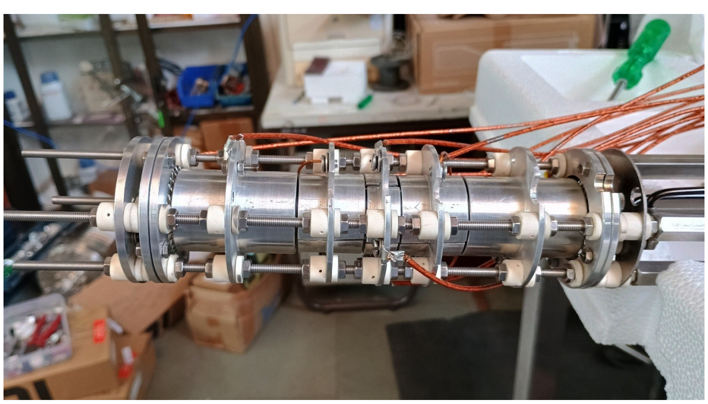


Figure A.3.7: Linear cylindrical Penning – Malmberg Trap made up of five concentric cylindrical ring electrodes, grids and filament.

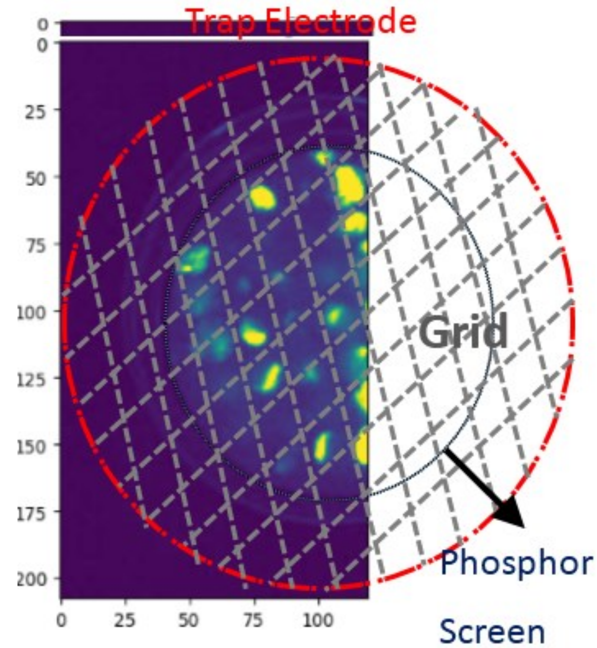


Figure A.3.8: Left) Phosphor screen image of electron plasma captured with shadow of collector grid. Right) Image without overlaying of the grid.

A3.3 Applied Plasma Physics Experiments in Linear Device (APPEL-Device)

<u>*APPEL Device Overview and Recent Experimental Highlights:*</u> The APPEL (Applied Plasma Physics Experiments in Linear) device recently commissioned at the institute serves as an intermediate-scale test bed aimed at advancing plasma material interaction (PMI) research and simulating tokamak-relevant plasma conditions. It offers a versatile platform for diagnostic development, plasma source optimization, and physics experiments under controlled magnetic fields.

APPEL features a system of 16 electromagnets generating a steady-state axial magnetic field exceeding 0.4 T across a 3.5 m length, with exceptional radial uniformity (2%) over a 32 cm diameter. Within this configuration, a 3.5 m long helium plasma column was produced at pressures below 2.0 Pa, achieving densities in the range of 10^{17} –10^{18} m^{-3}, and ion fluxes on the order of 10^{21}–10^{22} $m^{-2}\cdot s^{-1}$.

The device has also validated the use of an m = 0 mode spiral antenna as an effective RF pre-ionization source, highlighting its potential for studies relevant to tokamak startup and RF-induced breakdown. Experiments showcased a long plasma column with a

visibly bright core and a diminishing (or "furred") periphery. Corresponding density profiles indicate suitability for pre-ionization studies showcasing profiles optimized for uniform and reliable breakdown.
A coaxial plasma gun designed for compact toroid (CT) injection in axisymmetric magnetic field has been constructed and installed. The gun is powered by a pulsed power supply, charged up to 20 kV, and delivers discharge pulses in the microsecond range of pulse width. This addition significantly extends APPEL's capabilities, enabling investigations into high-speed plasma injection, CT formation, and fast-transient plasma dynamics crucial for compact torus and fusion relevant studies.

Plasma Source Development & RF Measurements Highlights:

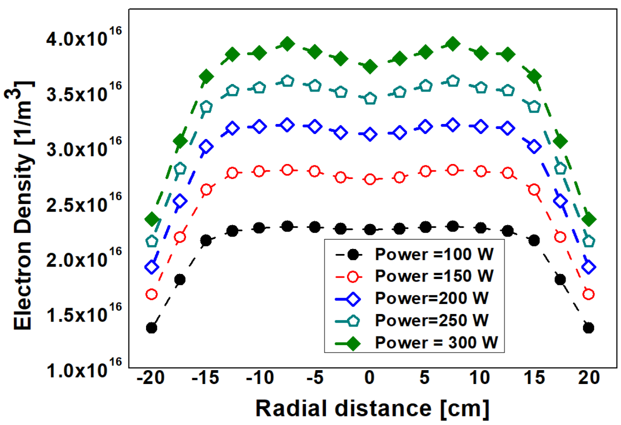


Figure A.3.9. Electron density plot of LAPS source at pressure 2 Pa and various RF powers.

An indigenously developed, CCP (capacitively coupled plasma) Large Area Plasma Source (LAPS) with a processing area of 40 cm² has been created for coating and etching applications. It delivers uniform electron density and temperature across the entire surface. Figure A.3.9 presents the spatial distribution of electron density across the source. Indigenous developed low cost the VI sensor for RF power measurements and compared its measurements with Octiv Poly 2.0 VI Probe.

A3.4 Inertial Electrostatic Confinement Fusion (IECF) Device

Improvement in Ion Confinement Time With Multi-grid Configuration in an Inertial Electrostatic Confinement Fusion Device: Improvement in the functionality of an inertial electrostatic confinement fusion (IECF) device has been investigated through kinetic simulation. Previously, we achieved a neutron generation rate of 10^6 neutrons per second, but higher rates and better plasma confinement are necessary for broader applications. We compared a traditional single-grid IECF device with a triple-grid variant to evaluate the benefits of using multiple grids for ion confinement. Our computational models, using the 2D-3V XOOPIC code, suggest that the triple-grid device, with its optimized potentials, could significantly enhance ion confinement. The models show that the triple-grid design directs ion beams more effectively to the center, in contrast with the more scattered ion distribution in the single-grid design. This results in longer ion lifetimes in the triple-grid system due to its modified electrostatic fields. In the standard single-grid IECF device, the primary reasons for ion loss are chaotic ion trajectories and interactions with residual gases. By operating the triple-grid device under very low background gas pressure and with a focused field structure, we expect to achieve improved ion confinement (Figure A.3.10).

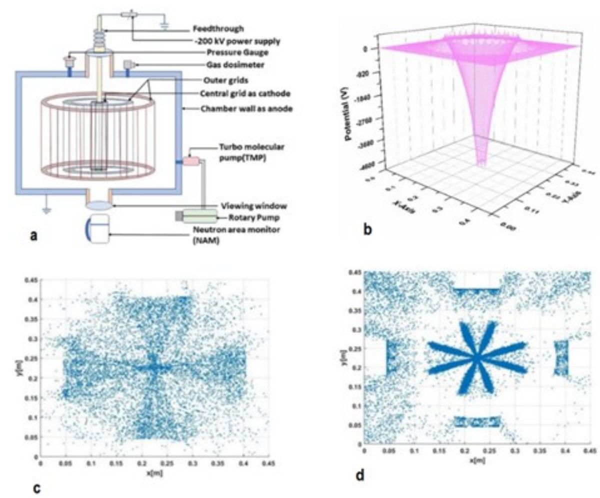


Figure A.3.10: a) IECF Experimental setup, b)3D surface potential profile for triple grid configuration c) single grid ion phase space plot d) triple grid ion phase space plot.

Behaviour of Tungsten Surface Under Exposure of Hydrogen Plasma Stream in Pulsed Plasma Accelerator: In this work, the high speed Hydrogen plasma stream is allowed to fall on Tungsten substrates placed at a distance of 10 cm from the end of the electrodes. The measured heat energy density of the Hydrogen plasma stream at this position is 0.205 MJ/m^2 while it increases up to 0.224 MJ/m^2 under an influence of 0.1 Tesla externally applied longitudinal magnetic field.

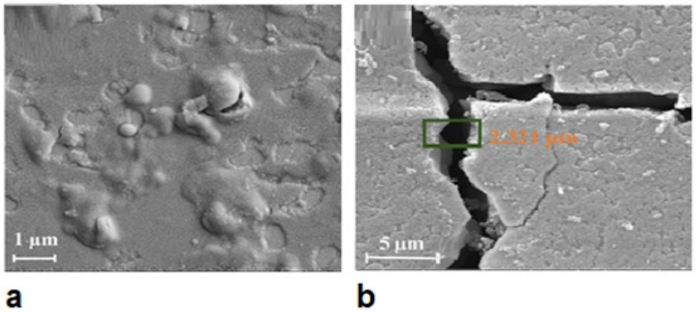


Figure A.3.11: a) Blisters and b) cracks formation on tungsten surfaces under the exposure of plasma stream.

The characterization of exposed samples is carried out using X-ray diffraction (XRD) analysis, field emission scanning electron microscope (FESEM) with Energy Dispersive X-ray (EDX) analysis. The plasma matter interaction (PMI) at this condition creates blister formation to the surface of Tungsten material for single exposure. However, cracks started to form for 5 numbers of plasma stream exposure under magnetic field. The cracks, displacement of plane on cracked surface, dust formation, re-deposition are observed in SEM analysis while XRD analysis shows residual stress for exposed samples. The cracks are found to be widening as we increase the number of exposure of plasma to the samples in an order of 5, 10 and 15 numbers of exposures. The larger crack widths observed are more than 1 mm (Figure A.3.11). The results of this type of interaction due to 0.2 MJ/m^2 the heat energy density of plasma stream on Tungsten material resembles either to a mitigated type-I Edge Localized Mode (ELM) or lower energy type-I ELM and the reported results are highly relevant for fusion reactor

<u>*Extraction of Negative Hydrogen Ions*:</u> Negative hydrogen ions were successfully extracted using the new experimental setup at Negative Hydrogen Ion Extraction Laboratory. This extraction was accomplished through a two-grid system, consisting of a plasma grid and an extraction grid. The plasma grid was connected to the negative terminal of the high-voltage (HV) power supply, while the extraction grid was electrically grounded. After evacuating the vacuum chamber, the two-grid system was conditioned under three conditions: in vacuum, with minimal hydrogen gas pressure, and following plasma production. This conditioning process allowed the grid system to sustain a high voltage of approximately 6 kV.

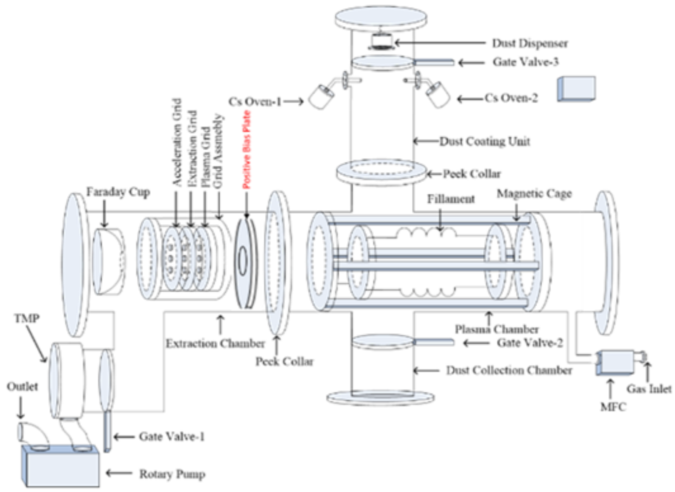


Figure A.3.12: Schematic of the experimental setup with the positive bias plate (labelled in red).

A Faraday cup was installed in the extraction section of the vacuum chamber, positioned about 5 cm away from the extraction grid. Hydrogen plasma was generated using a filamentary DC discharge technique, with a discharge current of approximately 10 A, achieved by applying a discharge voltage of around 100 V. The hydrogen gas pressure was maintained at ~ 2 x 10^{-4} mbar. After plasma production, a 6 kV voltage was applied across the grid system, with an additional 9V supplied between the source (negative terminal) and the plasma grid. To produce negative hydrogen ions, initially tungsten (W) dust particles were coated with Cesium (Cs). For this, two Cs ampoules were broken, and the ovens were heated to 150 °C. At this stage, the electrometer connected to the Faraday cup via a vacuum feedthrough recorded a stray current of ~0.04 mA. Tungsten dust particles were then introduced from above, passing through the dust coating unit (DCU) before entering the plasma. Once the dust particles were introduced into the plasma, the current measured by the electrometer increased to 2.21 mA. The observed difference in current values, with and without Cs-coated tungsten dust ~ 2.17 mA, is attributed to the presence of negative hydrogen ions (Figure A.3.12).

<u>*Studies on the Synthesis of One Dimensional Tungsten Oxide Nanomaterials for Treatment of Wastewater:*</u> Our previous studies showed that stoichiometric tungsten-oxide nanomaterials with good crystallinity, small particle sizes should be most ideal for integrated treatment of wastewater, through photocatalytic decomposition of harmful dyes under optical light, surface adsorption of contaminants and antibacterial properties. Metal-oxides in one dimensional

form should be even better, because they possess much higher porosity and specific surface area. For production of those materials, W is biased negatively (-45 V) and irradiated under very high He^+-flux (~10^{23} $m^{-2}s^{-1}$), with variation of both target-temperature (780°C-1426 °C) and He^+ fluence (3.1×10^{26} m^{-2} —1.7×10^{27} m^{-2}), for production of filament like W-nanostructures.

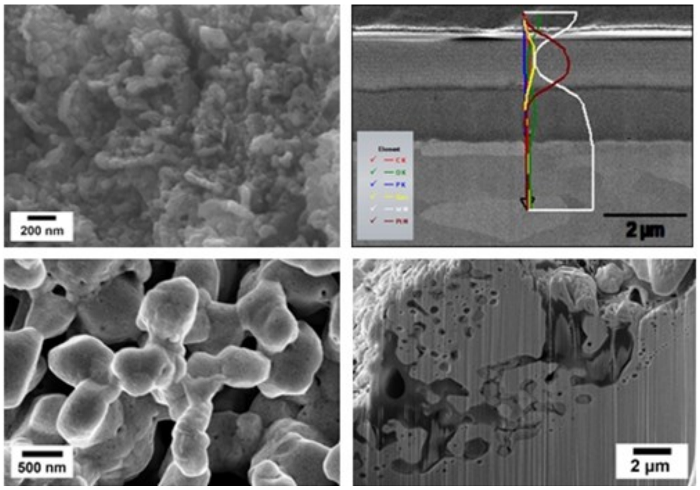


Figure A.3.13: FESEM micrograph shows tungsten-oxide nano-tendrils (995 °C target temperature, 3.1×10^{26} m^{-2} He^+ ion-fluence) retains the structure of the original metallic filaments (top, left); cross-section of the same W plate target shows micrometre thick fuzz-oxide layer, EDX superimposed (top, right), FESEM micrograph shows large tendrils are produced at 1426 °C and longest ion-fluence of 1.7×10^{27} m^{-2} (bottom, left), FESEM of the cross-section of the same sample confirms the W-tendrils are badly aggregated, formation of micrometre sized helium bubbles.

They are then annealed in a tubular furnace at 400 °C for 1 hour for conversion into oxides. The one-dimensional γ-WO_3 nanotendrils retain their original morphologies and size to a large extent. The sample synthesized at the target temperature of 995 °C and ion-fluence of 3.1×10^{26} m^{-2} has a fuzz layer thickness of about few microns, are likely to be most ideal for the projected application. An acute advantage of this nanomaterial is, they may be very easily isolated from the treated water, once the respective processes are completed because the oxide-tendrils remain attached to the tungsten plate below. A much thicker fuzz-layer is generated for the highest target temperature (1426 °C) and longest ion-fluence (1.7×10^{27} m^{-2}) condition, but the corresponding sample is unlikely to possess large porosity and specific surface area, as the sizes of the individual tendrils are comparatively much larger and they also got badly aggregated. We also studied the basic mechanism for formation of the sub-surface helium-bubbles, which are considered to be the precursors for formation of the nanotendrils, especially under the high target temperature and long ion-fluence conditions, which was explored relatively less before. Very large, up to micron sized helium-bubbles are identified buried under the exposed-surface, because the very high target temperature promotes large mobility of the helium-clusters and small helium-bubbles, leading to their growth through fast coalescence (Figure A.3.13).

<u>*Synthesis of Tungsten Trioxide Nanoparticles Through Plasma Electrolysis:*</u> During operation of plasma electrolysis using tungsten wire electrodes and plasma forming at the cathode, nanoparticles of tungsten oxide are formed in the electrolyte through anodic dissolution of anode and thermal evaporation of cathode. The solution was centrifuged and dried to obtain blue powder, which on annealing at 550 ^{o}C for 4 hours, we get greenish-yellow powder with production rate of ~ 0.636 g/hr. XRD analysis shows the samples to be tungsten trioxide (WO_3) nanoparticle. The photocatalytic activities were tested by adding 30 mg of WO_3 nanoparticles and 0.75 ml of H_2O_2 to 150 ml of 20 ppm MB dye solution and exposed to visible light. The degradation efficiency of the exposed sample is given in figure A.3.14, which shows complete degradation of the dyes in 100 minutes of exposure. Figure A.3.14 shows samples kept in dark or exposed to light with nanoparticles or H_2O_2 alone has negligible degradation.

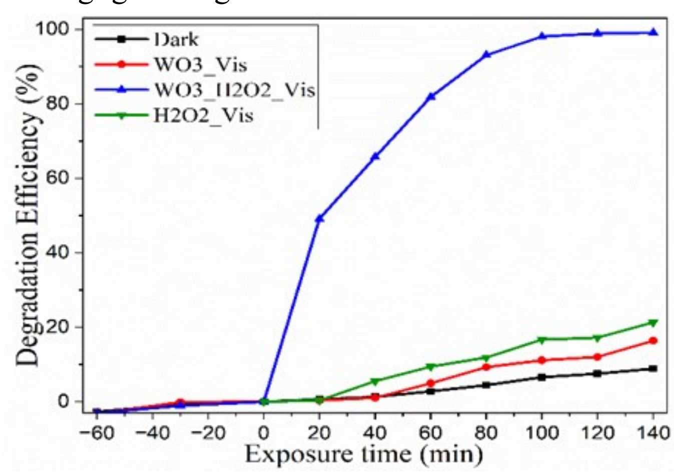


Figure A.3.14: Degradation Efficiency of MB dye solution with WO_3 nanoparticles and exposed to visible light.

<u>*Production of N_2-fixation Products like Ammonium nitrate in a Coaxial Dielectric Discharge Plasma*</u>

System: Plasma-induced chemical processes are currently under extensive research as a green alternative to artificial N_2-fixation. NH_3 synthesis by non-thermal plasma, an oxidizing medium is critical, because NH_3 is itself a reduced end-product of N_2-fixation. We carried out N_2-fixation in coaxial-dielectric barrier discharge (DBD) plasma reactor.

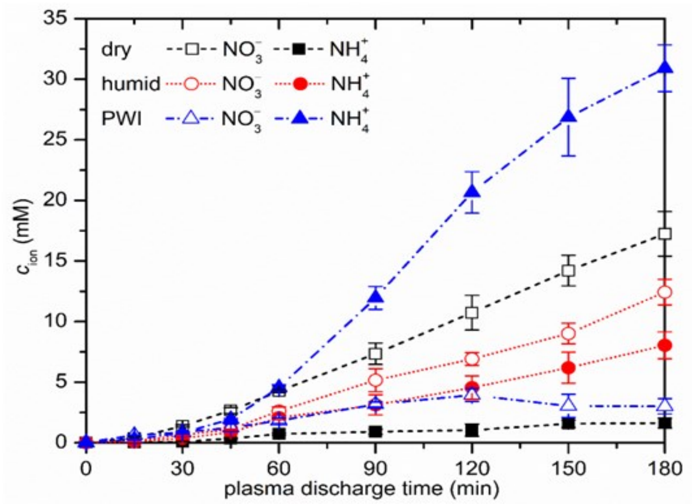


Figure A.3.15: Time-dependent variation of NO_3^- and NH_4^+ ion concentrations under 15 kV AC plasma discharge voltage and flow rate of 1 $Lmin^{-1}$.

Dry feed gas bubbling through de-ionized water inside the reactor, i.e., the PWI condition was found to be a simple but effective technique for N_2-fixation towards NH_3 synthesis. In fact, this plasma-water interaction (PWI) method (PWI-$C_{NO3^- + NH4^+} \approx 34$ mM) surpassed the humid (Humid- $C_{NO3^- + NH4^+} \approx 21$ mM) and dry feed gas methods (Dry - $C_{NO3^- + NH4^+} \approx 19$ mM) by 1.6–1.8 times. In this study, we calculated the energy cost to produce NH_4^+ in 3hour plasma exposure using dry feed gas was ~0.1 MJ.mol^{-1}, which was improved by an order of magnitude to ~0.02 MJ. mol^{-1} using humid feed gas. However, a substantial improvement was observed in the PWI condition, where the energy cost declined to be ~0.0054 MJ. mol^{-1}. The novelty of the present work using PWI technique is the use of air and water as the sources of N and H, respectively, instead of preparing N_2 and H_2 prior to plasma exposure which is again an energy consuming process. Thus, this method can conveniently be used for on-site small scale production of ammonium. Furthermore, the reaction products NO_3^- and NH_4^+, in our system suggests a possible formation of NH_4NO_3, which is a profitable product as a fertilizer (Figure A.3.15).

A3.5 Inverse Mirror Plasma Experiment Device (IMPED)

The IMPED (Inverse Magnetized Plasma Experimental Device) is a linear plasma device, generates a uniform plasma column of approximately 2.2 m with a uniform axial magnetic field. A unique experimental control parameter in IMPED is the ratio $R_m=B_m/B_s$ where B_m and B_s denote the magnetic fields in the main and source chambers, respectively. By varying R_m, gradients in equilibrium quantities such as density, temperature, and potential are tailored, thereby providing the free energy necessary to excite intrinsic fluctuations. These fluctuations drive low-frequency instabilities, including drift waves (DW), Rayleigh–Taylor (RT), and Kelvin–Helmholtz (KH) instabilities (Figure A.3.16), which enhance anomalous cross-field transport and degrade plasma confinement—similar to the processes observed in toroidal fusion devices such as tokomaks. Recently the coexistence of DW and KH instabilities in

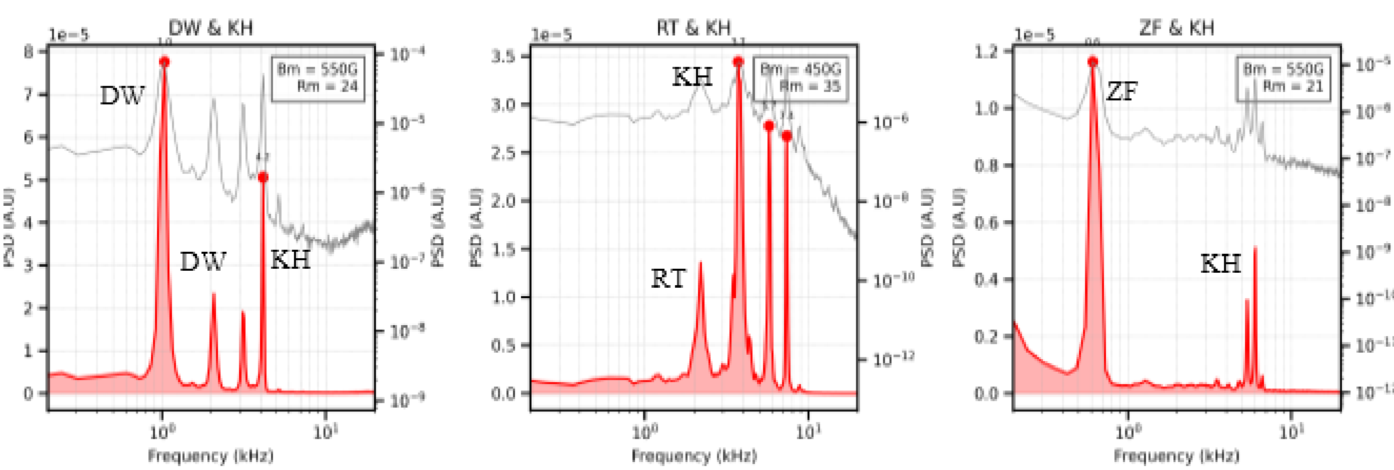


Figure A.3.16: Time-dependent variation of NO_3^- and NH_4^+ ion concentrations under 15 kV AC plasma discharge voltage and flow rate of 1 $Lmin^{-1}$.

IMPED is demonstrated and identified the mechanisms of their nonlinear interactions in regulating transport. Furthermore, a parameter regime has been observed where flute-like RT and KH instabilities coexist, with their nonlinear coupling strongly dependent on collisionality, resembling conditions relevant to ionospheric plasmas. The interplay between the density gradient scale length (L_n) and the shear scale length (L_s), controlled through modifications of the density and electric field profiles, plays a central role in this behavior. Notably, the radial dc electric field can reach values as high as 180 V/m in the low-R_m regime, where shear-driven effects dominate. In addition to primary instabilities, secondary meso-scale structures such as zonal flows and streamers have been identified, which emerge through progressive three-wave coupling among unstable DW or KH modes. Zonal flows and streamers are of particular importance in ITER-like fusion plasmas, as they regulate turbulence and transport, yet experimental studies on these secondary structures remain limited. Advancing the understanding of their formation and dynamics will not only support the development of control strategies for cross-field transport in fusion devices but also provide valuable insights into similar processes in basic astrophysical and space plasmas.

A3.6 System for Microwave Plasma Experiment (SYMPLE) Device

System for Microwave PLasma Experiments (SYMPLE) Device:

Figure A.3.17: SYMPLE experimental set-up. 1. Mode Converter, 2. DC Break, 3. Stub Tuner, 4. Directional Coupler, 5. Circulator, 6. Variable Attenuator, 7. Dummy Load, 8. Magnetron and 9. Electromagnet.

SYMPLE system has been set-up for investigating interaction of electromagnetic wave and plasma at various power levels. System consisting of a high power microwave source coupled to plasma is shown in figure A.3.17. As a part of experiments to elucidate linear resonance absorption of electromagnetic waves in plasma, experiments were undertaken at low power (around 100 W) in order to experimentally validate the theoretically predicted Dinizov-like dependence of wave absorption in plasma. These experiments specially aimed at resonance wave absorption, the parameters to be optimized and controlled include, (i) the "effective angle of incidence q_{eff}" given by $\sin^{-1}\sqrt{e_{r,crit}}$ where where "$e_{r,crit}$" is the relative permittivity of the plasma corresponding to the location of wave return, which depends on the microwave mode and the plasma radial extent, and (ii) the plasma axial density gradient scale length L_n. The experiments thus required a careful control of the excited mode of the wave as well as the plasma radial and axial density extents and profiles. Various modes (TM_{01}, TM_{02}, TM_{03} etc.) were excited by installing appropriate microwave step transition structures coupled with a TE - TM mode converter. The fractional absorption of wave in the over-dense plasma is measured using wave reflection experiments for various wave and plasma parameters. Figure A.3.18. shows the initial experimental results where the absorption data obtained are applicable to the right half of the theoretical Dinizov – curve (blue curve).

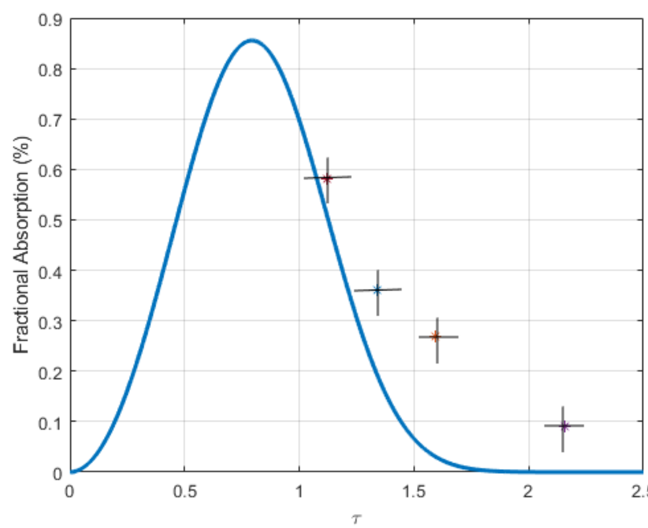


Figure A.3.18: Fractional wave absorption vs the parameter 't' which is a function of wave effective angle of incidence, plasma radial extent and the plasma axial density gradient scale length.

Experiments are under way to minimize the errors, cover the whole parametric range and to have more data generated in order to validate the theory of resonance wave absorption, an area much less explored experimentally in literature.

A4. Plasma Based Technologies and Applications

Plasma based technologies and applications is a key area with far reaching technological and societal benefits. New projects in these areas have been added and good progress continues. The highlights of the current year are being detailed in the following subsections.

A4.1 Plasma Surface Engineering Applications

Reactive Molecular Dynamics simulation (RMD) of the Carbendazim Degradation Induced by Reactive Oxygen Plasma Species:

Carbendazim (CBZ), a systemic benzimidazole carbamate fungicide, used in agriculture, forestry, and veterinary practices to combat fungal diseases, is classified as a hazardous chemical by the World Health Organization. Though, Cold Atmospheric Plasmas (CAPs) have demonstrated successful pesticide degradation experimentally with notable removal rates, energy efficiency, and eco-friendly attributes; alternatively RMD simulations may predict breaking and formation of chemical bonds that occur during interactions. Using RMD simulations, primary reaction pathways have been identified, which show how reactive oxygen species (ROS) such as O atom, OH radical, and O_3 molecule induce degradation pathways in CBZ. During the reaction process of ROS with the methoxycarbonyl group, four potential interaction mechanisms (labeled as R_1, R_2, R_3, and R_4) have been identified (figure A.4.1).

Due to the presence of the electron rich methyl group, the first reaction is H-abstraction reaction from the $–CH_3$ which results in unstable structure triggering four different reaction pathways. The reaction R_1 can be observed with OH radicals and O_3 molecules, while R_2, R_3 and R_4 can occur with O atoms and O_3 molecules. The disruption of the methoxycarbonyl group always leads to a reduction in toxicity. The simulation results indicate that as the concentration of ROS increases, there is a corresponding rise in H-abstraction and C-O bond formation. Furthermore, the simulations show that OH, O, O_3 lead to the destruction of the toxic methoxycarbonyl group through processes like hydrogen abstraction/dehydrogenation, oxidation, decarbonization and decarboxylation reactions, resulting in the formation of small molecules such as CO_2. The destruction of this key structure suggests a reduction in CBZ activity. The elucidated chemical pathways and statistical data provide insights into the atomic-scale degradation mechanism of CBZ, offering a theoretical foundation for optimizing pesticide degradation strategies in future applications.

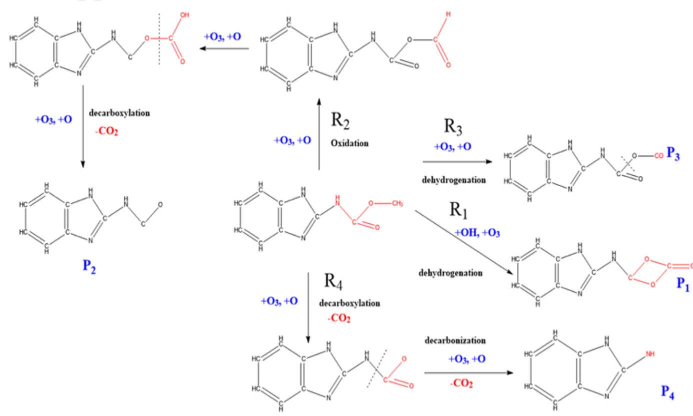


Figure A.4.1: Different reaction pathways obtained at the methoxycarbonyl group of CBZ.

Antibacterial Copper Oxide Coating on Polypropylene Fabric Using Magnetron Sputtering:

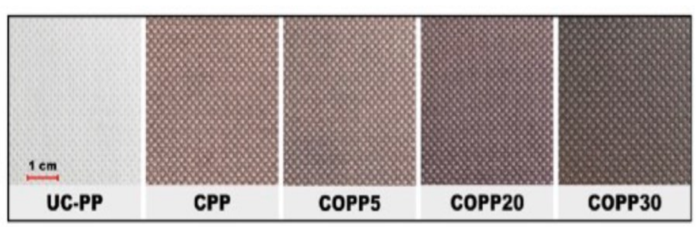


Figure A.4.2: Coated and un-coated fabric: Uncoated polypropylene (UC-PP), Copper coated polypropylene (CPP), Copper oxide at 5 % Oxygen partial pressure (COPP5), Copper oxide at 20% oxygen partial pressure (COPP20), copper oxide at 30 % Oxygen partial pressure (COPP30).

Coatings of copper and its oxides have been deposited on polypropylene (PP) fabrics through magnetron sputtering, with variations in oxygen partial pressures. The presence of these copper oxides has been verified through surface morphology analysis using Scanning Electron Microscopy (SEM) and X-Ray Diffraction (XRD). Additionally, the antibacterial efficacy of the coated fabrics has been investigated. The antibacterial results shows that both copper and copper oxides perform well with 4-log reduction of gram-positive bacteria. The images of coated fabrics at different oxygen partial pressure are presented in figure A.4.2, along with their corresponding terminologies for identification.

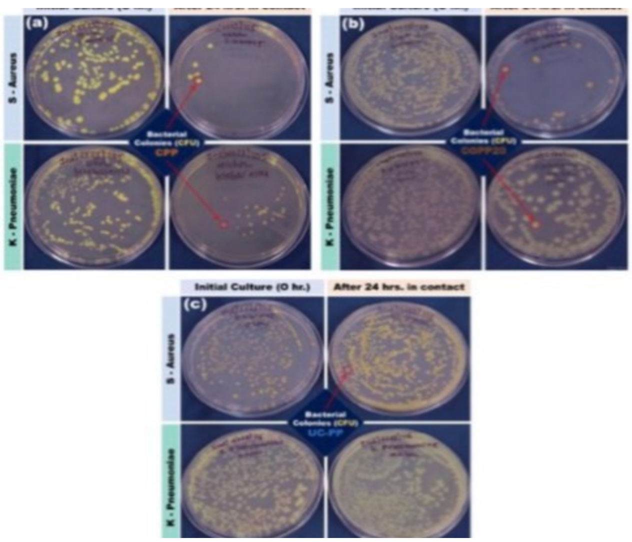


Figure A.4.3: Antibacterial efficacy by AATCC-100 method for (a) CPP (b) COPP20 and (c) UC-PP.

The appearance of the coating surfaces is influenced by the partial pressure of oxygen, which may result from the varying amounts of oxide formation. Three types of fabrics—uncoated, copper-coated, and copper oxide-coated (COPP20)—have been chosen for the AATCC-100 test, which assesses the contact killing mechanism and provides quantitative data. Among these fabrics, COPP20, which consists solely of oxide phases, has been compared to CPP and UC-PP in terms of antibacterial effectiveness. The number of colonies formed on each fabric type for both gram-positive bacteria (Staphylococcus aureus) and gram-negative bacteria (Klebsiella pneumoniae) is illustrated in figure A.4.3. The quantified CFU results indicate that the uncoated fabric (UC-PP) supports a higher growth of bacterial colonies after 24 hours of contact. In contrast, the coated fabrics (CPP and COPP20) demonstrate a significant reduction in colony formation.

Spacecraft Plasma Interaction Experiments–SPIX-III: To simulate Low Earth Orbit (LEO) condition in plasma studies experiments, plasma density was kept in the range of 1 - 5 x 10^{12} /m^3 and electron temperature in the range of 3eV-5 eV. These LEO plasma parameters have been achieved by using an indigenously developed ECR (Electron Cyclotron Resonance) plasma source integrated with the SPIX setup. Figure A.4.4 shows an image of the indigenously developed ECR plasma source used for plasma production.

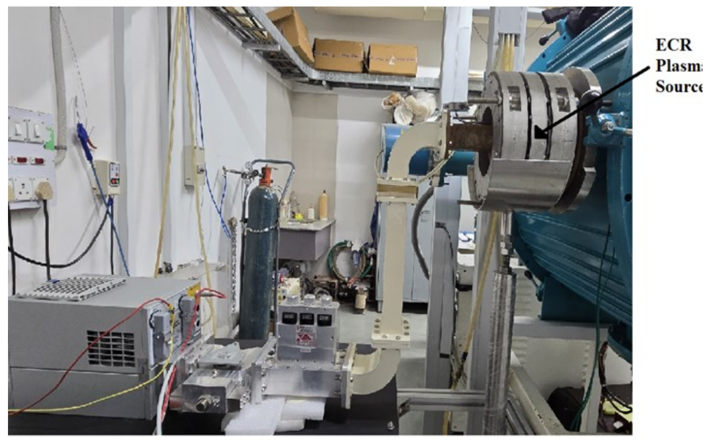


Figure A.4.4: Indigenously developed ECR plasma source used for plasma production.

Figure A.4.5: Arc locations captured during a LEO primary arc experiment performed using new ECR plasma source.

To validate the performance of the indigenously developed ECR source, LEO primary experiments were conducted on a test solar coupon. Figure A.4.5 shows various arc locations during a test LEO primary arc experiment performed with a newly developed ECR plasma source. Total 41 numbers of LEO and GEO experiments were performed in the augmented SPIX-III facility on various types of solar coupons provided by URSC, Bangalore.

A4.2 Atmospheric Plasma Applications

Testing of RAUDRA™ Plant at the Institute:

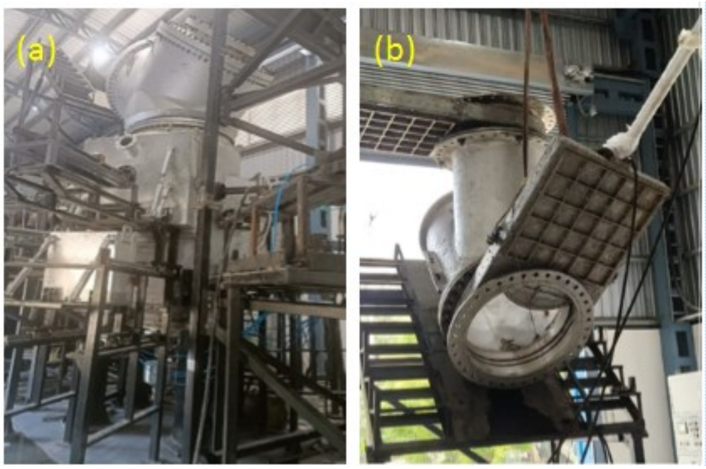


Figure A.4.6: a) Normal temperature damper and b) primary chamber.

The sub-systems of five tons per day (5-TPD) RAUDRA™ plant such as primary chamber, secondary chamber, gas cleaning system, high temperature slide plate dampers, normal temperature slide-plate dampers (Figure A.4.6) have been delivered at the FCIPT campus.

Figure A.4.7: Testing of Integrated 5 TPD RAUDRA™ Plant at FCIPT Campus.

After successful testing of these sub systems for desired parameters, the RAUDRA™ plant has been integrated and the initial trial runs by operating three plasma torches (Figure A.4.7) in the primary chamber completed successfully. The testing of this *RAUDRA™* plant at its full preheating conditions is in progress. After successful testing, the plant will be disintegrated and packed for transportation to the Common Biomedical Waste Treatment Facility (CBWTF), Varanasi; along with other machineries and equipment such as Autoclave, Biomedical Waste Shredder, Continuous Emission Monitoring System, Effluent Treatment Plant, Nitrogen generator and Oxygen generator.

Signing of Incubation Agreements for Technologies Developed by APD:

Two incubation agreements were signed with start-ups Exxcarbon Private Limited and Ecoplaswa Technology Private Limited. Exxcarbon focuses on waste-to-energy applications and is incubated for the commercialization of RAUDRA Plasma Pyro-ysis technology. An agreement (2024-25) for transfer of technical knowhow and license for RAUDRA Plasma Pyrolysis Technology for disposal of organic waste was executed (Figure A.4.8*)* between Exxcarbon and AIC-Plasmatech Innovation Foundation (AIC-Plasmatech), a Section-8 company established by the institute.

Figure A.4.8: Incubation agreements signed with Exxcarbon Pvt. Ltd.

Ecoplaswa aims to develop products based on institute's patented Plasma Activated Water (PAW) technology for disinfecting and cleaning of containers used in the dairy industry, as well as for agricultural applications such as bio-nutrition and bio-fertilizers for crops (Figure: A.4.9*)*.

Figure A.4.9: Incubation agreements signed with Ecoplaswa Technologies Pvt. Ltd.

A4.3 Plasma Thruster Technology

Helicon Plasma Thruster (HPT): HPT is an experimental system, to demonstrate thrust generation using helicon plasma, and has applications in deep space propulsion. Thrust measurement sensor is one important component for the thrust demonstration experiments. A thrust balance system, shown in figure A.4.10 (Left) , has been successfully calibrated to measure forces up to 2 N. Figure A.4.10 (Right) shows natural frequency and self-damping mechanism of the system. The effective self-damping ensures that the balance quickly settles, providing stable and accurate thrust measurements. This sensor met specifications like space grade requirements. After its successful calibration, the thrust balance was seamlessly integrated with a large helicon plasma thruster system during experimental operation and thrust measurements shown in figure A.4.11.

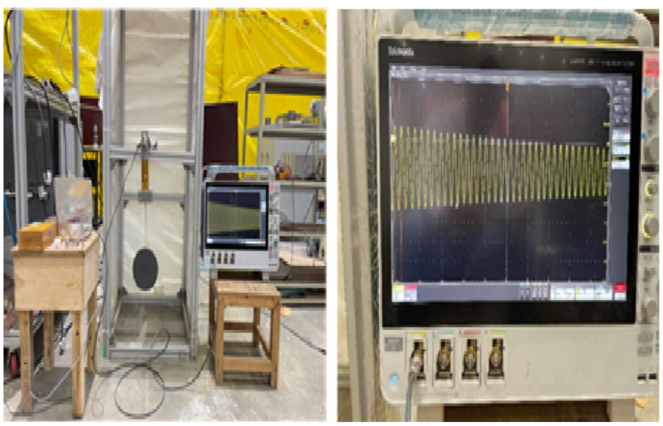
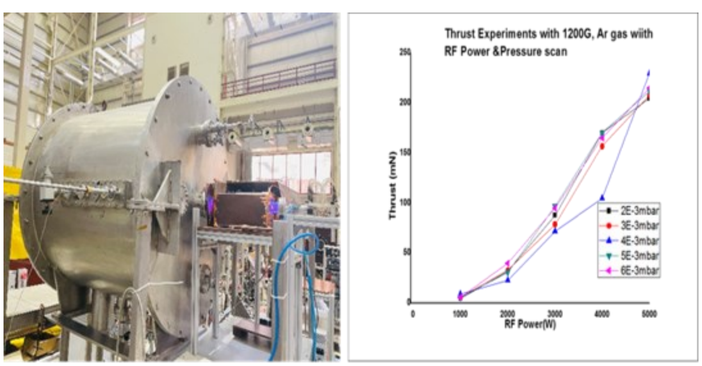


Figure A.4.10: (Left) Calibration setup. (Right) The signal of natural frequency of balance.



(a) (b)

Figure A.4.11: (a) Large Helicon Plasma Thruster System (b) Measured Thrust data .

A key goal of these experiments was to optimize the thrust generated by the system. This involved systematically adjusting various operational parameters, such as magnetic field, gas flow rate and radiofrequency (RF) power for measuring the plasma thrust. Through this rigorous optimization, the helicon plasma thruster system achieved an impressive thrust of 5-230 mN by using 1-5 kW RF power and 1200 G magnetic field. This achievement marks a substantial advancement for high-power helicon plasma thrusters, showcasing their potential for future space propulsion where high thrust with reasonably higher specific impulse and thruster efficiency are desired. Plasma diagnostics are deployed for plasma characterization to measure plasma density (10^{11}- 10^{13} cm^3), plasma temperature (1 - 12 eV), and flow velocities (4-9 km/s and Mach number > 1-3). Utilizing a Langmuir probe, multiple density jumps were successfully detected within the source region of the helicon plasma. The experimental data identified four distinct helicon modes, designated W1, W2, W3, and W4 densities in range of ~ 5x10^{11} 2x10^{13} cm^3.

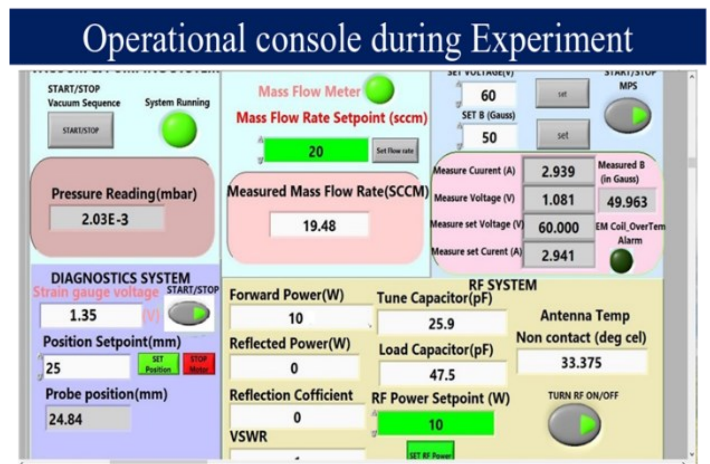


Figure A.4.12: Operation control HPT subsystems during experiments.

Automation control of the Helicon plasma thruster system is demanding as experimental HPT is a diverse system having multiple subsystems like Vacuum subsystem, magnet subsystem, RF Generators etc. Integrated and automated operation of all the subsystems is required for monitoring and control of subsystems parameter (RF power, vacuum chamber pressure, Magnetic field etc) through single GUI console. Sub-systems, connected through heterogeneous hardware, software, and communication interfaces, poses challenges for integration.

Integrated operation of Helicon Plasma Thruster has been achieved by implementation of sequential control on PLC and programming of heterogeneous communication protocols. The control system is integrated using LabVIEW as SCADA. The developed integrated GUI operation has been integrated and validated with prototype HPT system (figure A.4.12).

A4.4 Other Technologies

Development of Microwave Absorbing Plasma Panel: Absorption of Microwave (MW) radiation is imperative for reduction of RADAR Cross Section (RCS) of a metallic target. Plasma of suitable parameters is capable of absorbing and scattering of incident MW signals. This property of plasma has been harnessed to develop plasma panels for RCS reduction. Initial experiments were carried out using commercially available fluorescent lamps as plasma chamber. These plasma tubes were then embedded in a Teflon housing of appropriate dimensions to form a plasma "panel". The performance of the plasma panels were tested in an anechoic chamber as well as free space in outdoor environment. The plasma tiles demonstrated MW absorption up to 50 to 80% of incident MW power. These results are validated with simulations MW power. These results are validated with simulations studies also.

Development of Large Cryopump Test Facility (LCTF): Large size vacuum environments are extensively used for the various applications like space research, nuclear fusion, accelerators, atmospheric simulators and material processing. The necessity of cost effective high speed vacuum pumping solution is in high demand. The efficacy, cost and applicability are the major challenges in conventional way and to cater the need, liquid nitrogen cooled large size cryopump is one of the promising solutions. Aiming to that objective, a Large Size Cryopump Test Facility (LCTF) is developed at the institute (Figure A.4.13 & A.4.14). For this LCTF, a 1250 mm diameter LN_2 cooled sorption cryopump is designed, fabricated and experiments were performed for the pumping of nitrogen, argon and air as per American Vacuum Society (AVS) Standard. The pump having inlet diameter 1250 mm and length 800 mm houses an annulus LN2 bath as radiation shielding. The copper made cryopumping panels get conduction cooled near 82 K when filled by liquid nitrogen. Geometric configuration of the cryopump is optimized using Molflow+ simulation software for the design validation, structural and thermal analysis is carried out using ANSYS. In the LCTF, base vacuum of $7x10^{-9}$ mbar is achieved using the LN_2 cryopump having charcoal coated cryopanels and a small turbo-molecular pump. Experimentally measured average pumping speeds as per AVS standard are 32,742 l/s for Nitrogen, 20,605 l/s for Argon and 25,409 l/s for Air. Experiments were conducted in the pressure range of $1.15x10^{-7}$ mbar to $3.68x10^{-6}$ mbar with a dosing rate of $4.0x10^{-3}$ mbar l/s to $8.0x10^{-2}$ mbar l/s.

Figure A.4.13: Actual photograph of the Cryopump AGASTYA-1250.

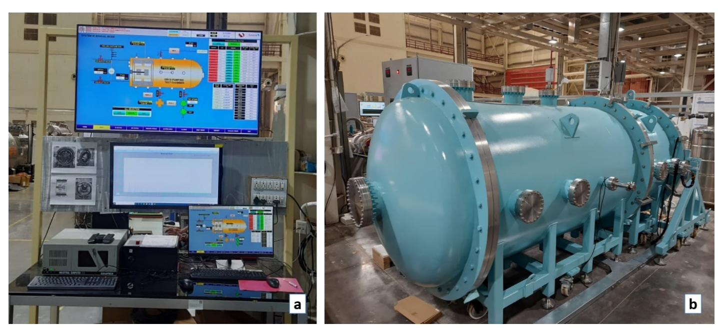


Figure A.4.14: (a) DAQ system and (b) integrated LCTF system.

A5. Theoretical Modelling and Computational Plasma Physics

Several upgradations are done with high performance computing system and advanced modelling and simulation studies have been carried out related to theoretical fundamental plasma science, fusion science and technology etc.. A brief about the studies carried in the current year have been highlighted in the following subsections.

A5.1 High Performance Computing

Scientific Computing and Applications

Operational management of the existing High Perfomance Computing (HPC) system (ANTYA) continues. ANTYA is being used for a variety of numerical simulations covering computational fluid dynamics, particle-in-cell, Molecular Dynamics, MHD, AI/DL etc. It has achieved ~75% average utilization during reporting period. The work management and support (HPC libraries and required software management on HPC systems) is provided to all HPC users.

New HPC System : ANTYA-GPU

10 AI peta flops (Mixed Precision) High Performance Computing System ANTYA-GPU is functional in the institute's Containerized Data Center to cater scientific computational needs.

A5.2 Tokamak and Fusion Reactor Studies

Effect of Size of a Circular Tokamak Plasma on Self-Magnetic Field: A Numerical Approach: The topology of magnetic field due to a filamentary current carrying conductor is not very difficult to follow and rich literature gives a number of clues to estimate the field at desired locations. The real situations do not always deal with the current sources that can be regarded as filamentary. One of such examples is the toroidal current in tokamak like toroidal machines and the subject points, at which the magnetic field needs to be estimated due to this current, remains, may be, at a close vicinity of the torus. For these situations, the magnetic field topology can always not be approximated by the filamentary current model, in which the entire current is assumed to flow through the geometric center of the column and the magnetic field depends on the distance from this center. Moreover, the current density in toroidal machines may have specific radial profiles and hence the corresponding impact of the profile on the external magnetic field topology needs to be explored, provided the accuracy in the estimated magnetic field is a major concern. In literature, it is reported that the cross-sectional area of the toroidal current column has a significant impact on the external magnetic field topology at the vicinity of the machine and magnetic field is very sensitive to the choice of location, at which the measurement of magnetic field, i.e., B, is subjected, though the physical interpretation for such an impact is not addressed. A numerical study has been performed to investigate the impact of the change in cross-sectional area as well as the change in the current density profiles on the nature of external magnetic field. Consequently, the fundamental nature of dependency of magnetic field on the geometrical aspect of the source conductor is explored. All these interesting behaviours are summarized in terms of mathematical interpolating expressions, which essentially conclude about the existence of a magnetic center, playing a crucial role in determining the nature of external magnetic topology. Hence, the applicability of such analysis for any toroidal machine, including tokamaks, is established.

Gyrokinetic Simulations of Electrostatic Microturbulence in ADITYA-U Tokamak: The effect of impurity on the electrostatic microturbulence in ADITYA-U tokamak is assessed using global gyrokinetic simulations. The realistic geometry and experimental profiles of the ADITYA-U are used, before and after the argon gas seeding. Before the impurity seeding, the simulations show the existence of the trapped electron mode (TEM) instability in three distinct regions on the radial-poloidal plane. The mode is identified by its linear eigenmode structure and its characteristic propagation in the electron diamagnetic direction. The simulations with Ar^{1+} impurity ions in the outer-core region show a significant reduction in the turbulence and transport due to a reduction in the linear instability drive, with respect to the case without impurity. A decrease in particle and heat transport in the outer-core region modifies the plasma density profile measured after the impurity seeding. It, thus, results in the stabilization of the TEM instability in the core region. Due to the reduced turbulence activity, the electron and ion temperatures in the central region increase by about 10%.

Global Gyrokinetic Study of Density Gradient Driven Instability in Tokamaks: The ubiquitous mode is investigated in the linear regime for the first time using a global gyrokinetic model. These modes are driven by the density gradient in trapped electron population but with mode frequency in the ion diamagnetic drift direction, in contrast to the conventional trapped electron mode. The dispersion relation is calculated along with the global mode structure. The ubiquitous mode is quite global although appears at a shorter wavelength ($(1/2)k_y^2\rho_i^2 > 1$). We show that the main driving mechanism is the density gradient and the temperature gradient has only a modest effect; the mode can persist at higher temperature gradient scenarios making it another possible channel of anomalous transport. The magnetic shear reduces the growth of the mode; while the electron to ion temperature ratio has a nonmonotonic effect on the mode growth rate—growth rate increases initially for the ubiquitous branch of the mode and decreases afterwards as the conventional trapped electron mode starts dominating. The role of safety factor and toroidicity is also analyzed. Finally, a mixing length-based estimation of transport is presented.

Automated Labelling and Correlation Analysis of Diagnostic Signals from ADITYA Tokamak for Developing AI-Based Disruption Mitigation Systems: AI/ML-based data-driven methodologies are becoming effective in predicting plasma disruption in tokamaks by identifying critical signatures in various diagnostic signals. A high-performance ML-based disruption predictor requires accurately labelled data. Until now, plasma shots from the ADITYA tokamak have primarily been classified (labelled) as disruptive or non-disruptive manually. Three computational techniques have been developed for automatic labelling of the ADITYA data namely the Sorted-array approach, the Interval comparison approach and the Threshold-Straight line method. Statistical analysis and comparison between automatic labelling and manual labelling indicate the promising potential of the proposed techniques. A correlation analysis is also conducted by incorporating plasma diagnostics such as Plasma current, Loop voltage, Bolometer, Mirnov, Hard X-ray, Soft–X-ray, Radiation from Hydrogen-alpha, ionised oxygen and ionised carbon. This comprehensive study offers valuable insights into diverse physical phenomena associated with disruptions. Furthermore, correlation analysis based on current quench time highlights the significance of different diagnostics in providing distinct signatures related to plasma disruption. The insights can play a pivotal role in advancing the development of data-driven disruption prediction systems for ADITYA tokamak.

Effect of Electron and Ion Mobility on Edge Biasing in Tokamak Plasmas: An improved model has been developed for the studying the edge biasing of a tokamak plasma that incorporates electron and ion mobility contributions. The non-ambipolar nature of the drifts due to the electron/ion mobility terms influences the space charge separation due to edge biasing and affects plasma dynamics in the edge and SOL regions in a significant manner. In contrast to earlier studies, the present model enables simulation studies at higher biasing voltages. The inclusion of mobility enhances/decreases the effect of negative/positive biasing. The radial profiles of plasma density, electron temperature, radial electric field, and its shear for positive as well as negative biasing are investigated as a function of mobility.

Deconfinement of Runaway Electrons by Local Vertical Magnetic Field Perturbation: Runaway electron (RE) deconfinement and subsequent suppression is of prime importance for successful long-term operation of any tokamak. The efficacy of local vertical field (LVF) perturbation on RE deconfinement and their mitigation has been explored numerically. The study is carried out by simulating the drift orbits of the REs in magnetostatic perturbed fields and estimating the resulting orbit losses for different initial energies and magnitudes of LVF perturbation. The pre-existing PARTICLE code has been extended to the relativistic full-orbit-following code PARTICLE-3D (P3D) integrated with the magnetic field calculation code EFFI and plasma equilibrium field calculation code IPREQ to include the required fields for studying particle dynamics in general; this is then used to numerically model LVF perturbation-assisted RE deconfinement experiments conducted in the ADITYA tokamak. Simulation results show a significant (~90%) deconfinement of REs with the application of LVF perturbation of a suitable amplitude (~0.1% of the total magnetic field) in a preferred direction. The existence of a threshold magnitude of the applied field is also established, which is observed to be dependent on the energy of the REs. The simulation results reproduce all the experimental observations and reveal other interesting features of RE mitigation using LVF perturbation. The temporal map of orbiting time of REs shows that REs originating from the inboard side edge region ($\psi_N > 0.5$) of the plasma are relatively more prone to be lost with the application of suitable LVF perturbation than those originating from the plasma core. Interestingly, the simulation results demonstrate the existence of strong correlation between the safety factor (q) profile in the plasma edge region ($\psi_N > 0.7$) and the level of RE deconfinement using LVF perturbation.

Magnetic Shaping Effects on Turbulence in ADITYA-U Tokamak: Numerical simulations are carried out using two approaches for studying magnetic shaping effect on turbulence in ADITYA-U tokamak. In the first approach, numerical simulations are conducted to examine the impact of magnetic equilibrium shaping (elongation and triangularity), on both conventional Ion Temperature Gradient (ITG) modes and short wavelength ITG modes. This analysis is performed considering the experimental profiles and parameters of the ADITYA-U tokamak, employing the nonlinear global gyrokinetic Particle-in-Cell code ORB5. The linear and nonlinear collisionless electrostatic simulation of these modes are carried out with kinetic ions and adiabatic electrons. From the linear results, it has been observed that the magnetic equilibrium shaping slightly reduced the growth rates and widened the spectrum, and the maxima of growth rate curve is shifted to higher toroidal wave number. It is observed that the heat flux is reduced by a significant $\simeq 35\%$ for the true circular magnetohydrodynamic magnetic equilibrium as compared to ad-hoc concentric circular equilibrium. A further $\simeq 10\%$ reduction in the heat flux is seen with magnetic equilibrium shaping. In the second approach, linear collisionless electrostatic simulation studies of ITG coupled with fully kinetic electrons (both trapped and passing electrons are treated kinetically) using a drift-kinetic ordering is performed. It can be seen from the linear results that, in presence of kinetic electrons, the growth rate and real frequency of the ITG mode are increased significantly for ADITYA-U parameters and a mode propagating in the electron diamagnetic direction is identified at high toroidal wavenumbers.

Spin of Plasma Blob in Edge and Scrape-Off Layer Regions of a Tokamak: Rotation/spin of plasma blob in the edge and SOL regions in the presence of interchange plasma turbulence with a finite ion temperature gradient ($\nabla \perp Ti \nabla \perp Ti$) has been studied. It is observed that the $\nabla \perp Ti \nabla \perp Ti$ destabilizes the plasma, but damps the eddies related to the plasma blob by enhanced viscosity, therefore, rotation is important for plasma dynamics as the rotation further stabilizes the blobs. The turbulence has been simulated numerically and results show monopolar vorticity is responsible for blob rotation, but the physics is different in the edge and SOL regions. A radial profile of vorticity, and angular speed of a typical plasma blob have been addressed. The role of $\nabla_\perp Ti \nabla_\perp Ti$ has also been studied.

A5.3 Fusion Technology Related Simulation

Dynamic Simulation of ITER Cryo-Distribution System Using Aspen HYSYS: The ITER cryogenic system consists of the Liquid Helium (LHe) plant, the Cryo-Distribution (CD) system, and the cryo-lines. There exist other components like the Auxiliary Cold Boxes (ACBs) dedicated to cooling the superconducting (SC) magnet system and the Cryoplant Termination Cold Box (CTCB) of the ITER CD system. The internal components of ACBs, *e.g.*, cryogenic valves, a cold compressor (CCp), heat exchangers, and a cold circulator (CCr), have been sized and assembled, ensuring their functionality. The interdependency of the functional parameters of one component over the others needs to be assessed, as their integrated performance under the dynamic heat load deposition from the SC magnets may impact the overall operation of the ITER cryogenic system. The ACBs are equipped with two helium baths having ~ 1200 kg of He inventory and situated inside the tokamak building. These baths act as a thermal buffer for the LHe plant, situated in the cryoplant building, allowing it to operate at a quasi-steady state despite heat load variation from the applications. Such a large helium inventory can challenge the secondary confinement system of ITER due to helium ingress accidental events and thus needs to be optimized. The integrated system-level simulation is therefore necessary for the safe and reliable operation of the cryogenic system under such demanding requirements. Numerical simulations have been carried out to study the integrated performance of ACBs dedicated to the magnet system, including CTCB for the enhanced ITER operation modes. The results show that the LHe baths inside the ACBs can be used as a thermal buffer with the proposed limit of initial filling and by keeping a constant opening of the respective J-T valves upstream of the LHe baths. The study outcome and the proposed recommendations would be beneficial to mitigate the pulsed heat load to the LHe plant while minimizing the helium inventory.

Design and Analysis of Mixed Bed Solid Breeder Blanket with Titanium Berrylide as Neutron Multiplier: Solid Breeder blankets are promising candidates being proposed worldwide as a source of tritium production and heat extraction in a nuclear fusion reactor. In many of these concepts including the Indian HCSB (Helium Cooled Solid Breeder) concept, Lithium meta- titanate (Li_2TiO_3) pebble is used as tritium breeder whereas beryllium (Be) pebble is used as neutron multiplier for increasing the tritium breeding ratio. A study has been carried to replace Be with titanium berrylide ($Be_{12}Ti$) in the HCSB blanket concept. The study includes design modification, optimization and thermal hydraulics to accommodate the new material. $Be_{12}Ti$ shows effective performance compared to Be regarding high temperature operation, irradiation effects, tritium retention, swelling etc. The similar limiting temperatures for Li_2TiO_3 and $Be_{12}Ti$ complemented by lower swelling in $Be_{12}Ti$ makes it possible for these two materials to be used in mixed pebble bed form which in the case of the present concept is not feasible. Also, the cooling tube concept has been considered instead of plates by replacing the separate zones of breeder and neutron multiplier with a mixed pebble bed of Li_2TiO_3 and $Be_{12}Ti$ which resulted in an increase of 13 % by volume of functional material compared to the present concept with same size of blanket. The calculated TPR (Tritium production Rate) for the proposed concept is 78 mg per full power day compared to 62.4 mg in the present concept for the same blanket size which shows that TBR can be improved through design modifications in case of $Be_{12}Ti$. The details of blanket thermal –hydraulics, flow distribution in cooling tubes from blanket manifolds and also the neutronic analysis has been addressed on the modified concept. ANSYS thermal and ANSYS CFX simulation tools are used for the finite element and CFD analysis. The results show that temperatures are within the operating limits with some design modifications. The new concept features easy design flexibility for obtaining the desired temperature distribution as well as seems convenient to manufacture.

Systems Studies for the Fusion-Fission Hybrid Reactor: Systems studies for the hybrid reactor were completed using Systems Code PROCESS with an objective to develop an economically viable DEMO power plant & fissile fuel breeder. Optimization studies for both "fusion core" & hybrid blanket was performed for two kinds of machines based on copper & High Temperature Superconductor (HTS) magnets. It was found that copper magnets based fusion core is not economical because of large power requirements in the magnet systems. Further, two options were worked out for HTS magnets based reactor: (1) Small reactor for demonstration of proof-of-concept and (2) DEMO reactor with net electrical power generation and breeding of fissile fuel. The DEMO reactor is capable of producing net electrical power of ~480 MWe, 410 kg of net ^{239}Pu production in breeding plus fuel zones & ~150 kg of ^{233}U per full power year. Cost of these reactors was worked to be ~6,000 Cr for small & ~20,000 Cr. for DEMO reactor.

Radiation Shielding Studies for ITER Tokamak Complex: Enormous amount of 14 MeV neutrons (~$2X10^{20}$ n/s) will be produced during 500 MW DT fusion power operations resulting into high level of neutron and gamma radiation fields which poses problem for personnel safety and safe operation of the machine. Therefore nuclear analysis plays an important role in the design process to demonstrate the safe operation of the machine and fulfilment of regulatory requirements for personal safety.

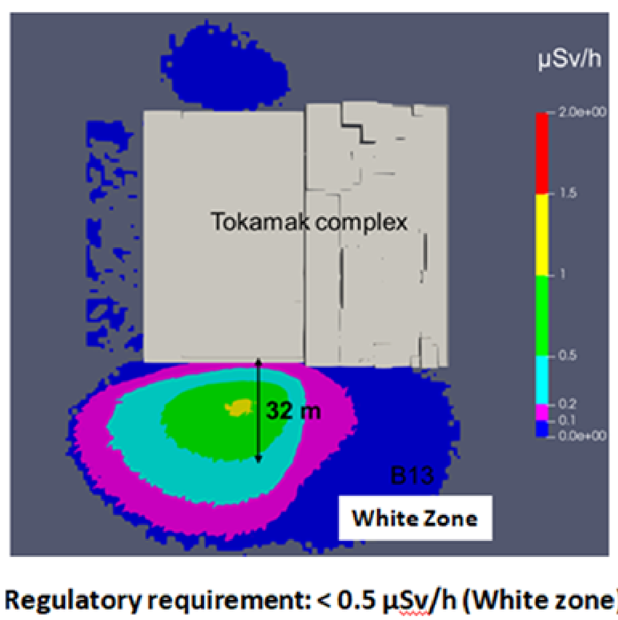


Figure A.5.1: Biological dose rate at ground level due to sky-shine, if penetrations above the primary coolant heat exchangers system containing ^{16}N γ-source, are not back-filled.

Work on a service contract entitled "Radiation calculations support for Penetration Working Group" signed between Indian Domestic Agency & ITER-IO was undertaken and it was successfully completed by delivering 8 deliverables under the task within schedule and following ITER quality standards. The work performed under this task included improvement of the radiation shielding at several places in tokamak complex (Figure A.5.1) & removal of shielding structure while fulfilling the requirements resulting into cost saving & reduction of load on building foundation. 3D radiation transport calculations which are deep shielding problems requiring intensive computing resources, which were provided by ANTYA supercomputing facility at the institute.

A5.4 Nonlinear Plasma Theory and Simulation

Turbulent Spot Formation in 3-D Yukawa Liquids-Effect of System Size: Classical 'first principles' 3D Molecular Dynamics (MD) (MD) simulation have been performed for a plane-Couette flow (PCF) of 3D Yukawa liquid. The main aim of the present investigation is to study the effect of stream-wise (flow -direction) and span-wise (transverse direction to the flow) width on the subcritical transition to turbulence in plane Couette flow (PCF). It is found that the stream-wise length enhances the large-scale energy, which gives rise to strong large-scale flow, and span-wise width enhances the small-scale energy, which gives rise to strong small-scale structures. In other words, topology of the turbulent spot is observed to change with the change in system size. The spectral separation between the modes governing the large and small-scale dynamics improves with the increase in system sizes. The connection between the stream-wise vortices and the stream-wise velocity streaks is investigated. It is found that the number of stream-wise velocity streaks is one unit larger than the number of stream-wise vortices. The behaviour of the system is observed to vary with the range of interactions among the dust grains.

Numerical Validation of Yukawa Fluid Excitations within the Quasi-localized Charge Approximation (QLCA) Theory: A first principle molecular dynamics (MD) simulation is carried out on the nonlinear excitations in a quasi-localized state of a Yukawa system. The simulation is performed to validate the findings of the nonlinear quasi-localized charge approximation (QLCA) model. Unlike solids or gases, quasi-localized states lack certain simplifying features, such as the ability to assume a fixed shape or volume, and they combine large displacements with strong interactions, further complicating the theoretical underpinnings of their behaviour. The simulation data shows that the screening and coupling parameters have a close agreement with the QLCA model findings. The MD simulations validate the prediction made by the QLCA model that the properties of a soliton remain unaffected by variation in the coupling parameters. The prediction made by QLCA regarding the formation of multiple solitons at higher screening parameter values has also been confirmed by the MD simulation.

Quasi-Longitudinal Electro-Magnetic Turbulence in Magnetized Plasmas: The quasi-longitudinal electromagnetic turbulence have been simulated for a magnetized plasma in the Electron magnetohydrodynamic (EMHD) plasma regime with the addition of ion-dynamics. The simulations have been performed using an in-house developed code. Anomalous features have been observed in the spectral domain for the resonant lower hybrid waves coupled to quasi-longitudinal EMHD waves. The observed features have application in understanding stability of tokamak plasma, space plasma and large volume laboratory plasmas.

A First Principles Study of Convection Cells to Shear Flow Instability in 2D Yukawa Liquids Driven by Reynolds Stress: The stability of kinetic-level convection cells (wherein the magnitude of macroscopic and microscopic velocities are of same order) is studied in a two-dimensional Yukawa liquid under the effect of microscopic velocity perturbations. The numerical simulations demonstrate that for a given system aspect ratio β viz., the ratio of system length Lx to its height Ly and number of convective rolls initiated Nc, the fate of the convective cells is decided by $\beta c = \beta/Nc$. For $\beta c < 1$, Reynolds stress is found to be self-consistently generated and sustained, which results in tilting of convection cells, eventually leading to shear flow generation, whereas for $\beta c \geq 1$, parallel shear flow is found to be untenable. An unambiguous quantitative connection between Reynolds stress and the onset of shear flow using particle-level data is established without free parameters.

A5.5 Fundamental Plasma Studies

Numerical Simulation of an Expanding Magnetic Field Plasma Thruster: A comparative Study for Argon, Xenon and Iodine Fuel Gases: During a space mission outside earth's gravity, switching to an electric propulsion system from chemical propulsion significantly reduces the mission's overall cost. Hall thruster and gridded ion thruster are the established technologies for an electric propulsion system. These thrusters compromise mission longevity due to continuous erosion of the device electrode material. To overcome this issue, an electrode less expanding magnetic field plasma thruster or helicon plasma thruster (HPT), is being explored by researchers worldwide. The HPT shows scaling of thrust with input power while Hall thrusters and ion thrusters do not. Typically, an inert xenon gas is used as a fuel in HPT devices due to a low ionization potential and non-hazardous nature. Xenon is not easily available in nature and during a space mission it needs to be stored in high pressure tanks. Recently, iodine has been proposed as an alternate to xenon as it is easily available and does not have any storage issues. In most of the numerical simulations, argon is used as a fuel gas to reduce the simulation cost. Simulations have been carried out using a 1D3V particle-in-cell Monte Carlo collision code. The code is able to capture the net thrust generated in the thruster for different fuel gases such as argon, xenon and iodine. Thrust and plasma flow are investigated for different magnetic field gradients in the plasma expansion region for unidirectional and bidirectional HPT. A significant increase in net thrust is obtained for the cases with iodine as a fuel at higher magnetic field divergence in comparison to xenon fuelled cases, for identical simulation parameters.

Particle-In-Cell Simulation of Electrostatic Waves in the Ionosphere: Plasma with two electron population is very common in the upper atmosphere (ionosphere). The cold electrons (Te∼1 eV) usually originate in the ionosphere, while the hot electrons (Te∼100 eV) come from the magnetosphere. In addition to these two electron populations, there may be a beam of electrons streaming along the magnetic field lines. These electrons are responsible for exciting various electrostatic wave modes. Using Particle-In-Cell simulations, a systematic study has been addressed for the evolution of the system, based on the beam energy. It is found that with an increase in beam velocity, the beam temporarily recovers a portion of its initial energy as well as a higher saturation energy. The wave energy is lost significantly before saturation and after linear growth at a relatively modest beam velocity. In addition, the low beam velocity generates BGK electron holes in the phase space, which are missing at higher beam velocities. Also, the analysis of the condition of sustained electron holes in the phase-space has been investigated.

Beam-Plasma Dynamics in Finite-Length, Collisionless Inhomogeneous Systems: A numerical study has been performed to investigate the streaming instability triggered by ion motion in a plasma system that is finite in length, collisionless, and inhomogeneous. Particle-In-Cell technique with kinetic equations have been utilised to examine how inhomogeneity emerges from integrating a cold ion beam with a background plasma within a confined system. The findings suggest that steady ion flow can modify ion sound waves through acoustic reflections from system boundaries, leading to instability. Such phenomena are known to be a hydrodynamic effect. However, there are signatures of the beam-driven ion sound instability where kinetic resonances play a pivotal role. The main objective is to understand the impact of a finite-length system on beam–plasma instability and to identify the wave modes supported in such configurations.

Reactive Molecular Dynamics Simulation of the Carbendazim Degradation Induced By Reactive Oxygen Plasma Species: Carbendazim (CBZ), a benzimidazole carbamate fungicide, used in agriculture, forestry, and veterinary practices to combat fungal diseases, is notably classified as a hazardous chemical by the World Health Organization. Cold Atmospheric Plasma (CAP) has demonstrated successful pesticide degradation with notable removal rates, energy efficiency, and eco-friendly attributes. A Reactive Molecular Dynamics (RMD) have been carried out to investigate the phenomena of reactive oxygen species (ROS) inducing degradation pathways in CBZ. Our simulations demonstrate that ROS, including O atoms, OH radicals, and O_3 molecules, play a pivotal role in initiating the modifications. Typically, the interaction between ROS and pesticides begins with H-abstraction, leading to the disruption and formation of key chemical bonds such as C=C, C-N, and C=O bonds, while facilitating the formation of C-C, C-O, and C=O bonds. The dose-dependent effects of ROS on CBZ has been examined by incrementally increasing ROS quantities within the simulation environment. It is found that as the ROS concentration increases, the degree of pesticide damage also increases. The elucidated chemical pathways and statistical data provide insights into the atomic-scale degradation mechanism of CBZ, offering a theoretical foundation for optimizing pesticide degradation strategies in future applications.

Charged Particle Dynamics in an Elliptically Polarized Electromagnetic Wave and a Uniform Axial Magnetic Field: An analytical study of charged particle dynamics in the presence of an elliptically polarized electromagnetic wave and a uniform axial magnetic field has been studied. It is found that a charged particle resonantly gains energy for $g\omega_0/\omega' = \pm 1$. ω_0, and ω' are the cyclotron frequency of the charged particle in the external magnetic field and Doppler-shifted frequency of the wave seen by the particle. g=+1 and g=-1 corresponds to the right and left-handedness of polarization. An explicit solution of the governing equation has been obtained in terms of particle position or laboratory time, for the specific case of resonant energy gain in a circularly polarized electromagnetic wave. These explicit position- or time-dependent expressions are useful for better insight into various phenomena, viz., cosmic ray generation, microwave generation, plasma heating, and particle acceleration.

Study of Magnetized Multi-Component Plasma Sheath with Three Isothermal Ion Species: The dynamics of magnetized plasma sheath with three isothermal ions is studied numerically using the fluid model. The three ions (Ar+,Kr+, and Xe+) are assumed to be singly charged and have the same temperature. In the beginning, the concentrations for Ar+ and Xe+ are taken in the same proportions, and then the Kr+ ion density is introduced slowly in the plasma. It is found that the presence of a third ion has changed the dynamics of ion densities inside the sheath and simultaneously their respective velocities. Ion density and electron density profiles are estimated inside the sheath region in the presence of a weak and strong magnetic field as well at different Kr+ ion concentrations. Further, the dependence of magnetic field obliqueness on the ion density profile and its velocities inside the sheath is also studied and observed ion density bunching at different conditions. Based on the results, it is tried to introduce a concept of the derivation of system Bohm velocity by considering the ion mass as equivalent mass for the three interacting ion systems in the plasma. It is found that the system Bohm velocity with the equivalent mass effect is larger than their individual thermal velocities and close to Ar+ Bohm velocity, and higher than the system Bohm velocity with reference to the density ratio and their respective individual Bohm velocities in an isothermal multi-component plasma.

Interaction of Driven 'Cold' Electron Plasma Wave with Thermal Bulk via Ion Spatial Inhomogeneity: The evolution of driven 'cold' electron plasma wave (EPW) in the presence of stationary inhomogeneous background of ions is studied using high resolution Vlasov-Poisson simulations. Mode coupling dynamics between 'cold' EPW with phase velocity v_ϕ greater than thermal velocity i.e. $v_\phi \gg v_{thermal}$ and its inhomogeneity induced sidebands is illustrated as an initial value problem. In driven cases, formation of Bernstein-Greene-Kruskal (BGK) like phase space structures corresponding to sideband modes due to energy exchange from primary mode to bulk particles via wave-wave and wave-particle interactions leading to particle trapping is demonstrated for inhomogeneous plasma. Qualitative comparison studies between initial value perturbation and driven problem is presented, which examines the relative difference in energy transfer time between the interacting modes. Effect of variation in background ion inhomogeneity amplitude as well as ion inhomogeneity scale length on the driven EPWs is addressed.

Merging Dynamics of Unidirectional Current Carrying Filamentary Plasma Blobs in the Edge Region of a Tokamak: A model has been introduced for studying the merging of two electromagnetically interacting blobs, which have unidirectional currents and are located in the tokamak edge region in a high beta plasma. Unlike the conventional plasma blobs with dipolar currents that originate from resistive drift/ interchange plasma turbulence, these unidirectional filamentary blobs arise from edge-localized mode ejection events. Two such blobs can interact strongly in the edge region to merge with each other in the poloidal direction. Detailed simulations reveal that the blobs rotate about each other during the merging process and the merging occurs with a rate of acceleration in the poloidal direction that is directly proportional to the square of the current density of the blobs and inversely proportional to its density. An analytic condition has been proposed for two poloidally separated plasma blobs to merge poloidally without a significant movement in the radial direction. Numerical simulations support this analytical condition. The separation distance between two high current density blobs is also seen to exhibit a sloshing behaviour. For a given blob radius and density, the radial velocity during merging decreases with the strength of the unidirectional current density.

Effect of Gas Pressure on Plasma Asymmetry and Higher Harmonics Generation in Sawtooth Waveform Driven Capacitively Coupled Plasma Discharge: The influence of gas pressure (5–500 mTorr) on plasma behavior has been examined using Particle-In-Cell simulations. The plasma is considered to be generated in a symmetric capacitive coupled discharge driven by a sawtooth-like waveform. For a fixed 50 A/m^2 current density, a strong plasma spatial asymmetry is observed at low pressure (5 mTorr), which decreases with increase in pressure and eventually transitions to a symmetric profile at high gas pressure. In contrary, flux asymmetry increases with increase in gas pressure. At low pressures, plasma asymmetry arises from high-frequency oscillations at the sheath edge caused by waveform asymmetry, while the flux asymmetry is limited by the collisionless plasma transport. At higher pressures, multistep ionization dominates via metastable states, that reduces the spatial asymmetry. The electron energy distribution evolves from bi-Maxwellian to near Maxwellian, with high-energy electron depletion at high pressures. Higher harmonics (up to the 26th) are observed in the bulk electric field at low pressure but diminish with increase in pressure. However, it has been observed the secondary electron emission has negligible impact on the overall trends.

Electromagnetic Vlasov-Maxwell Simulations of Trapping Oscillations in Nonlinear Saturated EM Microinstability: Electromagnetic Vlasov-Maxwell simulations are performed which exhibit trapping oscillations in nonlinear saturated state of Electromagnetic Whistler wave micro instability. Simulations have recovered frequency downshift in the warm electron whistlers and characterized Landau resonance of electrons at Doppler shifted whistler wave phase velocity. Complete phase space portrait of electron distribution at resonant phase velocity is available for kinetic modelling of right handed circularly polarized whistler waves interacting with the fast (runaway) electrons. These results have application in tokamak plasma disruptions.

Microscopic Structure of Electromagnetic Whistler Wave Damping by Kinetic Mechanisms in Hot Magnetized Vlasov Plasmas: Electromagnetic transverse perturbations propagating parallel to the external magnetic field in a warm electron plasma, specifically the warm electron whistler-mode waves, are simulated in Maxwellian as well as κ distributed (with energetic tail) electrons. The Vlasov-Maxwell phase-space continuum simulations are applied to the stable and unstable (i.e. isotropic and anisotropic) VDFs. The variation of real frequency from both numerical solution of dispersion relation and simulations show limited sensitivity to electron temperature in low wave-number regime as compared to high wave number regime, however the opposite holds for the imaginary frequency or the decay rate. The analytically predicted reduction in the decay rate of the whistler-mode with increasing electron temperature is recovered by the Vlasov-Maxwell simulations. The phase-space portraits of the these cases show that after the linear damping phase of the evolution, the particles are trapped in the wave magnetic field leading to the wave amplitudes oscillating about a mean value which follow the theoretical analysis.

Criteria for the Transition From Kinetic to Fluid Modelling Approach for Hollow Cathodes Associated with Plasma Switches: Hollow cathodes for plasma switch applications are numerically investigated in the channel and plume region. The numerical simulations have been performed using a 2D3V particle-in-cell technique. It is found that the kinetic nature of the plasma within the channel is dependent on the thermalization rate of electrons, emitted from the insert. When Coulomb collisions occur at a faster rate than ionization or excitation collisions, the electron energy distribution function rapidly relaxes to a Maxwellian and the plasma within the channel can be described accurately modelled using a fluid model. On the other hand, if inelastic processes are faster than the Coulomb collisions, the electron energy distribution function in the channel exhibits a notable high-energy tail, and a kinetic treatment is necessitated. This criterion is applied to various hollow cathode studies from the literature. It is found that a fluid approach is suitable for most electric propulsion applications, whereas a kinetic approach is necessary to model plasma switches accurately.

Particle-in-cell Simulation of Electron Current Layers in Plasmas: Two dimensional simulations have been performed to study the electron current layers in plasmas connected to the kinetic effects of plasma tearing and surface-preserving instabilities. Tearing instability is responsible for magnetic reconnection, whereas the surface-preserving instability is responsible for preserving the magnetic topology. Simulations are performed to study both thermal and cold plasmas to understand the interplay of different simulation parameters. It is observed that the tearing instability increases with increase in temperature initially and then decreases as the temperature is further increased. In contrast, the surface-preserving instability continually increases with rise in temperature. For the cases where both tearing instability and the surface-preserving instability exists, it is found that, the growth rate of the instability initially increases with increase in temperature and then decreases with increase in temperature.

A5.6 Laser Plasma Interaction

Collisionless Absorption of Laser Energy in Laser-Cluster Interaction: The effect of circularly polarized (CP) laser fields on the cluster-electron dynamics is studied in the presence of an ambient magnetic field (B_0) in the transverse direction.

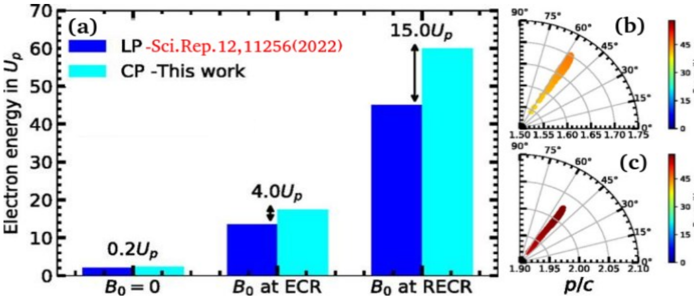


Figure A.5.2: FIG 1: (Left column) Schematic of comparison of average energy gain by a laser-driven cluster-electron for LP and CP fields with/without $\boldsymbol{B_0}$*. (Right column) Angular distribution of PIC electrons in the momentum space* (p,θ_p) *with their normalized momenta* p/c *vs* θ_p *: (b) for LP and (c) for CP. The polar coordinates* (p,θ_p) *of electrons are color-coded with their energy normalized by* U_p*. Cluster size R = 2.2 nm and laser intensity* $I_0 = 1.83 \times 10^{17}$ *W/cm*^{2}*.*

It is found that in contrast to previous studies, the use of CP light enhances the electron energy further by ≈10−20 Up (ponderomotive energy) beyond the previously reported values by the linearly polarized light (LP) light. These ejected electrons from clusters show narrow cone-like propagation (figure A.5.2, right column) as a weakly relativistic electron beam with an angular spread $\Delta\theta < 5°$ and the beam quality improves with CP as compared to LP. In all cases, RSM and PIC results show good agreement.

Generation of Terahertz Radiation From a Soliton Cavity in a Laser-Plasma System:

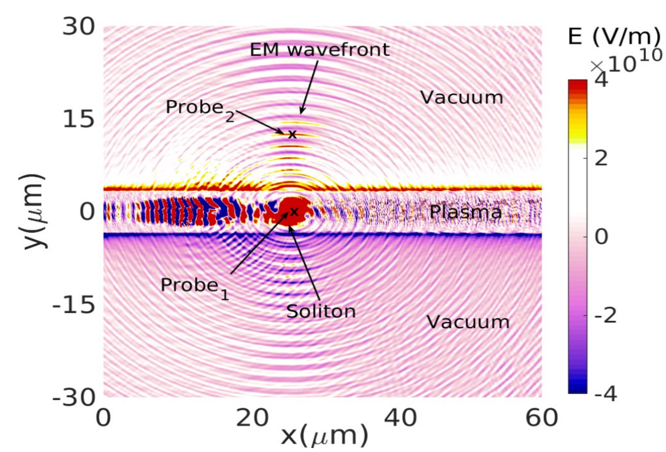


Figure A.5.3: The figure shows the emission of THz radiation from a soliton created by a laser pulse in an under-dense plasma.

Using particle-in-cell simulations, a novel mechanism for the generation of terahertz radiation in a laser-plasma system is demonstrated. The radiation originates from current oscillations trapped in a stable soliton cavity created by the laser in the under-dense plasma region. These oscillations behave like a current dipole antenna. The characteristics of the antenna can be controlled by tuning the laser- plasma parameters to achieve the desired output frequency (Figure A.5.3).

A5.7 Artificial Intelligence and Machine Learning

AI Software – DeepCXR as a Screening Tool for Nation: Trained first version of DeepCXR software on 54000 individual images with 300000 data points achieved 92 & 76 % of sensitivity and specificity on test dataset. The software is approved by DG ICMR and launched by Govt. of India on 24 March 2025. Consequently, the software is now catering 4 different states with 30 sites on boarded onto system. As on 31 March 2025, the software has generated AI reports for more than 23,000 CXR images and shared with states. Institute has launched its own medcloud system, a cloud based server solution wherein users can sync the drive and upload the CXR images and download reports. It has been actively taken up with states like Haryana, Himachal, Dadar & Nagar Haveli and Telangana.

A dashboard as shown in figure A.5.4 is being developed for effectively tracking and monitoring the site progress and utilization of DeepCXR software system on ground.

No	STATE
1	Haryana
2	Himanchal Pradesh
3	DNH_DD
4	Telangana
Total:	23682

Figure A.5.4: Dashboard for tracking & monitoring of sites.

Plasma Equilibrium Surrogate Model for Digital twin - Tokamak: Accelerating fusion research toward commercialization requires new technologies and innovative breakthroughs. It is envisaged that the adoption of cloud computing, artificial intelligence, advanced simulations, and technologies such as digital twins will supplant empirical methods in the design and optimization of present and future fusion devices. In way forward for a digital twin in the institute '*Feed forward based AI model training for*

Prediction of plasma equilibrium profile for ADITYA Tokamak and integration to ADITYA CAD Model' has been carried out.

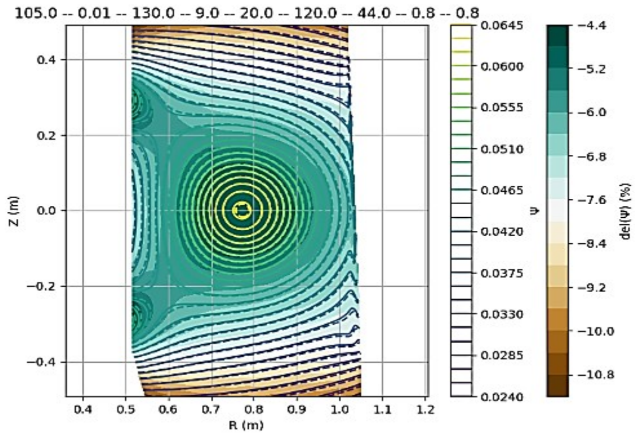


Figure A.5.5: AI generated magnetic field equilibrium profile for tokamak .

This work, explored analytical, numerical and AI based approaches to obtain GS solutions. The analytical method provides insights but is limited in handling complex geometries. The numerical solver ensures accuracy for arbitrary plasma shapes. Using simulation model synthetic data sets were generated for different cases of ADITYA Tokamak. For this Preliminary design and study of plasma equilibrium parameters for ADITYA Tokamak is initiated. Feed forward solutions are obtained by varying coil currents and other machine design. The solutions are benchmarked with the results from literature. Further an AI model is trained to generate equilibrium parameters and compared with analytical solution and simulation results. The AI surrogate model predicts equilibrium states efficiently in real time. The overall trend suggests that the AI model captures the RXD variations, reinforcing its potential as a predictive tool for plasma equilibrium (Figure A.5.5**)** studies.

Synthetic Data Set Generation Using AI : Deep neural networks require a large corpus of training data to learn complex and abstract features, so is the case for image classification models, but high quality images of rare diseases are usually even more rare and often causes the model to misclassify such rare cases and confuse it with other similar looking common abnormalities.

Figure A.5.6: AI generated synthetic images of abnormal X-rays.

Various techniques for generating such synthetic data was initiated, but these approaches had limitations regarding both quality and quantity, hence moving forward to AI based techniques. This involved study of image based AI techniques like Convolution neural networks, and architectures that use those. This included older architectures like VAE and UNET-VAE and later on moving to more advanced models like GAN and Diffusion. Work carried out in developing a novel architecture by modifying a GAN model which translates images from one dataset to another, and hence able to transform healthy normal X-Rays to multiple abnormal X-Rays containing symptoms of diseases. Standard GAN has the limitation of not being able to generate small variations, hence modifying GAN to focus on annotated regions for minute details was also performed. Hence we got a model that can generate a lot of synthetic abnormal chest-x-ray images using a given set of normal and abnormal X-Rays. Some generated samples are shown in figure A.5.6.

A6. Scientific, Technical & Civil Support

The following subsection briefs the activities and updates carried out by the scientific, technical and civil infrastructure support divisions to the institute's development, scientific and experimental programs. The details are highlighted below.

A6.1 Computer Division- IT Services and Infrastructure

Computer Division facilitates the IT services and infrastructure at Institute's (Main campus, FCIPT and CPP-IPR). The IT infrastructure is deployed and configured with High Availability (HA), and implementing cyber-security measures for all IT services including Websites, Webmail, various intranet services (INTRA portal services, IDRMS, E-cloud, etc.), critical Network services including video conferencing, broadcasting and data storage services. Computer Division has a state-of-the-art Data Centers (DC) to house all the critical IT infrastructure and HPC clusters which are monitored and maintained 24x7.

The major operational activities are:

Data Centers (DC)

Primary Data Center (PDC): This facility is providing required infrastructure for IT services running 24x7 for round the clock operations. The 100% uptime is achieved with smooth day to day operations & management in last one year. There was no unplanned downtime in this period. Managing round the clock internet services through Internet Service Providers (ISPs) and distribution to various public networks.

Containerized Data Center (CDC): The additional data centre requirements from various divisions are being catered by CDC for running servers/computing machines with 100% uptime.

Networking and IT Services: Operation & maintenance of the network and IT services at institute campuses with system administration, implementation of cyber-security measures and support for the developed applications.

The brief description is as follows:

Managing round the clock internet services through Internet Service Provider (ISP). Operational management of campus wide network (Wi-Fi, LAN, VPN, and ANUNET). Operational Management of IPR Email system and IPR Website services. In-house development of INTRA Portal Services: Development of utilities/modules, for various official requisition and online administrative approvals. On-premises private cloud-based file-sync data service named ECLOUD & MEGH to users for sharing files and working collaboratively. IP Address Management (IPAM) System portal for registering devices (mobile, laptop, desktop, tablet, etc.).

Centralized Authentication Management: Centralized Identity and Access Management (IAM) system integrated with web applications, web proxy for authentication and authorization for secure access to internet and other services.

Procurement and hosting of various scientific and IT Software and their license management for centralized services.

Operations and management of IT setups of all Committee Rooms, Seminar Hall, Board Room, Dean and Director Offices.

VC System for online meetings with other institutes.

Operational management of DAE BRNS Server hosted at the institute for BRNS website services.

Centralised storage capacity of 1.7 PB is functional with Enterprise File Share and Sync (EFSS) software providing the functionally like Dropbox, Google Drive, OneDrive etc.

A6.2 Scientific Information Resource Centre (SIRC)

Scientific Information Resource Centre (SIRC) is providing specialized Information Resources and Publication Management services using contemporary tools to the scientific community involved in the Research and Development activities of Plasma Physics and Fusion Science and Technology. The new library website was launched.

During the year 2024-25 a total budget of Rs. 17458634 was utilized and added the following to its collection: Library added 107 books to the collection, these include books added through the books exhibition. Library also added 61 eBooks from Institute of Physics (IoP). Reprints – 180; Pamphlets – 18. The library organized a two day books exhibition and procured 46 books.

The library has access to journals through One DAE One Subscription (ODOS) consortium and One Nation One Subscription (ONOS). It also continued to subscribe to non-ONOS journals and subscribed to 23 periodicals and added one new journal title as well as journal archive to the e-collection and continued to subscribe to major databases such as SCOPUS, NUCNET News service.

Library is continuously displaying the latest updates in the areas of Research on the Digital Display Board and providing email-based FYI-Fusion News Alerts services to the institute, CPP and ITER-India users. Total 841 News items were sent/displayed and archived as an Alerting Service. Scientific News in Hindi language are also displayed on the library noticeboard.

Library continued to collaborate with DAE units and other National and International libraries to provide Inter-Library Loan (ILL) services. 92.94% of the requests made by staff members were satisfied through ILL service. Institute's Library provided documents to other institutes against their queries and 100% of the total need were satisfied.In 2024-25, Library provided 28774 photocopies/ prints and 31238 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. A total of 576 manuscripts (Abstract/Papers) and 03 Patent information were broadcasted to the Staff through the Pre-Publication Broadcasting System and Pre-Patent Broadcasting System respectively on the Intranet portal.

SIRC published the following during the year 2024-25: Internal Technical Reports – 54; Internal Research Reports – 105; IPR Publications in Journals – 180; IPR Publications in Conference Proceedings – 28; Book Chapters – 6.

During the year 2024-25, the repainting of Library space was carried out, during this time uninterrupted user services were provided, and after completion of the repainting work, the library is re-organized to a more user-centric space.

Hands-on Training was imparted to the three MTS. Library Internship was provided to four library science students from Gujarat University, Ahmedabad. 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, National Science Day, etc. Library is also actively involved in OLIC and promoting usage of Hindi language.

A6.3 Mechanical Engineering Services Division (MESD)

MES division has four sections namely Engineering Design & Analysis Section (EDAS), Inspection & Quality Section (IQS), Drafting Section and Workshop Section. The activities undertaken by the division is conforming to full product cycle which includes concept to commissioning. The major tasks are design and analysis of the product/system, preparation of the engineering drawings, fabrication/ manufacturing and inspection, testing and commissioning. The division is also supporting the inspection of incoming stock items at Store. The division comprises of team of Mechanical Engineers, draftsman and technicians. MESD division has provided services to different divisions such as SST-1, Aditya, Magnet, Cryogenic, Neutronics, Remote handling, NBI, Fusion Blanket, Cryopump, Fundamental Physics etc. MESD also provided the extensive services to FCIPT.

The EDAS of MESD has been actively executing various tasks related to design, analysis, fabrication, inspection and testing. Since its inception, section has satisfactorily completed and report is submitted for more than 200 tasks for different divisions. The design is carried out using ASME, WRC codes, vacuum protocol etc. FEM analysis is performed to ensure the structural integrity of the system/product. Different kind of analysis such as structural, thermal and coupled is being carried out routinely using ANSYS.

The IQS of MESD has been actively executing various tasks related to Welding Procedure Specification, Manufacturing and Inspection Plan, Material testing, Quality Assurance, Quality Control, different kinds of Non-Destructive testing etc. The activity related to assembly, disassembly, interference checking, new components assembly etc. of the different components for SST-1 are also supported by this section. During the year, IQS division also completed more than 20 tasks.

The Drafting section of MESD is equipped with 6 licences of CATIA-V5 R13 installed on work stations for 3D modelling and 2D drawing preparation, HP inkjet printer T2300 plotter. Section has been supporting the users for designing and preparation of engineering drawings for various systems of the institute. During the year, section has executed more than 700 job cards for 3D modelling and 2D engineering drawing preparations. Section is also supporting the poster printing for different conferences and presentations.

The Workshop section of MESD is equipped with modern versatile machineries including machining and fabrication (shearing, rolling, TIG welding etc.) facilities catering for needs of the institute, FCIPT, ITER-India and CPP for the fabrication of a system/ product required by users. Workshop has the 3-axis abrasive water-jet machining facility useful for machining the intricate shapes of different materials at room temperature. It has also CNC and VMC machining centre. Workshop is also manufacturing vacuum components which are used as stores stock items. During the year, workshop has executed more than 1400 job cards (including 475 job cards of abrasive water jet machining) and fabricated systems/ product of different materials (Stainless steel, Aluminium, Copper, Brass, Ceramics, Teflon, Hylum, PEEK etc.) weighing more than 10500 kg.

New 15 MW Cooling Water System for ITER Deliverable Experimental Systems at ITER—India: A new Cooling Water System with 15 MW cooling capacity is constructed at institute's main campus for rejection of heat (to atmosphere) generated from various experimental systems of ITER-India and institute's laboratories with primary objective of testing of ITER Components being supplied to ITER Site, France and also meeting the requirements of cooling water for ongoing developmental projects of domestic fusion program.

Major equipment installed include 15 MW FRP Cooling Tower with 40,000 litre water basin, 2 x 300 TR Water Cooled Screw Chillers, 18 Centrifugal Pumps, 200 kW Motors and variable frequent drives, 5 Plate type Heat Exchangers upto 9 MW capacity, storage tank, valves, piping, power & Instrumentation cabling, MCC, PLC Panel and SCADA system.

A6.4 Civil Infrastructure Projects

Civil Renovation and Up-gradation Works: Civil Maintenance Section (CMS) is responsible for overall maintenance, repair and renovation of existing civil infrastructure comprising of buildings Water supply lines, Drainage line, Gardening, Horticulture operations in the institute and FCIPT Campus. Many civil renovation works have been completed, major among them include -
Construction of control cabin for 430kA magnet power supply area. Civil work including signage work in Gujarati Language at Main gate of the institute. Repainting of Gas storage tank vessels, fencing, support structure etc. and other allied civil works at Helium storage yard, civil works for Pre-cast covers for cable trenches, chain link fence for DG building, & safety grills in Neutronics building, construction shed behind underground water tank. Replacing of damaged roofs with PUF sheets and other miscellaneous civil works in different laboratories at FCIPT, renovation of washrooms at old office building and that of RFMS laboratory, development of area behind new office building on Miyawaki forest theme and Plantation of 650 saplings across campus.

Additional Civil Infrastructure Development: Major additional infrastructure developed in the institute campus during the year includes—Construction of Shed building at FCIPT campus – Work completed and taken over. Construction and Installation of new 100 KLD STP completed and successfully tested for its functional performance. Reception and Stores shed Building – Construction work in progress, nearing completion. Extension of existing workshop building – Tender process completed, work is awarded and construction is in progress. Renovation of guest house with provision for passenger lift -Tender process completed and work is awarded. Construction of new cubicles to set up offices for Atal Incubation Center in the Institute.

Water Cooling and Air Conditioning: Water Cooling

Figure A.6.1: a) 100 KLD Sewage Treatment Plant and b) FCIPT Shed.

and Air-conditioning Section (WC&ACS) is responsible to support for operation maintenance of Water Cooling and Air Conditioning plants at the institute's and FCIPT Campus. Installation, testing and commissioning of energy efficient inverter type split air conditioners with 5-star rating to replace old AC units in the institute and FCIPT campuses has been done.

A6.5 Ultra High Voltage Systems

Ultra High Voltage Systems Division is responsible for Indigenous development of Ultra High Voltage Power Supply System and Associated key Technologies essential for Fusion R&D Program & Industrial Applications. The primary objective is to develop High Voltage Equipment / System based on Modular / Scalable / Compact Design solutions; and ensuring Reliability, Availability, Maintainability, and Inspectability aspects of the system. Following are some of the major deliverables of UHVS Division since its inception.

500 kV/100 mA DC Power Supply Development: This Power Supply is best suited for Low Power (< 200 kW) and High Energy (>100 keV) DC Particle Accelerator based Applications and Electrical Systems/Equipment Testing purpose. The power supply is designed and built based on modular construction and Scalable to 1000 kV/100 mA. The Power Supply has been integrated, tested, commissioned and demonstrated its use for accelerating the 10 mA Hydrogen Beam at 200 kV and testing of various High Voltage components viz. Diodes, Capacitors, Insulators, Bushings, Feed-through, Transformers etc.

Each and every element of this Power Supply System viz. symmetrical voltage multiplier (SVM) units, High Frequency Source, High Frequency Step-up Transformer, Pneumatic Earth switch, Current Limiting Resistor is indigenously designed and built with the support of Indian MSME complying to Make In India (MII) initiatives of Government of India and may be considered as import substitution.

300 kV/2 A DC Power Supply Development: This Power Supply is best suited for High Power (> 1 MW) and High Energy (>100 keV) DC Particle Accelerator based Applications viz. NBI as being used for Heating & Current Drive System in Fusion R&D Program (Figure A.6.2). The Power Supply system is indigenously designed and built with support of Indian MSME's and in compliance to MII initiatives using modular construction which facilitates its scalability with ease to 500 kV/2 A. All the elements of power supply viz. Controlled Rectifier, Inverters, High Voltage Transformer and Rectifier (HV-TRU) are duly tested for its respective designed rated values and have been integrated, tested and commissioned.

Figure A.6.2: Development of 300kV, 2A DC power supply.

High Voltage Ion Extraction and Accelerator Grid System: High Voltage Ion Extraction and Acceleration Grid System (Figure A.6.3) is first of its kind development in India. The HV Grid System shall be integrated with ECR Ion Source and appropriately the beam shall be accelerated upto 300 keV followed by its neutralization so that neutral beam is formed and injected to Tokamak and / or targeted to Deuterium / Tritium target to produce Neutrons.

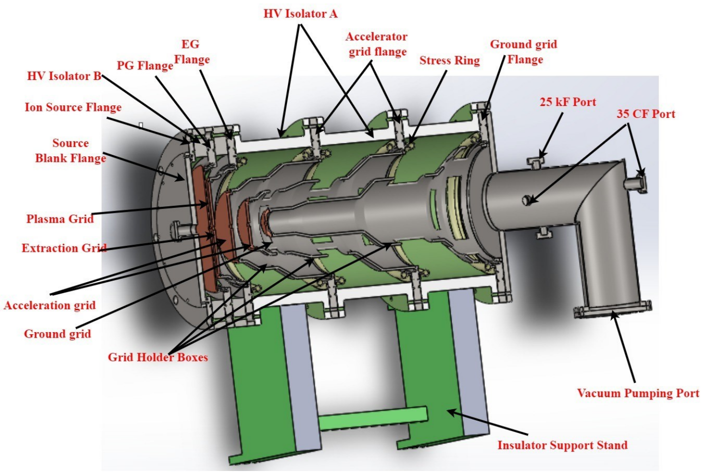


Figure A.6.3: *High Voltage Ion Extraction and Acceleration Grid System.*

The HV Grid System is indigenously designed and built taking into consideration the modularity, scalability to beam current upto 2 A, and ease of assembly. The HV Grid system is built, installed and tested for designed Leak Rate ($\leq 1.0 \times 10^{-8}$ mbar –l/s) and Vacuum holding capacity ($\leq 5 \times 10^{-5}$ mbar). High Voltage withstands capability, beam dynamics and diagnosis is planned as next course of action.

Mitigation of the voltage imbalance condition in Regulated High Voltage Power Supply:

Figure A.6.4: Photographs showing multi secondary transformers (MST) and switching power modules (SPMs).

Regulated High Voltage Power Supplies (RHVPS) have been developed and are being used by high power radio frequency devices and Neutral Beam devices at the institute. RHVPS are modular in which small voltage sources are added using PSM techniques to accomplish DC high voltage output. Small voltage sources are AC-DC power convertors namely Switched Power Modules (SPM) which are fed by Multi-Secondary Transformers (MST) (Figure A.6.4). MST provides input electrical power as well as HVDC isolation. It is having single primary and multiple isolated secondary windings. Isolated secondary windings possess inter-winding capacitance (Cw) with adjacent windings. During long pulse operation, RHVPS performance issues related to voltage imbalance across filter capacitors of SPM have been observed. This imbalance trips the concerned SPM, which results in an unregulated output.

A6.6 Electronics and Instrumentation

Electronics and Instrumentation Division provides services to all divisions involved in Tokamak operation and physics experiments at Institute. Division develops various kind of electronics systems which involves designing, prototyping, testing and integration of electronic systems in experiments. Team handles all aspect of projects from initial concept, design to final implementation internally.

Figure A.6.5: Signal conditioning electronics for Electromagnetic Diagnostics.

In year 2024-25, isolated signal conditioning circuit for 200 channels of Electro Magnetic Diagnostic for ADITYA-U, SST-1 and SS-ST machine has been developed (Figure A.6.5). The Electromagnetic probe diagnostics are used to measure essential plasma operational parameters, including plasma position, current, magneto hydrodynamic (MHD) activity, loop voltage, confinement time, plasma energy, and disruption events. A single 3U chassis consists of 32 channels of signal conditioning electronics with 5 kV common mode voltage two port isolation in each channel. Another development is Low noise front end electronics of 24 channel having current to voltage factor of 1 V/uA and 50 kHz bandwidth is developed to interface AXUV diode array in ADITYA-U Tokamak to measure radiated power from plasma. For upcoming Small Scale Spherical Tokamak at Institute, signal conditioning for different plasma diagnostics, HV control electronics for Photo multiplier tubes has been developed.

Self-reliant, flexibility, low cost and fast implementation is achieved in the development of various multichannel indigenous data acquisition systems, customized for different experiments like fast Doppler spectroscopy, operation and probe measurement in ADITYA-U Tokamak. The systems are based on single board computer and system-on-chip up to sampling rate of 10M Samples/sec/ch and 8Mx16 SRAM/512 MB DDRAM. Leveraging open source technologies, the application software of indigenous data acquisition system is developed in Python.

For electron plasma experiments in SMARTEX-C device, developed remotely configurable FPGA based operation and control electronics (Figure A.6.6) to generate voltage in step-up ramp for electrodes bias and control timing sequence for evaporative dump of electron plasma in two stage, associated signal conditioning electronics for capacitive probe current measurement and automated the baking system of device (Experiment is detailed in Sec. A3.2).

Neutron Radiation exposure of electronics components like ADC, Opto-coupler, SRAM, Instrumentation Amplifier using 14 MeV Neutron Source has been performed to validate radiation hardness of components for energy projects of Institute and ITER. Results of testing has been presented in conference organized at Institute (Figure A.6.7).

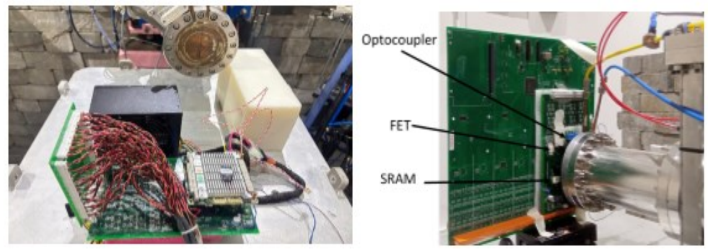


Figure A.6.7: Set-up for neutron radiation on electronics components.

Division members have presented their work in different conferences and published papers in IEEE transactions on plasma science, IEEE Xplore, NIMA and technical reports. The Division is regularly involved in providing projects to students of engineering colleges and equip them with necessary skills of industry. The division actively participated in an 18-month structured training program for newly joined stipendiary trainees.

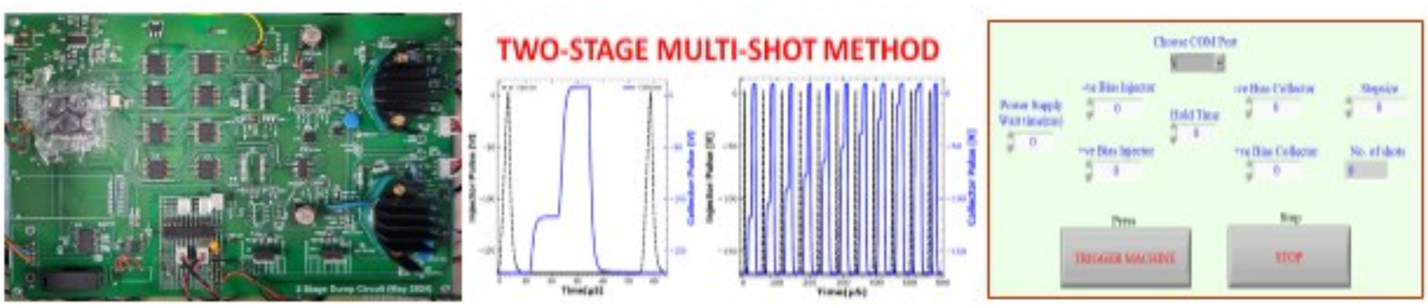


Figure A.6.6: Operation and Control electronics for experiments in SMARTEX-C.

A7. AIC, Patents & Technology Transfer

The following subsection briefs on the Atal Incubation Center, patents filed and external projects are being carried out by the institute.

A7.1 Atal Incubation Center—Plasmatech Innovation Foundation

AIC - IPR Plasmatech Innovation Foundation (Plasmatech) is a Section 8 company, fully owned by DAE. The company has been acting as the commercialisation arm of IPR as approved by the Governing Council of IPR. The company (Plasmatech) is mandated to act as a technology translation company and to support deep technology-based start-ups in the area of plasma and allied technologies. In these direction, In the FY 24-25, eight start-ups have been incubated. This includes, Ecoplaswa Technology, Coldray Plasma Labs and LBIS Research, Pedocrown, Exxcarbon, Zenex Life Care, Plasmazen and Pharma Envirocare India. Some of them have made strides towards developing products and are worth mentioning, as that also gives a snippet of the impact that these technologies promise going forward.

In the financial year 2024-25, AIC-IPR Plasmatech Innovation Foundation executed 6 nos. of technology transfer agreement with Indian companies and startups worth Rs. 29.31 Lakhs. The board of directors have also approved the revenue management policy of the company which acts as a guideline for reinvesting and utilizing the funds generated from the commercialization of IPR’s technologies.

In addition, Plasmatech has been actively fuelling events like colloquium and talks (from IP specialists, innovators and technology leaders) by joining forces with HBNI Institute Innovation Council to spread knowledge about start-up; the process and the journey. On the front of externally sponsored projects, discussions on domains of waste management and waste to energy which are expected to contribute to the larger cause of climate change mitigation and a sustainable and equitable future.

A7.2 Patents Filed

A Process for Producing Superhydrophobic Metallic Surface for Efficient Water Harvesting, Vivek Pachchigar, Basanta Kumar Parida, Mukesh Ranjan, Sooraj K. P., Indian App. No. 202421057885, dated 30 Aug 2024 - IPR.

A Novel System for Online Microscopic Image Examination, Agraj Abhishek, Abhishek Sharma, Manika Sharma, Naveen Rastogi, Jignesh P. Chauhan, K. K. Gotewal, Indian App. No. 202421058089, dated 06 Sep 2024 - IPR.

A Novel Dental Medium for Storage and Transportation of Avulsed Teeth, Yash Bafna (SPU), Shoba Fernandes (SPU), S. K. Nema, Vikas Rathore, Chirayu N. Patil, Matangi Joshi (SPU), Indian App. No. 202421058088, dated 13 Sep 2024 - IPR & NPDCH (Sankalchand Patel University).

A Dielectric Barrier Discharge Apparatus and a Process to Produce Moderately High Volume of Plasma Activated Liquids, Aadambhai Sanghariyat, Vikas Rathore, Chirayu Patil, Sudhir Kumar Nema, Indian App. No. 202521013977, 18 Feb 2025 - IPR.

A7.3 External Projects

A) PROJECTS COMPLETED				
Executed directly				
Sr. No	**Organisation**	**Description**	**Deliverables**	**Status**
01	Birla Institute of Technology (BIT), Mesra Jaipur campus	Supply of Atmospheric Pressure plasma jet	Atmospheric pressure plasma jet system	The system has been fabricated and delivered to BIT Mesra
02	Vedanta Aluminium and Power	Feasibility study for synthesis of Ti_3AIC_2 MAX phase material and its coating on Carbon material	Feasibility study report along with coated samples	The coating of nickel, Titanium and Ti_3AlC_2 on carbon samples were attempted using various techniques such as HVOF, laser cladding etc. The coated samples and final report submitted.
Executed through AIC-IPR Plasmatech Innovation Foundation (IPR's incubation center)				
03	Oscar Enterprise	Providing technical support for testing of secondary chamber of plasma pyrolysis system	System support	The testing of chamber has been completed and scope of the work
04	Cenerge Engineering Solutions	Engineering design of pillow sheet heat exchanger	Design report	The activities under the scope have been completed and the design report is submitted.

B) ONGOING PROJECTS				
Sr. No	**Organisation**	**Description**	**Deliverables**	**Status**
01	Excel Industries	Technical consultancy for setting up 75 kW thermal plasma system	Providing technical consultancy on advisory basis	Engineering Design of the thermal plasma system is completed. Procurement of the components and subsystems are in progress.

02	Space Application Center (SAC), ISRO	Development and supply of 1250 mm aperture sized, Liquid Nitrogen cooled cryopump (AGATSYA™)	1250 mm aperture sized liquid nitrogen cooled cryopump (AGATSYA™)	The main cryopump vessel and its components have been received and tested for vacuum and cryogenic performances. Assembly of system is in progress.
03	Sun Petrochemicals Private Limited	Feasibility study for Automatic Wire Explosion system for enhanced oil recovery	Feasibility study report	The final design of the mechanical tool and completed. The specifications of all components of electrical system with specific dimensions have been worked out. The procurement of components are in progress.
04	URSC (formerly ISAC), ISRO Bengaluru	Spacecraft Plasma Interaction eXperiments-III [SPIX-III]	Conducting LEO and GEO like space condition experiments on satellite solar panels	Validation experiments requested by URSC were completed. Project report is under preparation.
05	DST, New Delhi	Design and development of anti-UAV (Unmanned Aerial Vehicle)	Anti-UAV system	Scope of the project has been completed. Financial closing is in progress.
06	ICMR New Delhi & National Institute of Research in Tuberculosis (NIRT)- Chennai	Develop Deep Learning software for automated & fast identification of TB	Development and deployment of AI based tool for detection of TB	The 1st Milestone to develop a screening Tool to screen larger population of India is complete. DeepCXR has been validated independently and has received approval. It has been recommended to MOHFW - India to use it as screening Tool under National TB elimination Program - GOI. Several sites from multiple states of India is using it. Further collaboration is on with CTD-MohFW to scale it up and integrate it with digital hand held X-ray system to

				make a complete modular system to be used at remote places in India. Development work for 2nd milestone to develop DeepCXR as a diagnostic AI tool is presently being taken up where ICMR & other 20 institutes will provide data & IPR will develop the AI tool.
07	Saint Gobain India Private Limited	Feasibility study for application of plasma processing for textiles, technical textiles & coated abrasives.	Feasibility study report	Plasma treatment experiments have been completed and characterization of samples are in progress.
08	VSSC, ISRO	Plasma erosion Characterization of anode liner materials	Material Characterization report with erosion studies.	Ion erosion experiments on different ceramic materials are in progress.

C) TECHNOLOGY TRANSFER AGREEMENTS EXECUTED THROUGH AIC-IPR

Sr	Name of Organization	Technology	Executed on
01	Exxcarbon Private Limited	Plasma pyrolysis for organic waste	24th November,2024
02	Raut Unitech Private Limited	Wideband hybrid high power MW level CW radiofrequency (RF) combiner/ splitter”	17th December, 2024
03	Veeral Controls Private Limited	Feedback controlled modular High Voltage DC Power Supply	17th December, 2024
04	Urja Gasifiers Private Limited	Plasma pyrolysis technology for biomedical waste	30th December, 2024

D) MOU/COLLABORATION AGREEMENTS EXECUTED BY IPR WITH EXTERNAL AGENCIES		
Title	**Name of the organization**	**Executed on**
Collaboration on Academic Program on areas of mutual interest	Pandit Deendayal Energy University	02nd May, 2024
Collaboration on plasma technology applications and areas of mutual interest	Nirma University	07th June, 2024
Plasma Erosion Characterization of BN/Silica/Zirconia Composites	Vikram Sarabhai Space Center (VSSC), ISRO	05th April,2024
Collaboration on infrastructure, incubation and commercialization of know-how and expertise	AIC-IPR Plasmatech Innovation Foundation (IPR's incubation center)	15th April,2024

E) MOU/COLLABORATION AGREEMENTS EXECUTED BY AIC-IPR PLASMATECH INNOVATION FOUNDATION WITH EXTERNAL AGENCIES		
Title	**Name of the organization**	**Executed on**
Collaboration for support on activities of mutual interest	Atal Incubation Centre - Centre for Cellular and Molecular Biology	17th December,2024
Collaboration for RF Plasma characterization and its application in communications	Advanced Systems Laboratory, DRDO	28th March,2025

LIST OF START-UPS INCUBATED BY AIC-IPR PLASMATECH INNOVATION FOUNDATION		
Startup name	**Area/MVP**	**IPR's technology**
LBIS Research Pvt. Ltd., Ahmedabad	Plasma based coating for Biodegradable food containers	PECVD – SiOx coating
Ecoplaswa Tech. Pvt. Ltd., Ahmedabad	PAW system for agriculture applications	Plasma activated water
Exxcarbon Pvt. Ltd., Bengaluru	Plasma based gasification systems	RAUDRA™ Plasma pyro.

Pharma Envirocare India Pvt. Ltd., Chennai	RAUDRA™ system for disposal of pharmaceutical waste	RAUDRA™ Plasma pyro (BMW)
Plasmazen Pvt. Ltd. Ahmedabad	Plasma based system for seed treatment	DBD plasma expertise
Zenex Lifecare LLP, Hyderabad	Plasma sterilizer for surgical instruments	Plasma sterilizer

CHAPTER B

INTERNATIONAL COLLABORATIONS

B. International Collaborations

The institute is also actively participating and contributing to the following major international mega science experimental collaborations like ITER and Laser Interferometry Gravitational-wave Observatory (LIGO) setup as equal partner in designing, fabricating, testing and supplying various systems and subsystems. The major milestones achieved are detailed below.

B1. Activities of ITER - India

Figure B.1.1: The ITER DG explaining to the Heads of state.

ITER aims to produce 500 MW of power from D-T fusion with controlled burn of D-T mixture for over 1,000 seconds. ITER-India was created as the special agency to fulfil the Indian commitments towards ITER. Several key components and systems of ITER are being contributed in- kind by India.

Prime Minister of India Shri Narendra Modi along with his French counterpart President Emmanuel Macron visited the ITER site, France on 12 February 2025 (figure B.1.1 and B.1.2). The two heads of state showed keen interest in the developments of ITER which is also considered as a “model of science diplomacy in challenging times” for which the entire world should be proud of.

ITER-India continues its steady progress towards fulfilling Indian commitments to ITER. The following are the updates on In-Kind contributions to ITER project and R&D activities.

Figure B.1.2: Project Director ITER-India, Shri Ujjwal Baruah presenting memento to the honorable Prime Minister Shri Narendra Modi.

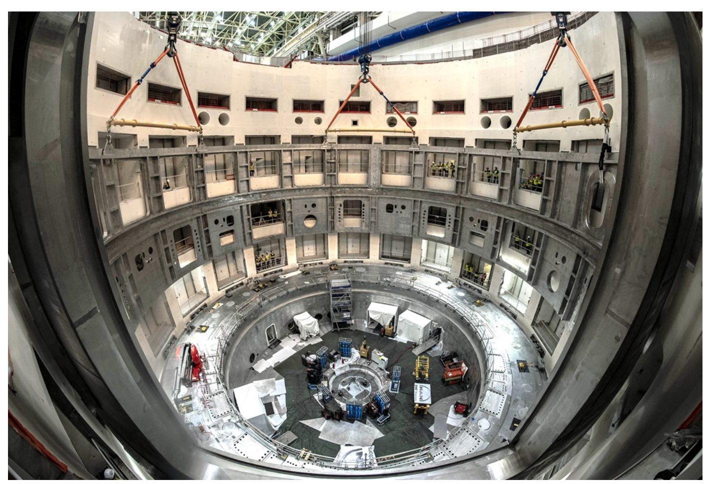


Figure B.1.3: Cryostat (Base section and Lower Cylinder) installed in Pit at ITER-Site.

<u>Cryostat and Torus Cryo-Pump Housing (TCPH):</u> The ITER Cryostat is a very large vacuum vessel, approx. 30 m tall and 30 m across, is the outer boundary of the reactor. This provides the vacuum

necessary to insulate the superconducting magnet coils operating at - 269 °C, also acting as the structural support to the whole tokamak. Approx. 4,000 tons of pre-fabricated sections of various geometry were shipped to ITER site where the final assembly and fabrication was done in a state- of-the-art workshop. The lower part of the cryostat (Base section and Lower cylinder) has already been installed in its designated place at ITER Site (figure B.1.3). The Upper cylinder and Top lid will be installed after vacuum vessel assembly.

a b

Figure B.1.4: Site inspection test of I&C Cubicles.

The site acceptance of Cryostat instrumentation and control (I&C) Cubicles (7 Nos.) has been completed (figure B.1.4a and B.1.4b). Delivery of the Cryostat Optical sensors (Displacement & Accelerometers) (figure B.1.5a and B.1.5b), Cables, Thermocouples, Strain gauges & I&C support (figure B.1.5c) have also been completed.

The Torus Cryo-Pump Housing (TCPH, figure B.1.6a) assembly is a penetration located on the Cryostat cylinder with main functions to accommodate and support the Torus Cryo-Pump (TCP), to connect it to the Vacuum Vessel and also to provide the confinement. It is manufactured from SS304/304L material using ASME Sec-VIII Div.2 with supplementary requirement of ITER Vacuum Handbook for cleaning and leak testing. Each TCPH is of ~20 tons with dimensions 4.3 m length X 3.2 m width X 3.75 m height. ITER-India has successfully supplied all six TCPH to ITER and the Site acceptance leak test (10^{-9} mbar l/s) (figure B.1.6b and B.1.6c) has been successfully completed at ITER.

a b c

Figure B.1.5: Optical sensors (accelerometers, displacement sensors) & Displacement Sensor Supports.

a b c

Figure B.1.6: Torus Cryo-Pump Housing and Helium Leak testing of TCPH.

Cooling Water System: Most of the equipment have already been commissioned. Heat rejection system (HRS) supplied by INDA is operational at ITER site, rejecting heat generated by cryo-compressors (figure 7). The contract has been placed for prototyping and manufacturing of safety-important class pneumatic butterfly valves.

Figure B.1.7: HRS under operation at ITER site.

In-wall Shielding Blocks: In wall shielding blocks are embedded in the walls of the Vacuum Vessel of ITER machine to provide shielding against the fast neutrons generated by fusion reaction. The complete scope of the in-wall shielding blocks as agreed in the Procurement Arrangement (PA) has been completed by India.

Cryo-distribution and Cryolines System: The ITER Cryo-Distribution (CD) system distributes liquid Helium at 4K at required flow rate to the superconducting magnets and cryopumps via five ACBs (Auxiliary Cold Boxes), one cryoplant termination cold box (CTCB), and one Thermal-shield Cold Valve Box. One is allocated to the cryopumps, remaining four to the Super Conducting magnet systems: (i) Central Solenoid coils, (ii) Toroidal Field coils, (iii) Poloidal Field & Correction Coils, and (iv) Magnet Structure.

All five Auxiliary Cold Boxes (ACBs) (with an overall dimension of 5.6 m length, 5 m width and 4.8 m height) of ITER Cryo-distribution system have been delivered at ITER site (figure B.1.8) after successful testing at the factory. The Factory acceptance test (FAT) of Thermal-shield Cold Valve Box (TCVB) has also been completed (figure B.1.9).

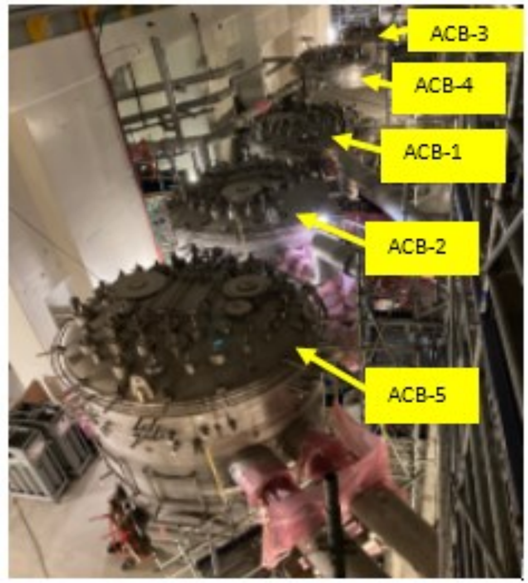


Figure B.1.8: ACBs at ITER site.

Figure B.1.9: TCVB during FAT.

Figure B.1.10: Leak Testing of ACB warm Panel.

Warm panel, part of cryo-distribution, is mainly assembly of safety valve trees for internal cryogenic circuits of ACB. Helium exiting from safety valves will be collected in common header (and send back to cryoplant via relief line). The manufacturing of warm panel is under progress (figure B.1.10).

Delivery of all Cryolines & Warmlines has been completed. Installation and warm acceptance testing have been completed in cryoplant building, ongoing in tokamak building and cryo-bridge, the global progress of installation is ~ 92%. Figure B.1.11a shows Installation of Seismic decoupling spool and figure B.1.11b shows installation of Warm lines in cryo-bridge leg connecting B52.

ITER-India has successfully completed factory acceptance test of I&C cubicles (figure B.1.12a Heater Cabinet and figure B.1.12b control cabinet.

<u>*Diagnostic Neutral Beam (DNB) System:*</u> Works towards testing the DNB system in ITER-India laboratory have made significant progress. The Site acceptance tests of Beam Line (BL) components have been completed and components have been integrated in vacuum vessel (figure B.1.13).

a b

Figure B.1.11: Installed Cryolines at ITER site.

a b

Figure B.1.12: I&C cubicles.

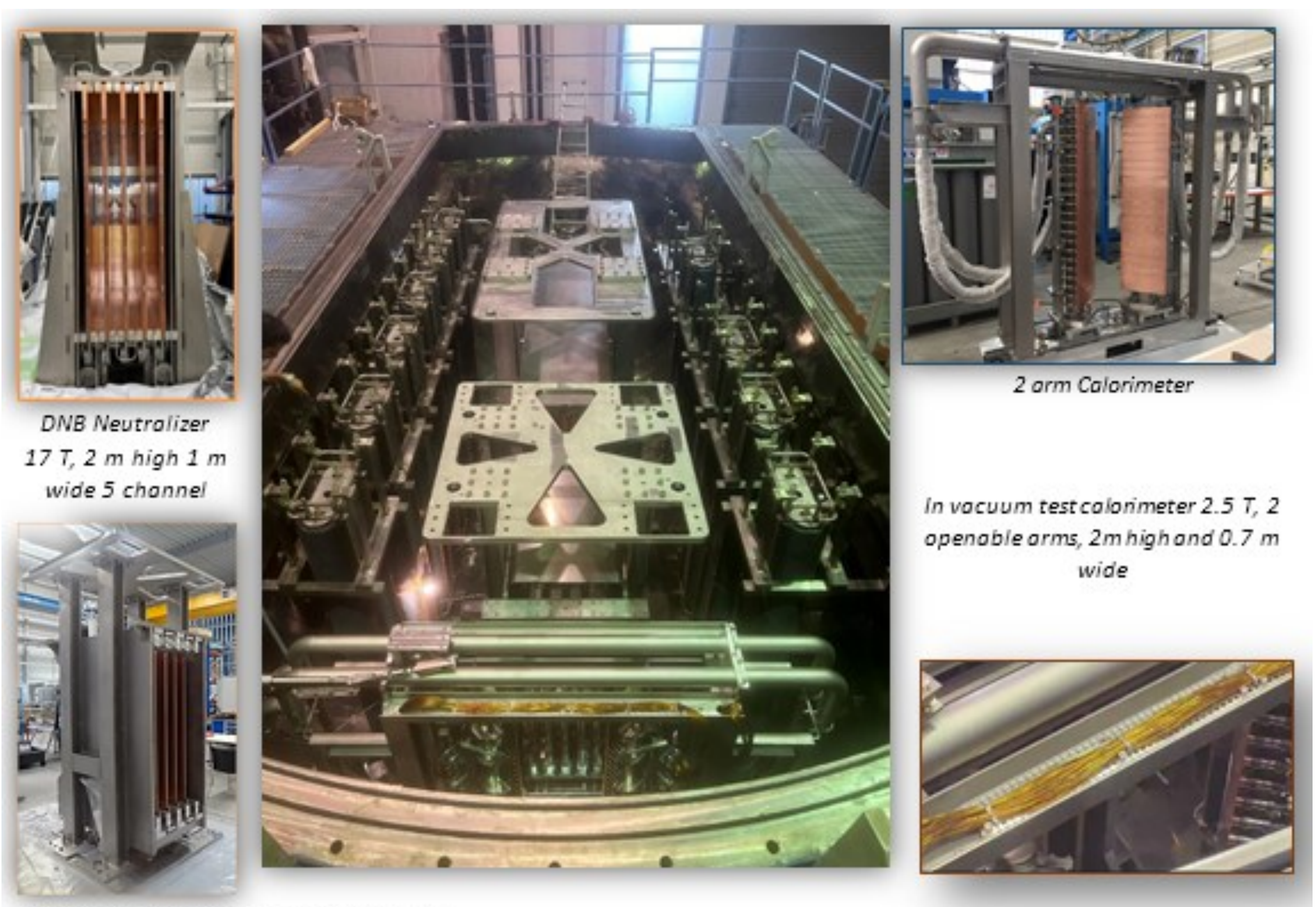


Figure B.1.13: Site acceptance tests of BL components.

The manufacturing and assembly of the ion source components are also progressing towards completion, with assembly of 3 grid accelerators (with dummy insulators) to check for alignment and interfaces is completed (figure B.1.14).

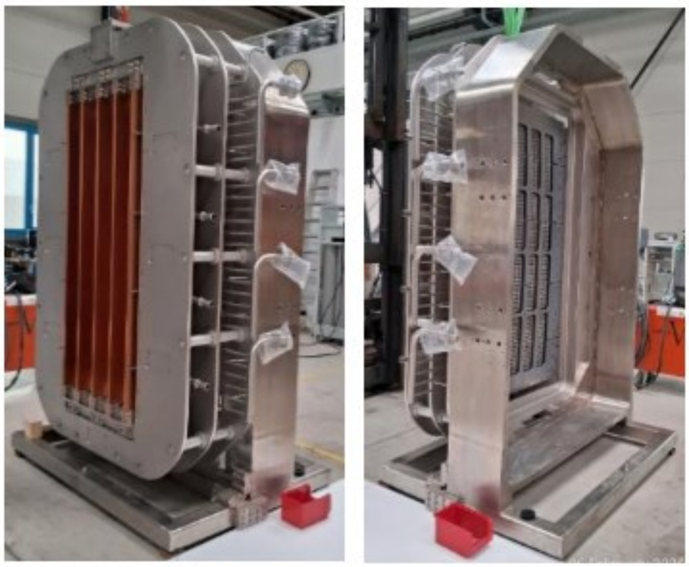


Figure B.1.14: Assembly of 3 -grid accelerator (with dummy insulators).

<u>Ion Cyclotron Resonance Frequency (ICRF) Heating Sources:</u> ITER requires ICRF for tungsten (W) control and for the flexibility of the experimental Programme, also for Ion Cyclotron Wall Conditioning (ICWC) to provide fuel removal associated with the use of boronisation. Each RF Source shall be capable to deliver 3MW power to load having Voltage Standing Wave Ratio (VSWR)-1.5 in between 40-55MHz. ITER-India is responsible for design, supply and site commissioning of 4 RF Sources. ITER-India has completed tube qualification using single chain (1.5 MW / 2000 s / 35- 65 MHz at VSWR 2.0 with any phase of reflection coefficient). Tendering to procure two RF sources is currently under progress. In-house developed 10kW Steady State Power Amplifier (SSPA) has been tested in 45 to 60 MHz frequency range with in house combiner (figure B.1.15).

Indigenously developed High Power Amplifier (HPA) (rated 120 kW/2000s in frequency range of 36 - 60 MHz) has been tested at 100kW (figure B.1.16).

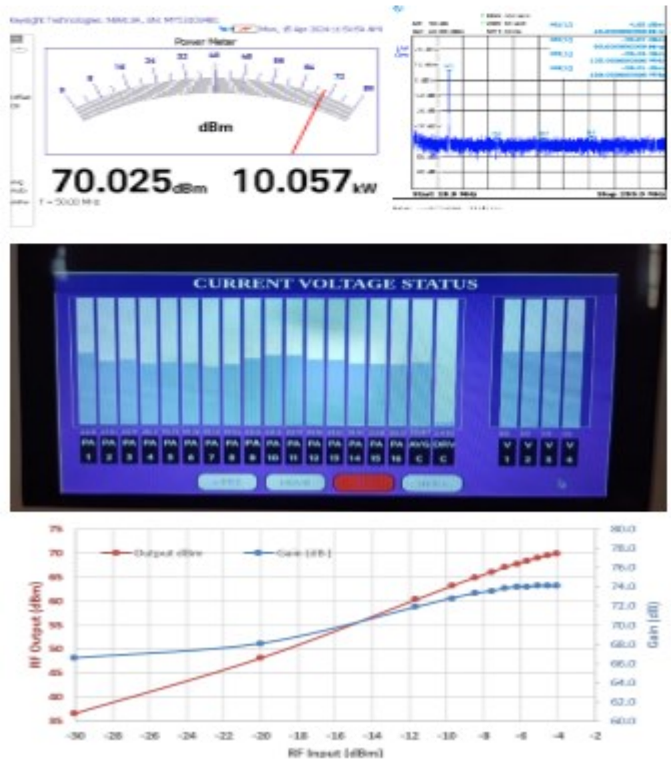


Figure B.1.15: SSPA Measurement @ 45 MHz.

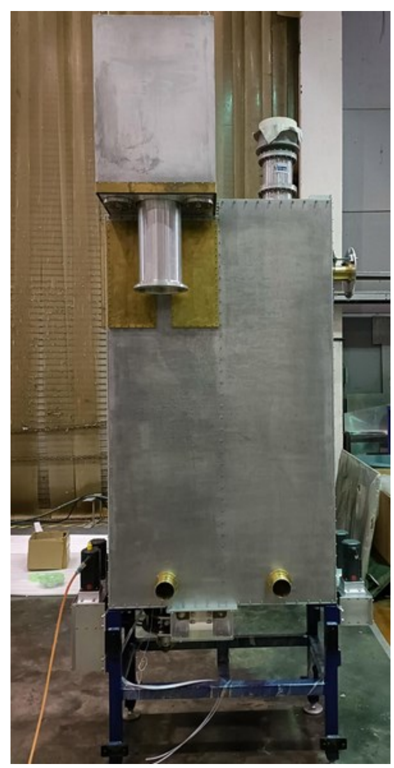


Figure B.1.16: HPA (rated 120kW).

Proof of concept testing of Direct Cavity Coupled Solid State RF Power Amplifier (10kW) has been completed on VNA at 500 MHz (figure B.1.17).

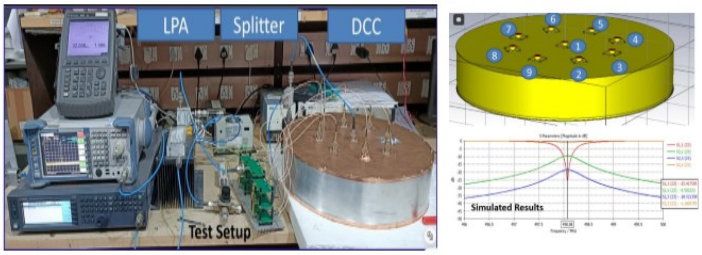
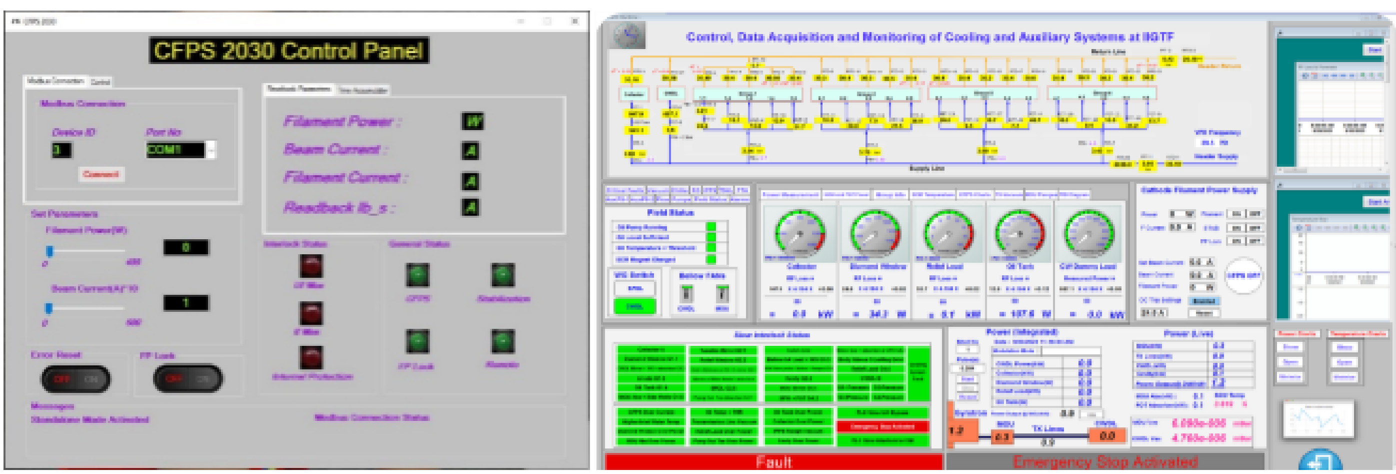


Figure B.1.17: 500MHz DCC test setup.

<u>*Electron Cyclotron Resonance Heating (ECRH) System:*</u> ITER-India has already successfully demonstrated ITER relevant parameters of 1 MW RF Power at 170 GHz for 1000 s at ITER-India Gyrotron Test Facility (Figure B.1.18). Further up-gradations and system improvements are ongoing to enhance the overall system performance and reliability. Activities towards final design review are also ongoing.

Figure B.1.18: Gyrotron set up at ITER-India Gyrotron Test Facility.

ITER-India developed .NET Software for New CFPS in IIGTF (figure B.1.19a) and updated PLC and WinCC SCADA application for additional data archiving of cooling lines (figure B.1.19b). Moreover, hardware architecture finalization for Gyrotron I&C deliverable was also performed.



a

b

Figure B.1.19: Gyrotron I&C development.

<u>*Multi Megawatt Power Supply Systems:*</u> A 25 kV, 100 mA PSM-based Body Power Supply (BPS) has been developed indigenously for Electron Cyclotron Resonance Heating (ECRH) systems. BPS has been integrated with 42 GHz Gyrotron and operated up to 15 kV for 100ms achieving 200 kW RF output power.

An indigenous development of 200 kW, 1MHz Solid State RF source is under progress for DNB Power Supply. High Frequency Inverter Modules (HFIM) have been configured and tested under matched and mismatched load conditions (VSWR 1 to 7) (figure B.1.20). DC Power supply (DCPS) is at final stage of manufacturing.

The successful site acceptance test of 5 kA, 500 V Thyristor stack (3-phase full bridge) converter on Inductive Load has been completed at ITER-India lab. The stack is installed at ITER-India lab (figure B.1. 21).

Figure B.1.20: HFIM Testing.

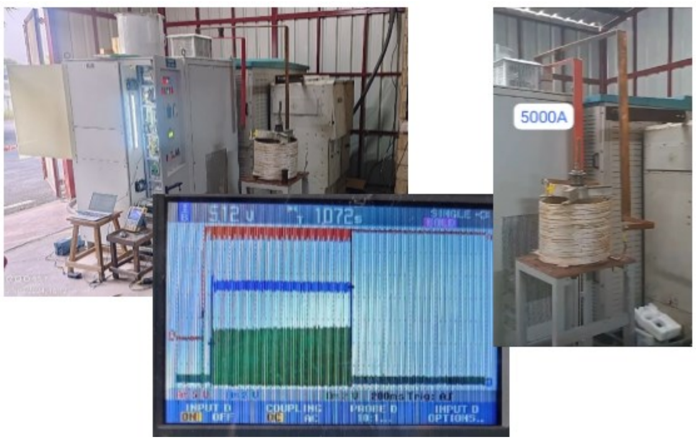


Figure B.1.21: 5kA/500V Thyristor Converter Test Setup and Results at Aditya-U extended Shed.

The 7.2 MW, 100 kV AGPS supplied by ITER-India has successfully completed 5 years of integrated operation on SPIDER experiments at NBTF, RFX Padua, Italy site with remote and on-site support from ITER-India.

<u>Diagnostics:</u> The development has continued on several diagnostics to be supplied to ITER.

<u>XRCS (Survey):</u> Prototype manufacturing (figure B.1.22) activities are under progress which includes development of Ray tracing tools (based on extended sources) for the design of X-ray spectrometers, first of a kind curved crystal design and development, experiments with fast hybrid photon counting detectors and In-house X-ray source for calibration experiments.

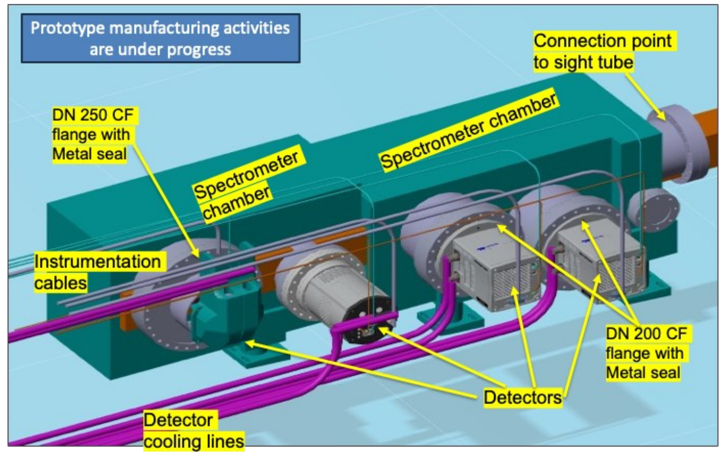


Figure B.1.22: XRCS Spectrometry prototype activities under progress.

<u>ECE:</u> Preliminary design review of ECE Ex-vessel transmission lines & receivers has been completed. The transmission line attenuation measurements of ECE prototype transmission lines using hot/cold sources and Fourier Transform Spectrometer (FTS) have been completed (figure B.1.23).

Figure B.1.23: R & D/Prototype Activities & Experiments-ECE.

<u>CXRS:</u> Prototype Misalignment Compensator (MAC) is under manufacturing, experiments with different shielding materials are being conducted in order to shield the motors from magnetic Field (figure B.1.24).

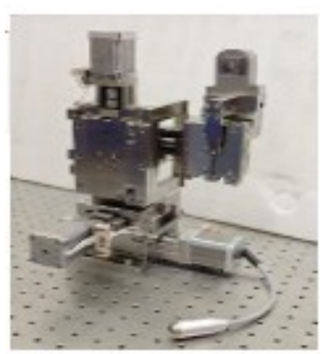


Figure B.1.24: A 40-channel prototype fiber bundle & magnetic field compatible motor (0.3T).

Technical Engagements other than in-kind Contributions: Apart from activities towards delivery of in-kind contribution, ITER-India is also engaged in various technical and managerial groups working in diverse areas of ITER. Some Indian members are participating in Task Forces formed to find resolutions of technical issues, some are also contributing to the efforts towards revision of scientific and technical baselines. ITER follows a consultative approach to major issues and Indian participation is actively pursued, and this is a continuous process.

Modelling Activities:

ITER-India has successfully installed and tested Integrated Modelling and Analysis Suite (IMAS) on ANTYA (1 Petaflop High Performance Computing system) . The development of a dedicated webpage (http://hpctutorial.ipr.res.in/imas) offering an introduction to IMAS and user training materials for running IMAS on ANTYA has been completed. An in-house developed INDUCT code has been adapted within IMAS framework, and its simulation results have been validated against experimental data from flux loops of SST-1 discharges. Moreover, the INDUCT code has also been coupled with OOPS, and this integrated code is being adapted in IMAS.

ITER-India also developed a free boundary Grad-Shafranov solver and the same has been benchmarked for the ITER equilibrium and it has been used to generate various magnetic equilibria (SN, DN positive and negative triangularity) for the SST-1 modification work and ADTYA- U.

The effects of magnetic equilibrium shaping on the linear and nonlinear ITG/SWITG/TEM modes for ADITYA-U have been performed using ORB5 (a nonlinear electromagnetic PIC gyrokinetic code).

Other Activities:
ITER-India migrated data center hardware from virtual environment in three-tier architecture to Hyper converged infrastructure (HCI Architecture). Data center is upgraded for local Disaster recovery (DR) for critical servers and services. End point security is implemented using eScan EDR (Endpoint Detection and Response) , EDP (Enterprise Data Protection) to provide security against Virus, malwares, ransomware and USB access control.

ITER-India conducted both basic and advanced CATIA training sessions and also coordinated SEE System Design training and facilitated ENOVIA DESA certification for three users

ITER-India has contributed to the development of revised ITER Research Plan and a Nuclear Fusion magazine Special edition, which includes topics like Magneto-Hydro-Dynamics (MHD), Disruption and control physics and the manuscript is currently under peer review.

Activities of the Knowledge Management Group:

India contributes about 9% of ITER Components. It is essential to have technical expertise and capability to manufacture the remaining 91% of reactor components. Components like SC magnets and their power supplies, vacuum vessel, divertor cassettes, shielding blankets are very complex in design and manufacturing process. The Knowledge Management (KM) group at ITER-India has been studying and archiving technical documentation of major ITER System systematically in our INDUS documentation system of ITER-India. A group of 12 engineers are working in KM. They also interact with institute experts working in this field for exchange of information and data. These documents cover Baseline documents (DDD, SRD etc.), CAD models and drawings, Procurement Arrangement Documents, Design reviews (CDR, PDR, FDR, MRR), Prototype, Manufacturing, Safety, ICDs and Interface Sheets, Assembly, Deviation Requests, Project change request, Project management, publications etc. In some of the critical components like Divertor, Blankets and remote handling, significant knowledge have been developed to launch R&D prototyping activity. A total of ~12000 technical document has been archived so far.

B2. Activities of LIGO India

Integration of LI-VISTA Facility: LIGO India – Vacuum Integrated System and Test Assembly (LI-VISTA) facility has been setup in LIGO Lab (Figure B.2.1). This setup comprises of two major vacuum equipments which are part of LIGO-India vacuum system integrated together – 80 K Cryopump and 20 m long Vacuum Vessel. These fabricated equipments are 1:1 scale prototypes covered in LIGO India project technology development activities. 80 K Cryopump as a part of LIGO India Vacuum System is installed to capture water vapor and prevent them from entering 4 km long beam tube layout. 1:1 scale prototype manufacturing helped to assess manufacturing feasibility and as a part of this facility during proposed experiments, its functional performance will be tested in demonstrating ultimate desired level vacuum along with its efficiency in capturing water vapour. Integrated Vacuum Vessel (IVV) is assembly of two 1.24 ID x 10 m long vacuum vessels connected with expansion joint (Bellows) of same I.D. X 635 mm length. IVV is installed on support structure resembling structure that is used to support beam tubes at specified intervals along its 4 km layout.

This setup shall be used to operate IVV and 80 K Cryopump in integrated facility and run experiments which will assist LIGO-India team in understanding following aspects –

Challenges in demonstration of vacuum < 1 x 10^{-9} mbar. Assess vacuum performance of large size vessel with / without vessel bake-out up to 150^0 C. Evaluate functioning of large size (1250 mm) gate valve (LGV) in UHV environment. Characterization measured leak (introduced) with the aid of RGA's placed on vessel ports. Evaluate 80K Cryopump performance in capturing water vapor passing axially through it.

Figure B.2.1: LI-VISTA facility setup in LIGO Lab area of R&D Building.

CHAPTER C, D & E

C. Academic Programme

D. Publications and Presentations

E. Other Activities

C. Academic Programme

C. Academic Programme

C1 Doctorate Program

During 2024-2025, a total number of 14 students (13 external and 1 internal) having Physics background have joined IPR's PhD (Physics) programme. In addition, six (6) new students from Engineering background (under DAE Doctoral Fellowship Scheme (DDFS)) have also joined in IPR's Engineering PhD programme. All of them are undergoing their course work. Overall, there are total Ninety Eight (98) PhD students in IPR, enrolled at present in HBNI for their PhD work.

Ph.D. Thesis Submitted (during April 2024 - March 2025)

1. Development of Pulsed Supersonic Beam System for Tokamak Edge Diagnostics and other Applications

Milaan Vijaybhai Patel

Homi Bhabha National Institute, 2024

2. Development of SERS Substrates Based On Self-Organized Nanoparticles for the Molecular Sensing Applications

Sebin Augustine

Homi Bhabha National Institute, 2024

3. Studies on Magnetic Field Effects in a Capacitive Coupled Cylindrical Radio Frequency Plasma Device

Swati

Homi Bhabha National Institute, 2024

4. Ratchet Effects and Collective Dynamics in Passive and Active Systems

Anshika Chugh

Homi Bhabha National Institute, 2024

5. Effect of Impurity Gas Seeding in the Boundary Region of Tokamak

Shrish Raj

Homi Bhabha National Institute, 2024

6. Sheath Effects on the Resonance Hairpin Probe in Negative Ion Diagnostics

Pawandeep Singh

Homi Bhabha National Institute, 2024

7. Experimental Studies of Confinement Improvement, Disruption Mitigations, and Runaway Electrons Mitigations in Aditya and Aditya-U Tokamak

Rakeshkumar L. Tanna

Nirma University, Ahmedabad, 2024

8. An Engineering Study of Concepts for Heat Extraction and Power Conversion from Moderate Sized Tokamak Fusion Reactors

Piyush Prajapati

Homi Bhabha National Institute, 2024

9. Turbulent Dynamo Action in a 3-Dimensional Magnetohydrodynamic Plasma

Shishir Biswas

Homi Bhabha National Institute, 2024

10. Laser Cluster Interaction in Strong External Magnetic Field

Kalyani Swain

Homi Bhabha National Institute, 2024

11. Study of Edge Plasma Dynamics in Tokamak ADITYA-U

Janmejay Umeshbhai Buch

Homi Bhabha National Institute, 2024

12. FPGA Based Real Time Density Feedback Control System for Aditya-U Tokamak

Kirankumar G. Patel

Homi Bhabha National Institute, 2024

13. Study of Electron Dynamics in Tokamak Plasma through Electron Cyclotron (EC) Emission using Radiometer

Varsha Siju

Homi Bhabha National Institute, 2024

14. Vlasov Maxwell Simulations of Whistler Mode Interaction with Bulk and Beam Plasma

Anjan Paul

Homi Bhabha National Institute, 2024

15. Molecular Dynamics Study of Subcritical Transition to Turbulence In A 3d Yukawa Liquid

Suruj Jyoti Kalita

Homi Bhabha National Institute, 2024

16. Study and Applications of Polarization Characteristics of Optical Media Using Stokes/Mueller Matrix Polarimetry

Asha Adhiya

Nirma University, Ahmedabad, 2024

17. Surface Modification of Silicone Catheters to Mitigate Bacterial Adhesion and Biofilm Formation

Purvi Dave

Homi Bhabha National Institute, 2024

18. Determination and Matching of Antenna-Plasma Coupling Impedance for Ion Cyclotron Range of Frequencies and its uses for Plasma Applications

Raj Singh

Banasthali Vidyapith, Rajasthan, 2024

19. Study of Neutron Induced Reactions of Different Materials for Reactor Applications

Mayur H. Mehta

Maharaja Sayajirao University of Baroda, Vadodara, 2024

20. Study of Process Parameters Affecting Secondary Phase Formation and Grain Size in Cu_2ZnSnS_4 Thin Film for Solar Cell Application

Sagar Agrawal

Homi Bhabha National Institute, 2025

21. Development of Machine Learning Based Technique for Disruption Control and Prediction in ADITYA-U

Rameshkumar Joshi

RK University, Rajkot, Gujarat, 2025

22. Experimental and Simulation Studies of Effective Thermal Conductivity of Compressed and Uncompressed Pebble Beds for Fusion Blankets

Patel Harsh Bhikhubhai

Homi Bhabha National Institute, 2025

C2 Summer School Program (SSP)

The summer school program for the year 2024 (IPR SSP - 2024) has been conducted between 27th May to 5th July, 2024 at the institute. The summer school students joined in the program have came from all across the country from various Universities, national institute etc. A total number of 25 students have joined in this program out of which 19 students are from Physics, 2 students are from electrical, 2 students from Electronics & Instrumentation and 1 student each from Mechanical and Computer disciplines. The students were given orientation about overall institute's activities, Library and Outreach programs. The program students were also addressed by the Director on overall activities and goals of the institute and followed by the talks from Dean Academic & Students Affairs, Dean Administration and Dean R & D. The students have attended popular lectures given by experts in the respective R & D fields in the institute along with lab visits including SST - 1, ADITYA-U, BETA, ITER India and FCIPT. The students also visited Vikram Sarabhai Space Exhibition (VSSE) Center in Ahmedabad to know more about the space research activities at ISRO. The students were taken to PRL observatory , Mount Abu under study tour program. The students were also engaged in various R&D labs and theory and simulation groups for project work on their respective fields. The students learning were accessed by project Oral presentation followed by poster presentations. Best project presentation awards were given on the concluding day along with participation certificates.

C3 UG/PG Academic Projects for External Students

Around 55 students, pursuing Under Graduate (UG)/ Post Graduate (PG) courses in science and engineering, were engaged to do various academic projects with the institute faculties under their course curriculum in different fields of science and technology from various colleges/Universities/institutes during April 2024 to March 2025.

D. PUBLICATIONS AND PRESENTATIONS

D1 Articles Publications

D1.1 Journal Articles

1. Nanofluids: Critical Issues, Economics and Sustainability Perspectives

SAYANTAN MUKHERJEE et.al.

Particuology, 87, 147, April 2024

2. Experimental Determination of Hydrogen Isotope Diffusivity, Solubility and Permeability in Molten Lead Lithium Eutectic Alloy

SUDHIR RAI et.al.

Fusion Engineering and Design, 201, 114233, April 2024

3. Effect of Secondary Phases Controlled By Precursor Composition on the Efficiency of CZTS Thin Film Solar Cell

SAGAR AGRAWAL et.al.

Solar Energy Materials and Solar Cells, 267, 112719, April 2024

4. Experiments on Capacitance Based Liquid Flow Meter with Parallel Channels used in Two-Phase

BINET MONACHAN…HARESH DAVE et.al.

Flow Measurement and Instrumentation, 96, 102522, April 2024

5. Design and Development of Hydrogen Isotopes Extraction System at IPR

RUDREKSH B. PATEL et.al.

Fusion Engineering and Design, 201, 114318, April 2024

6. Advancement of Langmuir Probe-Based Laser Photo-Detachment Technique for Negative Ion Density Measurement in a High-Power Helicon Plasma Source

D. MUKHOPADHYAY et.al.

Review of Scientific Instruments, 95, 043006, April 2024

7. Investigation of Facet Evolution on Si Surfaces Bombarded with Xe Ions

SUKRITI HANS et.al.

Physica Scripta, 99, 045954, April 2024

8. RF Antenna Helicity Dependent Particle Heating in a Helicon Source

K J STEVENSON…P SRIVASTAV et.al.

Plasma Sources Science and Technology, 33, 045009, April 2024

9. On the Measurement of Electron Temperature of a Pulsed Washer Gun Argon Plasma by Triple Langmuir Probe Diagnostic Technique

B K SETHY…A K SANYASI et.al.

Journal of Scientific & Industrial Research, 83, 375, April 2024

10. Charged Particle Dynamics in an Elliptically Polarized Electromagnetic Wave and a Uniform Axial Magnetic Field

SHIVAM KUMAR MISHRA et.al.

Physics of Plasmas, 31, 043106, April 2024

11. Experimental Validation of the Analytic Model for the Temporal Decay of the Density Auto-Correlation Function in a Strongly Coupled Dusty Plasma

ANKIT DHAKA et.al.

Physics of Plasmas, 31, 043703, April 2024

12. Characterization of ROBIN Ion Source under Volume Mode Operation Using Langmuir Probe, Cavity Ring-Down Spectroscopy, and Optical Emission Spectroscopy

DEBRUP MUKHOPADHYAY et.al.

IEEE Transactions on Plasma Science, 52, 1315, April 2024

13. Design, Simulation, Analysis, Fabrication, and Testing of Toroidal Field Power Supply (TFPS) for Simple Tight Aspect Ratio Machine Assembly

SUPRIYA A. NAIR et.al.

IEEE Transactions on Plasma Science, 52, 1366, April 2024

14. Production of Large Quantity of Plasma Activated Water using Multiple Plasma Device Setup

VIKAS RATHORE et.al.

Current Applied Physics, 61, 121, May 2024

15. Determining Sheath Edge Electric Field around Cylindrical Pins of a DC Biased Hairpin Resonator Probe

PAWANDEEP SINGH et.al.

Plasma Sources Science and Technology, 33, 055012, May 2024

16. Micro-Particle Injection Experiments in ADITYA-U Tokamak using an Inductively driven Pellet Injector

SAMBARAN PAHARI…J. GHOSH et.al.

Nuclear Fusion, 64, 056007, May 2024

17. Design, Fabrication and Validation of an Electrical Conductivity Principle Based Two-Phase Detection Sensor Array for Molten Lead (Pb) based Heavy Metal Coolants up to 600°C

A. SARASWAT et.al.

Journal of Instrumentation, 19, T05018, May 2024

18. In-Vessel Inspection System: Development and Testing Activities of High Vacuum and Temperature Technologies for Fusion Remote Handling

MANOAH STEPHEN M. et.al.

Fusion Engineering and Design, 202, 114368, May 2024

19. An Apparatus to Measure Thermal Conductivity of Ceramic Pebble Beds under Uniaxial Compressive Stress

HARSH PATEL et.al.

Measurement, 230, 114484, May 2024

20. Turbulent Spot Formation in Three-Dimensional Yukawa Liquids using Large-Scale Molecular Dynamics Simulation-Effect of System Size

SURUJ KALITA et.al.

Physica Scripta, 99, 055246, May 2024

21. Development and Testing of Lab-Scale Atmospheric Molecular Sieve Bed with Zeolite 4A Adsorbent

DEEPAK YADAV et.al.

Fusion Engineering and Design, 202, 114427, May 2024

22. Particle-In-Cell Simulation of Electrostatic Waves in the Ionosphere

RAKESH MOULICK et.al.

Advances in Space Research, 73, 4393, May 2024

23. Commissioning and Initial Operational Experience of 2 MVA AC/DC Power Converter at IPR for Neutral Beam Injector Applications

ARITRA CHAKRABORTY et.al.

IEEE Transactions on Plasma Science, 52, 1832, May 2024

24. Sunlight Driven Photocatalytic Degradation of Organic Pollutants by Solvothermally Synthesized Rgo-Bivo4 Nanohybrids

ROSALIN BEURA, K.P. SOORAJ et.al.

Chemical Physics Impact, 8, 100595, June 2024

25. Relativistic Atomic Structure Calculations of Li-Like Ions Used for Plasma Diagnostic Studies

GAJENDRA SINGH et.al.

Physica Scripta, 99, 065408, June 2024

26. Position Estimation of Current-Carrying Filament using Different Magnetic Sensors in ADITYA-U Tokamak

ROHIT KUMAR et.al.

Fusion Engineering and Design, 203, 114405, June 2024

27. Electron Beam Profile Measurement Using Enhanced Dual-Techniques in High Heat Flux Test Facility at Institute for Plasma Research

SUNIL BELSARE et.al.

Review of Scientific Instruments, 95, 065109, June 2024

28. Charge Fluctuations on the Dust Grains in the Presence of Energetic Electrons

R PAUL et.al.

Physica Scripta, 99, 065602, June 2024

29. Microscopic Structure of Electromagnetic Whistler Wave Damping by Kinetic Mechanisms in Hot Magnetized Vlasov Plasmas

ANJAN PAUL et.al.

Physica Scripta, 99, 065610, June 2024

30. Characterization of Vacancy Defects Using TEM in Heavy-Ion-Irradiated Tungsten Foils

PRASHANT SHARMA, P. N. MAYA et.al.

Metallurgical and Materials Transactions A: Physical Metallurgy and Materials Science, 55, 2932, June 2024

31. Observation of Electron Temperature Anisotropy in the Magnetic Filter of a Hot Cathode Discharge

JOCELYN SANGMA…MONOJIT CHAKRABORTY et.al.

Physica Scripta, 99, 065612, June 2024

32. Simple Tight Aspect Ratio Machine Assembly to Study ECR-Produced Magnetized Toroidal Plasma

TULCHHI RAM et.al.

IEEE Transactions on Plasma Science, 52, 2059, June 2024

33. Development of Superhydrophobic PTFE Surface Using Oxygen Plasma Processing

SHRUTI KUMARI, VIVEK PACHCHIGAR et.al.

IEEE Transactions on Plasma Science, 52, 2524, July 2024

34. Event Driven High Speed Data Acquisition with IEEE 1588 Synchronization for Long Pulse Operations of Indian Test Facility for ITER DNB

HIMANSHU TYAGI et.al.

Fusion Engineering and Design, 204, 114487, July 2024

35. Effect of Electron and Ion Mobility on Edge Biasing in Tokamak Plasmas

VIJAY SHANKAR et.al.

Nuclear Fusion, 64, 076041, July 2024

36. Fabrication Aspects and Performance Characterization of α-Al2O3/AlPO4 Based Sandwich Configuration Flow Channel Inserts and Coatings for High Temperature Liquid Metal Applications

ABHISHEK SARASWAT et.al.

Journal of Nuclear Engineering and Radiation Science, 10, 030902, July 2024

37. Low Frequency Dust Acoustic Drift Instability in the Equatorial Electrojet

SANJIB SARKAR, JYOTI K. ATUL et.al.

Advances in Space Research, 74, 1011, July 2024

38. Numerical Approach for Investigating the Influence of Various Flow and Fluid Parameters on the Performance of a Cryogenic Two-Phase Flow Meter

BINET MONACHAN…HARESH DAVE et.al.

Flow Measurement and Instrumentation, 97, 102617, July 2024

39. Neutron Emission Characterization of IPR 14 MeV Neutron Generator

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175. Merging Dynamics of Unidirectional Current Carrying Filamentary Plasma Blobs in the Edge Region of a Tokamak

SOUVIK MONDAL et.al.

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176. Enhanced proton conductivity in low-temperature sintered pristine and Ca-doped LaNbO4 nanocrystals synthesized via microwave hydrothermal method

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SUDHEER…MUKESH RANJAN et.al.

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178. Simultaneous Positioning and Operation of Multiple Probe Drives for Inverse Mirror Experimental Plasma Device

JIGNESH PATEL et.al.

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179. Effective Cryosorption of Trace Levels of Hydrogen Isotopologues on MS 13X Zeolite: Implications for Fusion Fuel Cycle Applications

V. GAYATHRI DEVI et.al.

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180. Parallel Propagation Effects on the Dust Acoustic Drift Instability in the Equatorial Electrojet

SANJIB SARKAR…PRABAL K. CHATTOPADHYAY et.al.

Advances in Space Research, 75, 4795, March 2025

D1.2 Conference Papers

1. Advancements in High Performance Computing Cluster Resource Utilization through a Comprehensive Monitoring Dashboard

DEEPAK AGGARWAL, et.al.

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2. Time-Varying Linear Quadratic Control of Modular Multilevel Converter

KUMAR SAURABH, et.al.

2024 International Conference on Computer, Electrical & Communication Engineering (ICCECE), Kolkata, 2-3 February 2024, (pp. 1-5, Published in April 2024)

3. Visible Camera-Based Diagnostic to Study Negative Ion

Beam Profiles in ROBIN Ion Source

SIDHARTH DASH, et.al.

Journal of Physics: Conference Series, 2743, 012074, May 2024

4. Development of Wireless Serial Server Module for the Remote operation of various Serial Field Device in ITER-India

DEEPAK MANDGE, et.al.

2024 3rd International Conference for Innovation in Technology (INOCON), Bangalore, 1-3 March 2024, ISBN: 979-8-3503-8193-1, pp. 1-4, May 2024

5. A Novel Design of Ohmic Transformer Power Supply (OTPS) for Spherical Tokamaks

AYUSH URMIL THAKER, et.al.

2024 IEEE 9th International Conference for Convergence in Technology (I2CT), Pune, 05-07 April 2024 (Published in June 2024)

6. Stability and Sedimentation Characteristics of Water Based Al2O3 and TiO2 Nanofluids

SAYANTAN MUKHERJEE, et.al.

Proceedings of the Institution of Mechanical Engineers, Part N: Journal of Nanomaterials, Nanoengineering and Nanosystems, 238, pp. 17-30, March-June 2024

7. Analysis of Different Inference Implementations for Deep Learning Model on ADITYA-U Tokamak

RAMESH JOSHI, et.al.

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8. A Compact Half-Mode Substrate Integrated MIMO Antenna for 5G Communication

SWAPNIL SHEKHAR, SHRUTI PRIYA, et.al.

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9. Estimation of Energy Transmission to Workpiece in Wire Electrical Discharge Machining Process

PARTH SATHAVARA, PARITOSH CHAUDHURI, et.al.

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10. Resistively Loaded Cavity-Backed Spiral Antenna for Optimal Antenna-Plasma Coupling in Tokamaks

DIMPLE YADAV, RAJ SINGH, et.al.

2024 IEEE Space, Aerospace and Defence Conference (SPACE), Bangalore, pp. 1248-125, 22-23 July 2024 (Published in September 2024)

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MEDDI THARUN, et.al.

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12. A NodeMCU-Based Programmable Reconfigurable Intelligent Surface for mm-Wave 5G Applications

B. ANIL BABU, et.al.

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13. Commissioning of MW Class Gyrotron Test Facility at ITER-India & Demonstration of ITER Relevant RF Performance (1MW for 1000 s at 170 GHz)

S.L. RAO, et.al.

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14. Upgradation of 82.6 GHz ECRH System for SST-1 and Aditya-U

BRAJ KISHORE SHUKLA, et.al.

EPJ Web of Conferences, 313, 02004, November 2024

15. Recent Results From Electron Cyclotron Emission (ECE) Radiometer Diagnostics In The Presence of Electron Cyclotron Resonance Heating (ECRH)

VARSHA SIJU, et.al.

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16. Design, Development and Characterization of Indigenously Developed High Temperature Black Body Source for Calibration of ECE Diagnostics

ABHISHEK SINHA, et.al.

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17. Observer-based Time Varying Linear Quadratic Control of Modular Multilevel Converter

VIVEK PATEL, et.al.

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18. Analysis of Ring Core Hollow Photonic Crystal Fiber Based on Chalcogenide Glass For Transmission of Orbital Angular Momentum Modes In The Near-Infrared Region

ISHANI DE, ANKITA GAUR, et.al.

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19. An Experimental Study of Stable and Chaotic Structures in a Plasma System Analogous To Earth Magnetosphere

J. GOSWAMI, et.al.

Journal of Physics: Conference Series, 2919, 012022, December 2024

20. Preparation, Stabilization, and Thermal Characterization of CuO/Water Nanofluids Applicable to Domestic Solar Water Heater

DRASHTI SHAH, SAYANTAN MUKHERJEE, et.al.

Materials Today: Proceedings, 99, 49-55, 2024

21. Modeling of Single and Multi-Grid IECF Device to Study Plasma Particle Dynamics

DARPAN BHATTACHARJEE, LUCKY SAIKIA, et.al.

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22. Stand-Off Fabrication Of Heat Resistive Superhydrophilic Silicon Using Nd:YAG Laser

RUDRASHISH PANDA, JINTO THOMAS, et.al.

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23. Thermal Analysis of IGBT for High-Frequency Inverter

KUMAR SAURABH, et.al.

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24. Design Up-gradation of Electronics for PMT Sensor based Systems in ADITYA-U Tokamak

MINSHA SHAH, et.al.

2024 International Conference on Communication, Control, and Intelligent Systems (CCIS), Mathura, pp. 1-6, 6-7 December 2024 (Published in March 2025)

25. A Simulation Analysis of 300 kV DC Power Supply for Neutral Beam Injector Accelerator Grid

ARITRA CHAKRABORTY, et.al.

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26. Optimization of Multi-phase Buck Converter

AAKASH SHUKLA, DISHANG V. UPADHAYAY, et.al.

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27. Study of Ion Density Profile in Compact-IECF Device in the Presence of External Magnetic Field

N. BHARALI, et.al.

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28. Design, Simulation and Testing of Wave Collection and Transport System for Michelson Interferometer Diagnostic

ABHISHEK SINHA, et.al.

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D1.3 Book Chapters

1. Introduction to Different Types of 2D Carbon and Nanodiamond

RAJASHREE SAHOO, et.al.

Diamond: Fabrication, Properties and New Advances in 2D Diamond, Institute of Physics Publishing, April 2024, ISBN: 9780750359375

2. Design and Simulation Study of Bi-Frequency and Dual-Band Magnetically Insulated Line Oscillator (MILO)

ARJUN KUMAR, PRABHAKAR TRIPATHI, et.al.

Microwave Devices and Circuits for Advanced Wireless Communication: Design and Analysis, CRC Press, pp. 64-83, August 2024. ISBN: 9781032656021

3. Microwave and Millimeter-Wave Radar Imaging: Challenges and Applications

VINEET SINGH, PRABHAKAR TRIPATHI, et.al.

Microwave Devices and Circuits for Advanced Wireless Communication: Design and Analysis, CRC Press, pp. 84-98, August 2024. ISBN: 9781032656021

4. Graphene Oxide (GO) and Reduced Graphene Oxide (rGO) Based Humidity Sensors

ALFA SHARMA, ASHA PANGHAL, et.al.

Nanotechnology: A Quick Guide to Materials and Technologies, pp: 335-364, Bentham Science Publishers, 2024. ISBN: 9789815256789

5. Critical research opportunities in ML/AI applications for fusion energy and plasma devices

VIPIN SHUKLA, MAINAK BANDYOPADHYAY, et.al.

Energy from Plasma: Production and Storage, Pages 325-344, Woodhead Publishing, January 2025. ISBN: 978-0-443-26584-6

6. Applications of Biofuel Cells

VIPIN SHARMA, SANDEEP RIMZA, et.al.

Biofuel Cells and Energy Generation, Woodhead Series in Bioenergy, Pages 429-452, February 2025. ISBN 9780443216022

D2. INTERNAL RESEARCH AND TECHNICAL REPORTS

D2.1 Research Reports

1. ANALYSIS OF MICROWAVE REFLECTOMETRY SIGNAL FOR AUTOMATED MEASUREMENTS FOR TOKAMAK PLASMAS

SUBRAMANIYAN N, JJU BUCH, et. al.

IPR/RR-1635/2024 APRIL 2024

2. EFFECT OF DEGREE OF POLARIZATION ON SPECTROSCOPIC CHARACTERIZATION OF LASER PRODUCED ALUMINIUM PLASMA

GEETHIKA B R, et. al.

IPR/RR-1636/2024 APRIL 2024

3. QUASI-LONGITUDINAL WHISTLER PROPAGATION IN PRESENCE OF FINITE ION RESPONSE

GAYATRI BARSAGADE, et. al.

IPR/RR-1637/2024 APRIL 2024

4. ADHESION AND GROWTH OF TITANIUM NITRIDE COATING DEPOSITED ON AISI 316L USING CYLINDRICAL MAGNETRON SPUTTERING

KUNAL TRIVEDI, et. al.

IPR/RR-1638/2024 APRIL 2024

5. EFFECT OF IMPURITY SEEDING ON EDGE TOROIDAL ROTATION IN ADITYA-U TOKAMAK

ANKIT KUMAR, et. al.

IPR/RR-1639/2024 APRIL 2024

6. DEVELOPMENT OF A PXIe BASED DATA ACQUISITION AND CONTROL SYSTEM FOR HYDROGEN PELLET INJECTION SYSTEM

M. BANAUDHA, et. al.

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7. ON PLASMA BLOB FORMATION MECHANISM

N BISAI, et. al.

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8. PLASMA PERFORMANCE ENHANCEMENT AND IMPURITY CONTROL BY NOVEL TECHNIQUE OF ARGON-HYDROGEN MIXTURE FUELED GLOW DISCHARGE WALL CONDITIONING IN ADITYA-U TOKAMAK

K. A. JADEJA, et. al.

IPR/RR-1642/2024 APRIL 2024

9. DESIGN, DEVELOPMENT AND OPERATION OF HEAT EXTRACTION SYSTEM FOR LEAD LITHIUM LOOP

A. DEOGHAR, et. al.

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10. CRYOSORPTION STUDIES OF TRACE LEVELS OF HYDROGEN ISOTOPOLOGUES ON MS 13X ZEOLITE

V. GAYATHRI DEVI, et. al.

IPR/RR-1644/2024 MAY 2024

11. LOW POWER BIO-MIMETIC BEHAVIOURS IN Au/TiOx/Ti SYNAPTIC DEVICE USING OXYGEN ION IMPLANTATION STRATEGY

SUDHEER, et. al.

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12. MINIMIZATION OF ANISOTROPIC LSPR SHIFT IN SEQUENTIALLY GROWN Ag NANOPARTICLES ARRAYS OVER ION BEAM PRODUCED NANORIPPLE

TARUNDEEP KAUR LAMBA, et. al.

PR/RR-1646/2024 MAY 2024

13. GENERATION OF DIELECTRIC BARRIER DISCHARGE PLASMA ON LARGE AREA ELECTRODE AT ATMOSPHERIC PRESSURE FOR AGRICULTURE APPLICATIONS

ANAND VISANI, et. al.

IPR/RR-1647/2024 MAY 2024

14. REAL TIME VERTICAL POSITION ESTIMATION OF PLASMA COLUMN USING FAST IMAGING IN ADITYA-U TOKAMAK

S. AICH, et. al.

IPR/RR-1648/2024 MAY 2024

15. SHEET MODEL DESCRIPTION OF SPATIO-TEMPORAL EVOLUTION OF UPPER-HYBRID OSCILLATIONS IN AN INHOMOGENEOUS MAGNETIC FIELD

NIDHI RATHEE, et. al.

IPR/RR-1649/2024 MAY 2024

16. INVESTIGATION THE ROLE OF PLASMA-ACTIVATED WATER WASHING AND STORAGE ON THE SHELF LIFE OF CESTRUM NOCTURNUM L. (NIGHT-BLOOMING JASMINE) FLOWERS

VIKAS RATHORE, et. al.

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17. STUDY ON KELVIN HELMHOLTZ SHEAR FLOWS SUBJECTED TO DIFFERENTIAL ROTATION

PRINCE KUMAR, et. al.

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18. LASER-CLUSTER INTERACTION IN AN EXTERNAL MAGNETIC FIELD: THE EFFECT OF LASER POLARIZATION

KALYANI SWAIN, et. al.

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19. AN RF BASED SYSTEM FOR THE DETECTION OF UNMANNED AERIAL VEHICLES (UAV)

YASH VASANT AHIRRAO, et. al.

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20. STUDY OF THE DEPENDENCE OF BACKGROUND PRESSURE ON THE DYNAMICS OF THE REDEPOSITION OF A THIN FILM IN A REAR ABLATION GEOMETRY

RENJITH KUMAR R, et. al.

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21. EFFECTS OF O-MODE AND X-MODE ON THE DYNAMICS OF ECR PRODUCED PLASMA

TULCHHI RAM, et. al.

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22. EFFICIENT AND SUSTAINABLE SOLAR ENERGY UTILIZATION WITH NANOFLUIDS IN DIRECT ABSORPTION SYSTEMS

SAYANTAN MUKHERJEE, et. al.

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23. INVESTIGATING TRITIUM TRANSPORT PHENOMENA: A STUDY UTILIZING THE GAUSSIAN PLUME MODEL

SHAHRUKH BAREJIA, et. al.

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24. INFLUENCE OF PLASMA FORMING GAS (OXYGEN/ARGON) AND PLASMA SOURCE DRIVING FREQUENCY (13.56 MHz/40 kHz) ON SURFACE PROPERTIES OF SILICONE CATHETERS

PURVI DAVE, et. al.

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25. CHARACTERIZATION OF VACANCY DEFECTS USING TEM IN HEAVY-ION-IRRADIATED TUNGSTEN FOILS

PRASHANT SHARMA, et. al.

IPR/RR-1659/2024 JUNE 2024

26. EFFICIENT DATA-DRIVEN SIMULATION OF MICROWAVE INTERACTION WITH COMPLEX PLASMA PROFILES

PRATIK GHOSH, et. al.

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27. A NITROGEN ALTERNATIVE: USE OF PLASMA ACTIVATED WATER AS NITROGEN SOURCE IN HYDROPONIC SOLUTION FOR RADISH GROWTH

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28. GREEN SYNTHESIS OF AMMONIUM NITRATE (NH4NO3) FERTILIZER: PRODUCTION VIA PLASMA WATER/ICE INTERACTION WITH AIR AND NH3 PLASMA

VIKAS RATHORE, et. al.

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29. GAS CHROMATOGRAPHIC SEPARATION OF HYDROGEN ISOTOPES USING PLASMA ACTIVATED Al2O3 COLUMNS AT 77.4 K

V. GAYATHRI DEVI, et. al.

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30. SIMPLE FLUID APPROACH FOR THE NONLINEAR EXCITATIONS IN YUKAWA FLUIDS

PRINCE KUMAR, et. al.

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31. EXPLORATION OF GEOMETRIC PARAMETERS OF PILLOW PLATE PANEL FOR HEAT TRANSFER AND PRESSURE DROP CRITERIA FOR THE CRYOGENIC APPLICATION

HEMANG S. AGRAVAT, et. al.

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32. NONLINEAR MIXING OF WAVES IN A YUKAWA ONE COMPONENT PLASMA

AJAZ MIR, et. al.

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33. THE ROLE OF HELICAL AND NON-HELICAL DRIVES ON THE EVOLUTION OF SELF-CONSISTENT DYNAMOS

SHISHIR BISWAS, et. al.

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34. WIDE BAND RECONFIGURABLE SALT WATER COLUMN ANTENNA FOR RF COMMUNICATION

A. SARADA SREE, et. al.

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35. GENERATION OF MICRO/NANOSTRUCTURES ON THE BRASS BY NANOSECOND LASER: A COMPARATIVE STUDY OF LIBS SIGNALS FOR UNTEXTURED AND TEXTURED SURFACE

P. CHANDRAKANTA SINGH, et. al.

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36. MEASUREMENT OF NON-THERMAL BREMSSTRAHLUNG EMISSION IN PRESENCE OF LOWER HYBRID WAVE IN SST-1

J. KUMAR, et. al.

IPR/RR-1670/2024 JULY 2024

37. MINIMISATION OF PHASE ERROR OF ANTENNA-PLASMA COUPLING IMPEDANCE USING LEAST SQUARE TECHNIQUE FOR ION CYCLOTRON RANGE OF FREQUENCIES

RAJ SINGH, et. al.

IPR/RR-1671/2024 JULY 2024

38. LH LAUNCHERS FOR TOKAMAKS AT IPR

P. K. SHARMA

IPR/RR-1672/2024 JULY 2024

39. TRANSITION OF LARGE VOLUME PLASMA DEVICE (LVPD) TO LVPD-UPGRADE

L.M. AWASTHI, et. al.

IPR/RR-1673/2024 AUGUST 2024

40. AERODYNAMIC DRAG REDUCTION STUDIES IN THE PRESENCE OF DIELECTRIC BARRIER DISCHARGE PLASMA

J. CHOWDHURY, et. al.

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41. REACTIVE MOLECULAR DYNAMICS SIMULATION OF THE CARBENDAZIM DEGRADATION INDUCED BY REACTIVE OXYGEN PLASMA SPECIES

RUCHI MISHRA, et. al.

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42. DESIGN AND PERFORMANCE ANALYSIS OF RECONFIGURABLE CORNER REFLECTOR ANTENNA WITH PLASMA REFLECTORS

MANISHA JHA, et. al.

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43. PLASMA NITRIDING AND PLASMA CARBURIZING PROCESS ON AISI 1020 SPUR GEAR

G. JHALA, et. al.

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44. RF TECHNOLOGIES FOR KLYSTRON BASED LOWER HYBRID CURRENT DRIVE (LHCD) SYSTEM AT IPR

P. K. SHARMA, et. al.

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45. ELECTROSTATIC FIELD ANALYSIS OF HIGH-VOLTAGE TRANSMISSION LINE FOR NEUTRAL BEAM INJECTORS

ADITYA NAUGRAIYA, et. al.

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46. GREEN PATHWAY OF UREA SYNTHESIS THROUGH PLASMA-ICE INTERACTION: OPTIMIZATION AND MECHANISTIC INSIGHTS WITH N2 + CO2 AND NH3 + CO2 GAS MIXTURES

VIKAS RATHORE, et. al.

IPR/RR-1680/2024 AUGUST 2024

47. INSTALLATION, THERMAL CURING, QUALIFICATION TESTING OF DIVERTOR AND POSITION CONTROL COILS IN ADITYA-U TOKAMAK

ROHIT KUMAR, et. al.

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48. Al7075 / Ti3AlC2 MAX-PHASE SURFACE COMPOSITE GENERATED BY FRICTION STIR PROCESSING: MICROSTRUCTURE, MICROHARDNESS, AND TRIBOLOGICAL CHARACTERISTICS

VYOM DESAI, et. al.

IPR/RR-1682/2024 AUGUST 2024

49. INTERACTION OF DRIVEN "COLD" ELECTRON PLASMA WAVE WITH THERMAL BULK VIA ION SPATIAL INHOMOGENEITY

SANJEEV KUMAR PANDEY, et. al.

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50. CCDPx: A VERSATILE EXPERIMENTAL DEVICE FOR STUDYING MULTI-DIMENSIONAL COMPLEX PLASMA CONFIGURATIONS

ANKIT DHAKA, et. al.

IPR/RR-1684/2024 SEPTEMBER 2024

51. EFFECT OF PLASMA CONFINEMENT MAGNETS ON ROBIN PERFORMANCE

K. PANDYA, et. al.

IPR/RR-1685/2024 SEPTEMBER 2024

52. CONVECTIVE CELL TO SHEAR FLOW INSTABILITY IN 2D YUKAWA LIQUIDS DRIVEN BY REYNOLDS STRESS: A FIRST PRINCIPLES STUDY

PAWANDEEP KAUR, et. al.

IPR/RR-1686/2024 SEPTEMBER 2024

53. DEVELOPMENT OF LASER HEATED OXIDE COATED CATHODE EMISSIVE PROBE (LHOCCEP) DIAGNOSTICS FOR LARGE VOLUME PLASMA DEVICE – UPGRADE

A. K. SANYASI, et. al.

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54. DEVELOPMENT OF A CRYOGENIC PELLET INJECTOR UTILIZING A PNEUMATICALLY DRIVEN MECHANICAL ACTUATOR

J. MISHRA, et. al.

IPR/RR-1688/2024 SEPTEMBER 2024

55. EFFECT OF GAS PRESSURE ON PLASMA ASYMMETRY AND HIGHER HARMONICS GENERATION IN SAWTOOTH WAVEFORM DRIVEN CAPACITIVELY COUPLED PLASMA DISCHARGE

SARVESHWAR SHARMA, et. al.

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56. ENHANCING PERFORMANCE WITH Al2O3-CuO/WATER HYBRID NANOFLUID: AN EXPERIMENTAL STUDY

SAYANTAN MUKHERJEE, et. al.

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57. MERGING DYNAMICS OF PLASMA BLOBS IN THE SCRAPE-OFF LAYER OF A TOKAMAK

SOUVIK MONDAL, et. al.

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58. DETERMINATION OF ELECTRODE CURRENT AND ITS TEMPORAL EVOLUTION USING A LEAKY CAPACITOR MODEL IN ADITYA TOKAMAK ELECTRODE-BIASING EXPERIMENTS

PRAVESH DHYANI, et. al.

IPR/RR-1692/2024 SEPTEMBER 2024

59. PROPERTIES OF A 13.56 MHz RF PLASMA FORMED BETWEEN A PAIR OF COAXIAL CYLINDERS WITH AXISYMMETRIC MAGNETIC FIELD

AKANSHU KHANDELWAL, et. al.

IPR/RR-1693/2024 SEPTEMBER 2024

60. DESIGN AND SIMULATION OF 15kV/5A DC POWER SUPPLY FOR RESIDUAL ION DUMP USING MODULAR MULTILEVEL CONVERTER

VIVEK PATEL, et. al.

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61. SPIRAL ANTENNA GENERATED PLASMA COLUMN IN APPEL DEVICE FOR TOKAMAK PRE-IONIZATION AND START-UP EXPERIMENTS

Y. PATIL, et. al.

IPR/RR-1695/2024 OCTOBER 2024

62. EFFECT OF ELECTRODE BIASING ON ELECTROSTATIC AND MAGNETIC FLUCTUATIONS IN ADITYA TOKAMAK

PRAVESH DHYANI, et. al.

IPR/RR-1696/2024 OCTOBER 2024

63. A METHOD OF LOCALIZED WALL CLEANING BY VARYING EC RESONANCE IN ADITYA-U TORUS

KISHORE MISHRA, et. al.

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64. NON-DESTRUCTIVE TESTING OF COPPER TO SS304L FRICTION WELDED JOINTS FOR FUSION RESEARCH APPLICATIONS

TAPAN PATEL, et. al.

IPR/RR-1698/2024 OCTOBER 2024

65. PROGRESS IN ICRF ANTENNA AND FEEDER SYSTEM RESEARCH IN TOKAMAK EXPERIMENTS AT IPR

KISHORE MISHRA, et. al.

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66. ANALYTICAL AND SIMULATION STUDY OF WINDOWLESS GAS TARGET SYSTEM FOR NEUTRONICS APPLICATIONS

MANISH TAK, et. al.

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67. ENGINEERING DESIGN OF A PROTOTYPE CENTER STACK TOROIDAL FIELD COIL FOR SPHERICAL TOKAMAK

A.K. VERMA, et. al.

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68. AN EXPERIMENTAL STUDY OF THE EXISTENCE REGIONS AND NON-LINEAR INTERACTIONS OF DRIFT WAVE AND KELVIN-HELMHOLTZ INSTABILITIES IN A LINEAR MAGNETIZED PLASMA

ROSH ROY, et. al.

IPR/RR-1702/2024 NOVEMBER 2024

69. MHD, DISRUPTIONS AND CONTROL PHYSICS IN TOKAMAKS: ON THE PATH TO BURNING PLASMAS

BANDYOPADHYAY, et. al.

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70. NOVEL LIMITER DESIGN FOR TOKAMAK OPERATION

C. S. NIRANJANA, S. PUROHIT, et. al.

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71. CALIBRATION AND SIGNAL PROCESSING METHODS USED FOR DENSITY PROFILE MEASUREMENTS FROM THE DEVELOPED FMCW REFLECTOMETRY SYSTEM FOR ADITYA-U TOKAMAK

JJU BUCH, et. al.

IPR/RR-1705/2024 DECEMBER 2024

72. GYROKINETIC TRANSPORT DRIVEN BY UBIQUITOUS MODES IN LTX-LIKE TOKAMAK WITH "FLAT" TEMPERATURE

SAGAR CHOUDHARY, et. al.

IPR/RR-1706/2024 DECEMBER 2024

73. FAST VISIBLE IMAGING DIAGNOSTIC FOR INDUCTIVELY DRIVEN PELLET INJECTOR IN ADITYA-U TOKAMAK

DEVILAL KUMAWAT, et. al.

IPR/RR-1707/2024 DECEMBER 2024

74. INVESTIGATING THE INTERACTIONS OF MICROWAVE PLASMA WITH BACTERIAL CELL STRUCTURES: IMPACTS ON CELL INTEGRITY AND VIABILITY

TEJAL BARKHADE, et. al.

IPR/RR-1708/2024 DECEMBER 2024

75. CONCEPTUAL FRAMEWORK FOR ELECTROSTATIC FIELD ANALYSIS OF ION EXTRACTION AND ACCELERATION SYSTEM FOR NEUTRAL BEAM INJECTORS

ADITYA NAUGRAIYA, et. al.

IPR/RR-1709/2024 DECEMBER 2024

76. EXPERIMENTAL INVESTIGATION OF LOW RESISTANCE JOINTS FOR HIGH FIELD HTS MAGNETS

ANEES BANO, et. al.

IPR/RR-1710/2024 DECEMBER 2024

77. ECR PRODUCED PLASMA IN TIME-VARYING TOROIDAL MAGNETIC FIELD

TULCHHI RAM, et. al.

IPR/RR-1711/2024 DECEMBER 2024

78. INITIAL LOWER HYBRID CURRENT DRIVE EXPERIMENTS WITH PAM LAUNCHER IN ADITYA-U TOKAMAK

P. K. SHARMA, et. al.

IPR/RR-1712/2025 JANUARY 2025

79. STUDIES OF DENSITY BUILD-UP DURING PLASMA INITIATION IN ADITYA-U TOKAMAK

UMESH NAGORA, et. al.

IPR/RR-1713/2025 JANUARY 2025

80. APPLICATION OF FUNCTION PARAMETRIZATION FOR PLASMA POSITION ESTIMATION IN ADITYA -U TOKAMAK

SAMEER KUMAR, et. al.

IPR/RR-1714/2025 JANUARY 2025

81. BEHAVIOUR OF MAGNETO-CONVECTIVE FLUCTUATIONS IN MHD DUCT FLOW UNDER DIFFERENTLY

HEATED WALLS AND APPLIED MAGNETIC FIELD DIRECTION

SRIKANTA SAHU, et. al.

IPR/RR-1715/2025 JANUARY 2025

82. ELECTROCHEMICAL CORROSION INVESTIGATION OF PLASMA NITRIDED Ti-6Al-4V ALLOY IN DIFFERENT SIMULATED SOLUTION

PRAVIN DWIVEDI, et. al.

IPR/RR-1716/2025 JANUARY 2025

83. FLUID SIMULATION OF MAGNETIZED PLASMA SHEATHS IN A COLLISIONAL, MULTICOMPONENT DUSTY PLASMA INCORPORATING NON-THERMAL ELECTRONS AND IONIZATION EFFECTS

AKSHAYA KUMAR SHAW, et. al.

IPR/RR-1717/2025 JANUARY 2025

84. LIQUID METAL FLOW ANALYSIS IN A DUCT WITH SUDDEN EXPANSION UNDER INCLINED MAGNETIC FIELD

ARPITA VIPAT, et. al.

IPR/RR-1718/2025 JANUARY 2025

85. MICROSTRUCTURE AND THICKNESS DEPENDENT STEAM OXIDATION OF TiN COATING DEVELOPED ON ZIRCALOY-4 USING CYLINDRICAL MAGNETRON SPUTTERING

KUNAL TRIVEDI, et. al.

IPR/RR-1719/2025 JANUARY 2025

86. DESIGN AND EXPERIMENTAL VALIDATION OF PATTERN AND FREQUENCY RECONFIGURABLE CENTRAL PLASMA ANTENNA ARRAY

MANISHA JHA, et. al.

IPR/RR-1720/2025 FEBRUARY 2025

87. EFFECT OF LH AND ECR WAVES ON PLASMA PARAMETERS IN ADITYA UPGRADE TOKAMAK

S. AICH, et. al.

IPR/RR-1721/2025 FEBRUARY 2025

88. PROBING INTO SPACE CHARGE INTERACTIONS OF NEGATIVE ION BEAMS THROUGH IMAGING DIAGNOSTICS

SIDHARTH DASH, et. al.

IPR/RR-1722/2025 FEBRUARY 2025

89. INFLUENCE OF ION-NEUTRAL COLLISIONS ON THE IMPACT OF EDGE BIASING IN A TOKAMAK PLASMA

VIJAY SHANKAR, et. al.

IPR/RR-1723/2025 FEBRUARY 2025

90. TRANSFORMER FOR PREDICTING MAJOR DISRUPTIONS IN ADITYA TOKAMAK

JYOTI AGARWAL, et. al.

IPR/RR-1724/2025 FEBRUARY 2025

91. MODELING OF EXPERIMENTALLY OBSERVED TWO DIMENSIONAL PRECURSOR SOLITONS IN A DUSTY PLASMA BY THE FORCED KADOMTSEV–PETVIASHVILI EQUATION

AJAZ MIR, et. al.

IPR/RR-1725/2025 FEBRUARY 2025

92. NEW SYSTEMATIC DESIGN METHODOLOGY OF MODULAR MULTILEVEL CONVERTERS IN RECTIFIER APPLICATIONS

MEDDI THARUN, et. al.

IPR/RR-1726/2025 FEBRUARY 2025

93. 3D COMPUTATIONAL FLUID DYNAMICS ANALYSIS OF PROTOTYPE ION EXTRACTOR GRID-1 USING ANSYS

TEJENDRA PATEL, et. al.

IPR/RR-1727/2025 FEBRUARY 2025

94. NEW SYSTEMATIC DESIGN METHODOLOGY OF MODULAR MULTILEVEL CONVERTERS IN RECTIFIER APPLICATIONS

MEDDI THARUN, et. al.

IPR/RR-1728/2025 FEBRUARY 2025

95. SYNERGISTIC EFFECT OF ARGON PLASMA TREATMENT ALONG WITH HEXADECYLTRIMETHOXYSILANE (HDTMS) COATING ON THE JUTE FABRIC FOR SUPERHYDROPHOBIC APPLICATION

ROHIT SHARMA, et. al.

IPR/RR-1729/2025 MARCH 2025

96. SILVER NANOPARTICLES DECORATED ON MODULATED GRAPHENE OVER SILICON RIPPLE PRODUCED BY LOW ENERGY ION-BEAM FOR SERS APPLICATION

TARUNDEEP KAUR LAMBA, et. al.

IPR/RR-1730/2025 MARCH 2025

97. INSTALLATION, COMMISSIONING AND TESTING OF ALOW ENERGY ACCELERATOR BASED 14-MeV NEUTRON GENERATOR FOR LAB SCALE FUSION NEUTRONICS EXPERIMENT

SUDHIRSINH VALA, et. al.

IPR/RR-1731/2025 MARCH 2025

98. VACUUM BRAZING ROUTE FOR LARGE-SCALE GRID MANUFACTURING IN NEGATIVE ION BEAM GENERATION

RAVI PANDEY, et. al.

IPR/RR-1732/2025 MARCH 2025

99. TERAHERTZ RADIATION GENERATION BY LASER-RESONANT EXCITATION OF TERAHERTZ SUR-

FACE MAGNETOPLASMONS ON A GRAPHENE-n-InSb SEMICONDUCTOR INTERFACE

ROHIT KUMAR SRIVASTAV, et. al.

IPR/RR-1733/2025 MARCH 2025

100. DEVELOPMENT OF PERMEATION BASED HYDROGEN ISOTOPES SENSOR AND ITS TESTING IN GAS PHASE AND MOLTEN PB-LI

RUDREKSH B. PATEL, et. al.

IPR/RR-1734/2025 MARCH 2025

101. A HIGH FLEXIBILITY ENABLED SINGLE LAYERED TUNABLE AND POLARIZATION INSENSITIVE RIS FOR MM-WAVE DYNAMIC BEAMFORMING APPLICATIONS

B ANIL BABU, et. al.

IPR/RR-1735/2025 MARCH 2025

102. EXPERIMENTAL, SIMULATION AND THEORETICAL STUDIES OF NON-PLANAR PINNED SOLITONS IN A DUSTY PLASMA

PRASANTA AMAT, et. al.

IPR/RR-1736/2025 MARCH 2025

103. UNDERSTANDING NONLINEAR BEHAVIOR OF CAPACITIVE PROBES TO STUDY DIOCOTRON MODES IN NON-NEUTRAL PLASMAS

KUNAL SINGHA, et. al.

IPR/RR-1737/2025 MARCH 2025

104. IGNITING INDIA'S FUSION FUTURE

D. RAJU, et. al.

IPR/RR-1738/2025 MARCH 2025

105. HAPTIC MASTER ARM DEVELOPMENT FOR TELE-MANIPULATION IN TOKAMAK LIKE CHALLENGING ENVIRONMENTS

NAVEEN RASTOGI, et. al.

IPR/RR-1739/2025 MARCH 2025

D2.2 Technical Reports

1. Testing of Shielding Effectiveness of Anechoic Chamber at IPR

B. RISCOB, et.al.

IPR/TR-798/2024 (April 2024)

2. Design and Analysis of the Components of Cryogenic Extruder for Producing Liquid Hydrogen

VISHAL GUPTA, et.al.

IPR/TR-799/2024 (April 2024)

3. Thermal Conductivity Measurement of the Adhesive at Cryogenic Temperatures Repeatedly Used in the Development of Indigenous Cryopumps

AVIJIT DEWASI, et.al.

IPR/TR-800/2024 (April 2024)

4. Design & Fabrication of Lithium Injector and Its Performance Testing

A. PRAJAPATI, et.al.

IPR/TR-801/2024 (May 2024)

5. Literature Study and Compilation of Neutron Radiation Effects on Electronic Devices

PRAMILA, et.al.

IPR/TR-802/2024 (May 2024)

6. Test Report on commissioning and I&C experiments of PILATUS-3 X-ray hybrid photon counting detector

DEEPAK MANDGE, et.al.

IPR/TR-803/2024 (May 2024)

7. Commissioning and Operational Experience of Cryocooler based Helium Circulation System at 55 K

PRADIP PANCHAL, et.al.

IPR/TR-804/2024 (May 2024)

8. Implementation of an Active Control of Multiple Gas Puff Pulses to Counteract Wall Loading in the ADITYA Upgrade Tokamak

PRAVEENLAL EDAPPALA, et.al.

IPR/TR-805/2024 (May 2024)

9. Vue Framework Empowered Website for Microwave and ECE Diagnostics Section: Bridging Scientific Communities for Enhanced Collaboration and Innovation

HIRAL HEBATPURIA, ABHISHEK SINHA, et.al.

IPR/TR-806/2024 (June 2024)

10. Recent Results from Electron Cyclotron Emission (ECE) Radiometer Diagnostics in the Presence of Electron Cyclotron Resonance Heating (ECRH)

VARSHA SIJU, et.al.

IPR/TR-807/2024 (July 2024)

11. RF Characterization of LHCD Transmission Line and High Power Divider Section for ADITYA-U Tokamak

K. K. AMBULKAR, et.al.

IPR/TR-808/2024 (July 2024)

12. Electronics, Data Acquisition and Control Systems for Aditya-U Tokamak

RACHANA RAJPAL, et.al.

IPR/TR-809/2024 (July 2024)

13. Setup for External-q Experiments in Current-less Plasma of Basic Experiments in Toroidal Assembly (BETA)

PRAVESH DHYANI, et.al.

IPR/TR-810/2024 (July 2024)

14. Finite Element Analysis of Pipe Bridge for Centralized LN2 and GN2 Distribution Piping

NARESH CHAND GUPTA et.al.

IPR/TR-811/2024 (July 2024)

15. Power Balance in Tokamak Fusion Reactor

ARITRA CHAKRABORTY, et.al.

IPR/TR-812/2024 (August 2024)

16. Design and Characterization of Multi-Channel Receiver system

VARSHA SIJU, et.al.

IPR/TR-813/2024 (August 2024)

17. Development and Characterization of Indigenously Developed High Temperature Black Body Source for Calibration of ECE Diagnostics

ABHISHEK SINHA, et.al.

IPR/TR-814/2024 (August 2024)

18. Real-time UAV Detection through RF Signal Analysis and Machine Learning

YASH AHIRRAO, et.al.

IPR/TR-815/2024 (August 2024)

19. Simulation and Analysis of Nanosecond Pulse Electric Field Generator for Valorization of Food Waste

SUPRIYA NAIR, et.al.

IPR/TR-816/2024 (August 2024)

20. Simulation Analysis of 1500kW, 600V Thyristor Controlled Rectifier

KUMAR SAURABH, et.al.

IPR/TR-817/2024 (August 2024)

21. Activation Cross Section for 85Rb(n,2n)84mRb and 85Rb(n,p)85mKr Reactions with Uncertainty Propagation and Covariance Analysis

MAYUR MEHTA, et.al.

IPR/TR-818/2024 (September 2024)

22. Design and Investigation of View-Dump for Vertical Electron Cyclotron Emission (V-ECE) Receiver System

PRABHAKAR TRIPATHI, et.al.

IPR/TR-819/2024 (September 2024)

23. Shutter Closure and False Trigger Problem in High Resolution Visible Imaging Diagnostics installed in Aditya-U

S.K. GUPTA, et.al.

IPR/TR-820/2024 (September 2024)

24. Remote Operation of RF Generator, Magnets, and Diagnostics of Helicon Plasma Thruster

PRASHANT KUMAR, et.al.

IPR/TR-821/2024 (September 2024)

25. Development of a Multi-Purpose High-Speed Reciprocating Probe Drive System for Investigating Edge Plasma Dynamics in ADITYA-U Tokamak

KAUSHLENDER SINGH, et.al.

IPR/TR-822/2024 (October 2024)

26. Development of a Desktop Application for Soft X-Ray Spectral Measurements at the Plasma Start-Up

M. CHAVDA, S. PUROHIT, et.al.

IPR/TR-823/2024 (October 2024)

27. Critical Current Measurement of REBCO Tape Using Solid Nitrogen Set Up

UPENDRA PRASAD, et.al.

IPR/TR-824/2024 (October 2024)

28. Neutron Capture Cross-Section of 186W Isotope in the Energy Range from 0.6-3.2 MeV with Covariance Analysis

MAYUR MEHTA, et.al.

IPR/TR-825/2024 (October 2024)

29. Extension of Effective Lifetime of a CCD Detector using PCIe to PCI Convertor based Assembly

AMAN GAUTTAM, et.al.

IPR/TR-826/2024 (October 2024)

30. Development of Ten Channels High Accuracy DAQ System along with Cubic Spline Interpolation for Nonlinear Sensor Response

DASHRATH SONARA, et.al.

IPR/TR-827/2024 (November 2024)

31. 3D DIC Diagnostics for Full Field In-Situ Strain Measurement on Plasma Facing Components in High Heat Flux Test Facility

KEDAR BHOPE, et.al.

IPR/TR-828/2024 (November 2024)

32. Experimental Test Set-up Preparation and Testing of NbTi CICC at 77K

C. DODIYA, et.al.

IPR/TR-829/2024 (December 2024)

33. Benchmarking of 3D FDTD Code for Monopole Antenna Studies

M. HIMABINDU, et.al.

IPR/TR-830/2024 (December 2024)

34. Development of -5kV, 1A High Voltage Dual Mode Power Supply for 1kW, 2.45GHz Magnetron Source

BHAVESH KADIA, et.al.

IPR/TR-831/2024 (December 2024)

35. Experience and Challenges involved during Alignment of Electrical Motors to the Helium screw Compressors at IPR

PANKIL SHAH, et.al.

IPR/TR-832/2025 (January 2025)

36. A Simulation Analysis of 300 kV DC Power Supply for Neutral Beam Injector Accelerator Grid

ARITRA CHAKRABORTY, et.al.

IPR/TR-833/2025 (January 2025)

37. Design and Development of a Line-Type Pulsed Modulator Driver for S-Magnetron for Microwave Plasma Interaction Experiments in SYMPLE

PRIYAVANDANA J. RATHOD, et.al.

IPR/TR-834/2025 (January 2025)

38. Design, Fabrication and Evaluation of Force-Reflecting 6 DOF Haptic Device for Remote Handling and Robotic Applications

JIGNESH CHAUHAN, et.al.

IPR/TR-835/2025 (February 2025)

39. Design Up-gradation of Electronics for PMT Sensor Based Systems in ADITYA-U Tokamak

MINSHA SHAH, et.al.

IPR/TR-836/2025 (February 2025)

40. Prototype Implementation of Security Operations Center (SOC) using Open-Source Tools

VIJAY PATEL, et.al.

IPR/TR-837/2025 (February 2025)

41. Setup and Benchmarks of TimescaleDB for Time-Series Based Sensor Data

PREM KUMAR, et.al.

IPR/TR-838/2025 (February 2025)

42. LIGO-Beam Tube: The LI-VISTA Experiment

ATUL K PRAJAPATI, et.al.

IPR/TR-839/2025 (February 2025)

43. Liquid Helium Level Monitoring System for Cryogenics

DASHRATH SONARA, et.al.

IPR/TR-840/2025 (February 2025)

44. Analysis and Experimental results of cool down time of 80K Cryopump for LIGO India Vacuum Integrated System Test Assembly (LIVISTA)

NARESH CHAND GUPTA, et.al.

IPR/TR-841/2025 (March 2025)

45. Feasibility Study for Upgradation in Superconducting Current Feeders System for SST-1

N. BAIRAGI, et.al.

IPR/TR-842/2025 (March 2025)

46. Characterization of W-band Trans-receiver system

VARSHA SIJU, et.al.

IPR/TR-843/2025 (March 2025)

47. Prototype implementation of Network Operations Center (NOC) using Open-Source Tools

VIJAY PATEL, et.al.

IPR/TR-844/2025 (March 2025)

48. Up-Gradation of Controller for DG Sets

CHIRAG BHAVSAR, et.al.

IPR/TR-845/2025 (March 2025)

49. Hardware in Loop (HIL) Testing System in SST-1

JASRAJ DHONGDE, et.al.

IPR/TR-846/2025 (March 2025)

50. Integration of Active Directory Server with Wazuh for Monitoring event logs

ARVIND M SINGH, et.al.

IPR/TR-847/2025 (March 2025)

51. Establishment of Site-to-Site (s2s) tunneling between two remote Sites

SHARAD JASH, et.al.

IPR/TR-848/2025 (March 2025)

52. Development and Evaluation of a Low-Cost Portable thin-film Analog X-ray Digitizer

ABHISHEK SHARMA, et.al.

IPR/TR-849/2025 (March 2025)

53. Enroot Installation, Configuration and Testing with PBS for container application on High Performance Computing with Multi-Node-Multi-GPU system

SHIVAM PATEL, et.al.

IPR/TR-850/2025 (March 2025)

54. Blockchain Based Document Signing and Validation Processes using Decentralized Database

A. ABHISHEK, et.al.

IPR/TR-851/2025 (March 2025)

D3. CONFERENCE PRESENTATION

International Conference on Advances in Aerospace and Energy Systems (IAES-2024), Liquid Propulsion Systems Centre (ISRO), Thiruvananthapuram, Kerala, 4-6 April 2024

Power Balance in Tokamak Fusion Reactor

Aritra Chakraborty, et.al.

Computational Fluid Dynamics Modelling and Validation of Rotating Detonation Engine

Sunil Bassi, et.al.

15th-ITER Neutronics meeting and Fusion Neutronics Workshop -2024, ITER Headquarters, France, 8-10 April 2024

Radiation conditions improvement in ITER tokamak complex due to leakage through penetrations

Jyoti Agarwal, et.al.

Overview of IN DA neutronics activities

Bhoomi Gajjar, et.al.

Nuclear analysis requirements for compact fusion pilot plants

P.N. Maya, et.al.

14 MeV Neutron source facility at Institute for plasma research: characteristics and applications

H. L. Swami, et.al.

10th Optical Terahertz Science and Technology, Philipps University, Marburg, Germany, 8-12 April, 2024

Generation of S-polarized Terahertz Radiation from Laser-Plasma Interactions

Anjana K P, et.al.

22nd Joint Workshop on Electron Cyclotron Emission (ECE) and Electron Cyclotron Resonance Heating (ECRH), Daejeon, South Korea, 22-26 April 2024

Design, Development and Characterization of Indigenously Developed High Temperature Black Body Source for Calibration of ECE Diagnostics
Abhishek Sinha, et.al.

Recent Results from Electron Cyclotron Emission (ECE) Radiometer diagnostics in the presence of Electron Cyclotron Resonance Heating (ECRH)

Varsha Siju, et.al.

16th International Reflectometry Workshop (IRW16), Max Plank Institute for Plasma Physics, Greifswald, Germany, 13-16 May 2024

Density profile measurements from the developed FMCW Reflectometry system for Aditya-U tokamak
J. J. U. Buch, et.al.

4th International Workshop on Measurement Techniques for Liquid Metals (MTLM2024), Dresden, Germany, 27-29 May 2024

Development of a highly sensitive electromagnetic flowmeter for high temperature liquid metals
Srikanta Sahu, et.al.

Plasmonica International School on Plasmonics and Nano-optics, Institute of Advanced Studies, Como, Italy, 3-7 June 2024

Tuning LSPR anisotropy in metal nanoparticles arrays by sequential deposition
Tarundeep K. et.al.

DAE-BRNS National Conference on Development of RF Components for Accelerators (DRCA-2024), Anushakti Nagar, Mumbai, 20-22 June 2024

Development of CE certified Signal Conditioning Module for Control & Instrumentation of High-Power RF System
Dipalkumari Soni, et.al.

Development of wideband 10 kW Solid State Power Amplifier - Challenges, Remedies and Test results
Manojkumar Patel, et.al.

Development of fast protection circuits for tube based high power RF amplifier
Hrushikesh Dalicha, Gajendra Suthar, et.al.

Fabrication and RF test results of 120 kW amplifier manufactured through Indian industry challenges, remedies and performance
Akhil Jha, et.al.

National Conference on Recent Trends in Materials Science and Technology (NCMST-2024), Institute of Space Science and Technology, Thiruvananthapuram, Kerala, 25-27 June 2024

Multipurpose Neutron Irradiation Facility for Nuclear and Space Application
H. L. Swami, et.al.

10th Plasma Science Society of India-Plasma Scholar's Colloquium (PSSI-PSC2024), Indian Institute of Technology, Delhi, 4-6 July 2024

Excitation of Precursor Solitons due to Charged Space Debris based on the forced Kadomtsev–Petviashvili model
Ajaz Mir, et.al.

3D plasma start-up studies with structured first-wall panels of ITER
Arzoo Malwal, et.al.

Spontaneous Convective Patterns in a Dusty Plasma
Ankit Dhaka, et.al.

Structure of Current Flow in the Magnetosphere of the Accreting Neutron Star
Anoop Singh, et.al.

Direct O-X-B mode conversion in STARMA device
Tulchhi Ram, et.al.

Study of Two-Electron Temperature Plasmas and Their Influence on Ion Acoustic Soliton in A Multi-Pole Line Cusp Magnetic Field Plasma Device (MPD)
Zubin Shaikh, et.al.

Surface Modification to form Nano-features Using RF Plasma Ion Beam Source
Tarundeep K. Lamba, et.al.

50th European Conference on Plasma Physics (EPS-2024), Palacio de Congresos Salamanca, Spain, 8 - 12 July 2024

Influence of dust grains and external magnetic field on the propagation of ion-acoustic waves in a two-electron temperature plasma
S.S. Kausik, et.al.

Emergence of a conical-spiral weakly relativistic electron beam from the laser-cluster interaction in an ambient magnetic field
Kalyani Swain, et.al.

Quasi-Longitudinal (QL) whistler turbulence induced reduced electrostatic particle flux in large volume plasma device
A. K. Sanyasi, et.al.

10th IEEE International Conference on Electronics, Computing and Communication Technologies (CONECCT 2024), J.N. Tata Auditorium, IISc, Bangalore, 12-14 July 2024

Simulation Study of 4 kV, 5A Modular Multilevel Converter as a Rectifier
Meddi Tharun, et.al.

29th International Cryogenic Engineering Conference, International Cryogenic Materials Conference 2024 (ICEC/ICMC 2024), Geneva, Switzerland, 22-26 July 2024

Development, Testing and Application of the Indigenously Built 80 K Sorption Cryopump
Vishal Gupta, et.al.

Investigation of the thermal emittance properties of multilayer insulation used in cryogenic applications
Uday Kumar, et.al.

Development of Glass Fiber Composite Axial Insulating Cryogenic Vacuum Barrier for Superconducting Feeders of SST-1 Tokamak
Rajiv Sharma, et.al.

Implementation and Enhancement of Safety Measures in SST-1 Cryogenic System at 77 K and 4.2 K
Rajiv Sharma, et.al.

21st International Congress on Plasma Physics (ICPP 2024), Ghent, Belgium, 08-13 September 2024

One-Dimensional Model for Plasma-Flow from the Accretion Disk towards the Neutron-Star Poles
Anoop Singh, et.al.

Plasma boundary simulations of limiter ramp-up phase of ITER
Arzoo Malwal, et.al.

Pulsed Hydrogen Plasma Stream Interaction on Tungsten Substrate
T. K. Borthakur, et.al.

DAE-BRNS 1st National Conference on Pulsed Power Science, Technology and Applications (PPSTA-2024), Bhabha Atomic Research Centre Facilities, Visakhapatnam, 12-14 September 2024

Enhancing High Heat Flux Test Facility Performance: The Potential of Indigenous Electron Beam Systems
Sunil Belsare, et.al.

26th International Workshop on ECR Ion Sources (ECRIS-2024), Darmstadt, Germany, 15-19 September 2024

Characterization of D+ Species in the 2.45 GHz ECRIS for 14-MeV Neutron Production
S. Vala, et.al.

77th Annual Gaseous Electronics Conference (GEC 2024), San Diego, California, USA, 30 September 2024 - 04 October 2024

Spontaneous Convective Patterns in a Dusty Plasma
Ankit Dhaka, et.al.

Experiments and characterization studies of 1 kW RF Helicon plasma thruster with plasma diagnostics techniques
Ramesh Kumar Buddu, et.al.

66th Annual Meeting of the APS Division of Plasma Physics (APS DPP 2024), Atlanta, USA, 7–11 October 2024

On the excitation of nonlinear ion acoustic waves in a two-electron temperature plasmas of Multi-pole line cusp Plasma Device (MPD)
Zubin Shaikh, et.al.

Nonlinear Mode Coupling in a 1D Dusty Plasma
Ankit Dhaka, et.al.

2nd Technical Meeting on Long Pulse Operation of Fusion Devices, IAEA Headquarters, Vienna, Austria, 14-18 October 2024

Performance of PAM launcher in ADITYA-U tokamak
P. K. Sharma, et.al.

40th DAE Safety & Occupational Health Professionals Meet 2024 (DAE-SOHPM), RRCAT, Indore, 17-19 October 2024.

Implementation of Safety Measures in SST-1 Cryogenic Systems at IPR
Rajiv Sharma, et.al.

22nd International Spherical Torus Workshop (ISTW-2024), Rhodes House, Oxford, 21-24 October 2024

Engineering Design of a Prototype Center Stack Toroidal Field Coil for Spherical Tokamak
A.K. Verma, et.al.

44th ITPA MHD, Disruption and Control (MDC) Topical Group Meeting, Institute for Plasma Research, Gandhinagar, 22-25 October 2024

Stabilization of sawtooth instability by short gas pulse injection in Aditya-U Tokamak
Suman Dolui, et.al.

4th International Workshop on Cooling Systems for HTS Applications (IWC-HTS 2024), Matsue, Japan, 23-25 October 2024

Recent Performance Results of Cryocooler based Helium Circulation System at 55 K
Pradip Panchal, et.al.

8th Asia-Pacific Conference on Plasma Physics (AAPPS-DPP 2024), Malacca, Malaysia, 3-8 November 2024
Toroidal flow & temperature measurements of neutral atoms in edge region of ADITYA-U Tokamak using Zeeman splitting
Ankit Kumar, et.al.

Fluid simulation studies of low temperature plasmas using COMSOL Multiphysics Software

Y. Patil, et.al.

Conference on Plasma Simulation (CPS-2024), Indian Institute of Geomagnetism, Navi Mumbai, 11-13 November 2024

Plasma transport study with 3D shaped first wall for limiter start-up phase of ITER
Arzoo Malwal, et.al.

Neutral Gas Puff Transport Modeling using DEGAS-2 Code
Ruchi Varshney, et.al.

Unstable Ion Acoustic Modes: A 1D Vlasov Study
Chingangbam Amudon, et.al.

14th Biennial Conference of Physics Academy of the North-East (PANE-2024), Tezpur Unversity, Assam, 12 -14 November 2024

Exploring plasma–liquid interactions for diverse applications
Ngangom Aomoa, et.al.

Experimental studies on the decomposition of CO_2 gas in non-thermal plasmas
Deepjyoti Mahanta, W Joychandra Singh, et.al.

Efficient and cost effective treatment of methylene blue dye by a non-thermal plasma
Flossie B F Ch Marak, W Joychandra Singh, et.al.

Particle-in-cell simulation of radio-frequency plasma discharges
Rakesh Moulick, et.al.

8th QST International Symposium, Aomori, Japan, 14-15 November 2024

Design and Commissioning of Experimental Helium Cooling Loop (EHCL)
Ankit Gandhi, et.al.

National Conference on Emerging Trends in Vacuum Electronic Devices and Applications (VEDA-2024), CSIR-CEERI, Pilani, Rajasthan, 18-20 November 2024

Development of Anode Power Supply for Gyrotron
Rasesh Dave, et.al.

9th International Symposium on Negative Ions, Beams and Sources (NIBS2024), ITER-India, Institute for Plasma Research, Gandhinagar, 19-22 November 2024

Mass spectrometry of an ECR based large volume negative ion beam system
Bibekananda Naik, M Bandyopadhyay, et.al.

Overview of activities at the ITER Neutral Beam Test Facility (NBTF) in view of the ITER NBI
D. Marcuzzi, M. Singh, et.al.
Assessment of signal reconstruction techniques for critical signals in high power negative ion based plasma sources
H Tyagi, et.al.

Neutral Beams in ROBIN: Present Status and Future Plans
K. Pandya, et.al.

Negative ion source R&D in IPR: Modeling contributions
M Bandyopadhyay, et.al.

Plasma Density estimation using Machine Learning for High power Ion Source
H Tyagi, et.al.

Probing into Space Charge Interactions of Negative Ion Beams through Imaging Diagnostics
Sidharth Dash, et.al.

29th National Conference on Cryogenics and Superconductivity (NCCS-29), Inter-University Accelerator Centre, New Delhi, 26 -29 November 2024

Performance results of upgraded Cryogenic System with 4 Cryo-Condensation pumps during 0.2 to 0.7 MW Positive Neutral beam Operation
Ch. Chakrapani, et.al.

Study of MgB_2 based superconducting current feeders system for fusion devices
Nitin Bairagi

Periodic testing of liquid nitrogen storage vessels
L.N. Srikanth. G, et.al.

Conceptual design of current leads for liquid nitrogen cooled copper coils in SST-1
Atul Garg, et.al.

High temperature superconducting magnet for magnetic fusion: R&D update and plan
Upendra Prasad, et.al.

Application of cryogenics in developing pellet injectors for fueling and plasma control in magnetically confined fusion devices
Jyoti Shankar Mishra, et.al.

3rd International Conference on Communication Control and Intelligent Systems (CCIS 2024), GLA University, Mathura, 6 -7 December 2024

Design up-gradation of electronics for PMT sensor based systems in ADITYA-U Tokamak
Minsha Shah, et.al.

13th ITER International School (IIS2024), Nagoya, Japan, 9-13 December 2024

Toroidal Electron Plasma Temperature Diagnostics in SMARTEX-C Partial Torus
Nikhil Mohurle, et.al.
Design and development of gas puff imaging diagnostic for aditya -u tokamak
Ruchi Varshney, et.al.

IEEE Microwave, Antennas and Propagation Conference (MAPCON 2024), Hyderabad International Convention Centre (HICC), Hyderabad, 09-13 December 2024

Design, Simulation and Testing of Wave Collection and Transport System for Michelson Interferometer Diagnostic
Abhishek Sinha, et.al.

Wide band reconfigurable salt water column antenna for RF communication
A. Sarada Sree, et.al.

34th Annual Conference & Exhibition on Non Destructive Evaluation & Enabling Technologies, Chennai, 12-14 December 2024

Non-Destructive Examination of Actively Cooled High Heat Flux Components Produced by Vacuum Brazing
Ravi Pandey, et.al.

Non-Destructive Examination & Testing of Integrated Vacuum Vessel Components
Atul K Prajapati, et.al.

1st International Workshop on Cold Plasma and Pulse Power Technologies for Food, Health, and Agriculture (COFHA-2024), IIT Jodhpur, 21-22 December 2024

Antibacterial Coatings on Yarn and Fabric using Plasma based magnetron sputtering
Ramkrishna Rane, et.al.

Correlation of Helium Mole Fraction for plasma jets at various angles
Akshay Vaid, et.al.

Application of Cold Plasma for Sterilization of Medical Equipment
Kushagra Nigam, et.al.

24th DAE-BRNS Symposium on Thermal Analysis (THERMANS-2024), Bhabha Atomic Research Centre, Mumbai, 16-18 January 2025

Pebble Bed Thermal Expansion and Sintering Investigation of Lithium Titanate for Fusion Blanket Application
Aroh Shrivastava, et.al.

International Conference on Energy Conversion and Storage (IECS 2025), Indian Institute of Technology Madras, Chennai, 27-29 January 2025

A Step towards Eco-friendly Electropolishing of SS304L Stainless Steel for Nuclear Fusion Applications
Uday Kumar, et.al.

13th International Conference on Photonics, Optics and Laser Technology (PHOTOPTICS 2025), Portugal, 22-24 February 2025

Sequential deposition of Ag NPs on rippled Si pattern for SERS application
Tarundeep Kaur Lamba

33rd DAE-BRNS National Laser Symposium (NLS-33), Medi-caps University, Indore, 6-9 March 2025

Analysis of LIBS signals on laser induced textured surface
P. Chandrakanta Singh, et.al.

AWARDS and ACHIEVEMENTS

Mr. Vinod Saini, Research Scholar, at IPR received the "**Best Paper Award"** at the International Conference on Advances in Aerospace and Energy Systems (IAES-2024), held during 04-06 April 2024 at the Liquid Propulsion Systems Centre (LPSC), Thiruvananthapuram, Kerala, for his paper entitled "Numerical Simulation of an Expanding Magnetic Field Plasma Thruster Using Iodine Fuel".

Dr. Swarnima Singh was awarded the "**Outstanding Student Award**" for the year 2023 in Physical Sciences by the Homi Bhabha National Institute for her PhD thesis entitled "Experimental Study of a Quasi Two-Dimensional

Complex Plasma". She completed her PhD at IPR under the guidance of Dr. Pintu Bandyopadhyay. She is currently a Post-Doctoral fellow at University of California, San Diego, USA.

Dr. Vikas Rathore was awarded the "**J.B. Joshi Research Foundation Innovation Award**" for the year 2023 in Engineering Sciences by the Homi Bhabha National Institute for his PhD thesis entitled "Study of Plasma Activation of Water and its applications in Antimicrobial and Agricultural activities". He completed his PhD at IPR under the guidance of Dr. S. K. Nema. He is currently a Post-Doctoral fellow at IPR, working in the field of field of plasma hydroponics and vertical farming.

Ms. Geethika B R, gave a talk on "Anisotropic Emission from Laser Produced Aluminium Plasma" at 10th Plasma Science Society of India - Plasma Scholars Colloquium (PSSI-PSC 2024), Indian Institute of Technology, Delhi, 4-6 July 2024, and have received the **"Best Oral Presentation Award"**. [Co-authors: Jinto Thomas, Milaan Patel, Renjith Kumar R, H C Joshi]

Ms. Komal, gave a poster presentation on "Investigating the effect of impurity seeding on the magnetic and electrostatic edge fluctuations in ADITYA-U tokamak" at 10th Plasma Science Society of India-Plasma Scholar's Colloquium (PSSI-PSC2024), Indian Institute of Technology, Delhi, 4-6 July 2024, and received "**Best Poster Award"**. [Co-authors: H. Raj, I. Hoque, S. Banerjee, A. Kumawat, B. Hegde, A. Kumar, K. Singh, S. Dolui, R. Kumar, S. Aich, S. Patel, A. Kanik, K. M. Patel, K. Galodiya, K. A. Jadeja, Laxmikanta Pradhan, Ankit Patel, R. L. Tanna, J. Ghosh]

Dr. Amreen Ara Hussain, gave a talk on "Enhanced Optoelectronic Devices Engineered with Lead (Pb) or Lead-Free Halide Perovskites Tailored for Environmental Stability" at International Conference on Energy and Environmental Materials (E2M-2024), Indian Institute of Technology, Indore, 11-13 July 2024, and have received "**Best Presenter Award"**.

DAE "Certificate of Excellence" for Swachhata Pakhwada

Swachhata Pakhwada was organized in all DAE units during 16 February - 28 February 2024. The committee constituted for the evaluation of **"Swachhata Pakhwada Awards 2024"** have assessed the activities carried out by various DAE units. IPR has been awarded the **'Certificate of Excellence' (consolation**

prize) as an appreciation for its innovative practices undertaken during the Swachhata Pakhwada. The award sets a new benchmark and a motivation to do even better and contribute towards keeping the surroundings clean, and also sensitize our society by raising awareness through such Swachhata Campaigns!

Ms. Pratibha Gupta, received **3rd Prize in essay competition** at Indian Association of Physics Teachers (IAPT) National Competition on Essay Writing in Physics (NCEWP - 2024), Dharamshala, Himachal Pradesh, on the topic "The Physics behind melodious music" on 16th October 2024

Mr. Souvik Mondal, gave a talk on "The dynamics of blob merging in the tokamak scrape-off layer region" at 8th Asia-Pacific Conference on Plasma Physics (AAPPS-DPP 2024), Malacca, Malaysia, 3-8 November 2024, and have received **Best Poster Award**. [Co-authors: N Bisai, A Sen, I Bandyopadhyay]

Dr. Jyoti Shankar Mishra, gave a talk on "Application of cryogenics in developing pellet injectors for fueling and plasma control in magnetically confined fusion devices" at 29th National Conference on Cryogenics and Superconductivity (NCCS -29), Inter-University Accelerator Centre, New Delhi, 26 -29 November 2024, and have received **Best Paper Presentation Award.**

Mr. Kedar Bhope, HTTD, received **Best Poster Presentation Award** for the paper titled "Eddy Current Thermography Technique for He cooled Plasma Facing Components" at the 34th Annual Conference and Exhibition on Non-Destructive Evaluation and Enabling Technologies (NDE-2024) held in Chennai, 12-14 December 2024. Hosted by the ISNT Chennai chapter. [Co-authors: Mayur Mehta, Alpesh Patel, Shailesh Kanpara, Samir Khirwadkar, Sunil Belsare, Tusharkumar Patel, Prakash Mokariya]

Mr. Ankit Kumar, gave a talk on "Effect of Impurity Seeding on Edge Toroidal Rotation in Aditya-U Tokamak" at 39th National Symposium on Plasma Science and Technology (PLASMA 2024), Pandit Deendayal Energy University (PDEU), Gandhinagar, 17-20 December 2024, and have received **BUTI Young Scientist Award**.

Mr. Bhavesh R Kadia, gave a talk on "Development of -5kV, 1A High Voltage Dual Mode Power Supply for 1kW, 2.45GHz Magnetron Source" at 39th National Symposium on Plasma Science and Technology (PLASMA 2024), Pandit Deendayal Energy University (PDEU), Gandhinagar, 17-20 December 2024, and have received **Z. H. Sholapurwala Award**. [Co-authors: Kirit Parmar, Shivam Sharma, Sunil Kumar and High Power ICRH Systems Division]

Dr. Jyoti Shankar Mishra, gave a talk on "Design and Experimental Study of a Differential Pumping System for Hydrogen Pellet Injector" at 39th National Symposium on Plasma Science and Technology (PLASMA 2024), Pandit Deendayal Energy University (PDEU), Gandhinagar, 17-20 December 2024, and have received **Z H Sholapurwala Award**.

Dr. Mamta, gave a poster presentation on "Interaction of Obliquely Incident Intense Laser with Inhomogeneous Plasma and Validation of Electromagnetic Fields for Different Polarization" at 39th National Symposium on Plasma Science and Technology (PLASMA 2024), Pandit Deendayal Energy University (PDEU), Gandhinagar, 17-20 December 2024, and have received **PSSI Poster Award (Fundamental Plasma)**.[Co-authors: Shakti Kushwaha, Nidhi Rathee, Mrityunjay Kundu, Bhavesh Patel, and Sudip Sengupta]

Mr. Vrushank Mehta, gave a poster presentation on "Various NF_3 Gas Abatement Techniques for the NF_3 RF Glow Discharge Plasma Etching System" at 39th National Symposium on Plasma Science and Technology (PLASMA 2024), Pandit Deendayal Energy University (PDEU), Gandhinagar, 17-20 December 2024, and have received **Poster Award (Plasma Application)**.

Mr. Someswar Dutta, gave a poster presentation on "Runaway Electron Dynamics in a Tokamak Under

The Influence of Local Magnetic Field Perturbation" at 39th National Symposium on Plasma Science and Technology (PLASMA 2024), Pandit Deendayal Energy University (PDEU), Gandhinagar, 17-20 December 2024, and have received **Poster Award (Simulation Plasma)**.

Ms. Geethika B R, gave a talk on "Characteristics of Polarized Emission from Laser Produced Plasma" at 24th National Conference on Atomic and Molecular Physics (NCAMP 2025), Indian Institute of Technology Dhanbad, 8-11 January 2025, and have received **Best Poster Award.** [Co-authors: Jinto Thomas, Renjith Kumar R and Hem Chandra Joshi]

Dr. Sebine Augustine, IPR Post-Doctoral Fellow, got the **First prize in poster presentation** title "Selforganized ordered nanoparticles for SERS application" in the workshop about Photonics for Energy, Sensing, and Education conducted by IIT Gandhinagar, 16-17 January 2025. Dr. Sebine earlier did his PhD from IPR as DGFS fellow.

Three of our ITER-India colleagues, Himanshu Kapoor, Anuj Kumar Garg, and Aditya Prakash Singh have been selected for the **'ITER Star Award'** for 2024.

Mr. Himanshu Kapoor, Technical Responsible Officer for ITER Cryolines and warmlines under INDA scope. He is also involved in providing his technical expertise for execution of the design and manufacturing of the cryolines needed for magnet cold test bench facility at ITER site.

Mr. Anuj Kumar Garg, I&C Responsible Officer for the ITER-India Cryo-Distribution system, is currently working on the design, manufacturing, execution, and inspection/ acceptance of Control Cubicles for Auxiliary Cold Boxes and TSCS, as well as software Task agreement activities for the ITER Magnet Cold Test Bench (MCTB).

Mr. Aditya Prakash Singh, is currently responsible for preparing Engineering Work Packages for the installation of the ITER Cooling Water System networks inside the Tokamak Complex and auxiliary buildings, as well as for the qualification and procurement of safety-important components.

Dr. W. Joychandra Singh, gave a talk on "Plasma Assisted synthesis of CuO Particles for Photocatalytic Application towards Dye Degradation" at International Workshop on Cold Plasma Technology and Applications (CPTA-2025), BIT Mesra, Jaipur Campus, 6-8 February 2025, and have received the "**Best Re-**

search Paper Award" on Societal Plasma Applications. [Co-author: Dr. Ngangom Aomoa]

D4. INVITED TALK DELIVERED BY IPR STAFF

DR. RAMKRISHNA RANE

Gave a keynote talk on "Plasma Surface Engineering for Biomedical Applications", at the 1st Global Forum and International Workshop in Hybrid mode on Industrial Plasma Processes and Diagnostics (IPPD 2024), organized by Department of Energy science and Engineering, IIT, Delhi, 9-10 May 2024

Gave an invited talk on "Non-Thermal Plasma Assisted Surface Modifications for Biomedical Applications" at DAE-BRNS Theme Meeting on Advanced Applications in Thermal and Non-Thermal Plasma (AATNT-2024), organized by Beam Technology Development Group, BARC, Mumbai, 8 June 2024

DR. SUDIP SENGUPTA

Gave an invited talk on "Breaking of Relativistically Intense Plasma Waves" at International Day of Light - 2024, Nuclear Photonics Symposium, Tata Institute of Fundamental Research (TIFR), Hyderabad, 16-17 May 2024

Gave an invited talk on "Sheet simulation of Upper Hybrid Oscillations in an inhomogeneous Magnetic Field" at Conference on Plasma Simulation (CPS-2024), Indian Institute of Geomagnetism, Navi Mumbai, 11-13 November 2024

Gave an invited talk on "Excitation of Electrostatic Standing Wave in a Cold Magnetized Plasma using Circularly Polarized Laser Pulses" at 33rd DAE - BRNS National Laser Symposium (NLS-33), Medi-caps University, Indore, 6-9 March 2025

DR. P. K. SHARMA

Gave an invited talk on "RF Technologies for klystron based Lower Hybrid Current Drive (LHCD) system at IPR" at DAE-BRNS National Conference on Development of RF Components for Accelerators (DRCA2024), Anushakti Nagar, Mumbai, 20-22 June 2024

DR. MUKESH RANJAN

Gave an invited talk on "Plasma for Material Processing and Industrial Applications" at 10th Plasma Science Society of India-Plasma Scholar's Colloquium (PSSI-PSC2024), Indian Institute of Technology, Delhi, 4-6 July 2024

Gave an invited talk on "Semiconductor Processing Using Plasma and Ion Beams" at International Conference on Semiconductor Technologies - Materials to Chips (ICST-2024), Amity Institute for Advanced Research and Studies (Materials & Devices), Noida, 18-20 September 2024

Gave an invited talk on "Sequential growth over patterns a way to minimise optical anisotropy"

at 3rd International Conference on Functional Materials and Applied Physics (FMAP-2024), SVNIT Surat, 18-19 October 2024

Gave an invited talk on "Ion beam-induced nanoripples patterns for SERS based saliva analysis to detect oral cavity cancer" in a Indo-French meeting focused on "Perspective and challenges of clinical Vibrational spectroscopy in point of care use" organized by ACTREC, Mumbai, 28-30 October 2024

Gave an invited talk titled on "Sequential growth of metal nanoparticles on low energy ion produced ripple patterns for the isotropic plasmonic response and wettability studies" in the National Conference on Frontiers of Ion Beam Science (FIBS-2024), Institute of Physics (IoP), Bhubaneswar, 4-7 November 2024

Gave an invited talk on "Growth dynamics of metal nanoparticles arrays and their optical properties" at International Union of Materials Research Societies-International Conference in Asia (IUMRS-ICA-2024), Indore, 3-6 December 2024

Gave an invited talk on "Ar plasma nanostructuring on PTFE surfaces for the wettability transition and sensing applications" at 1st International Workshop on Cold Plasma and Pulse Power Technologies for Food, Health, and Agriculture (COFHA-2024), IIT Jodhpur, 21-22 December 2024

Gave an invited talk on "Detection of Hazardous Molecules with Dense nanoparticles arrays" at Workshop on Photonics for Energy, Sensing, & Education, IIT Gandhinagar, 16-17 January 2025

Gave an invited talk on "Ar plasma Nanostructuring on PTFE surfaces for the self-cleaning and sensing application in Food, Agriculture and Medical Science" at the International workshop on Cold Plasma Technology and Applications (CPTA-2025), BIT Mesra campus, Jaipur, 06-08 February 2025

Gave an invited talk on "Reducing Carbon foot prints utilising plasma processing" at National Workshop on Shaping the Future with Nanotechnology: Energy Storage and CO_2 Utilization" at St. Xavier's College, Ahmedabad, 29-30 March 2025

DR. SURYAKANT GUPTA

Gave an invited talk on "Viksit bharat 2047 hetu plazma anusandhan sansthan ka sambhawit yogdan" at Institute for Plasma Research, 8-9 August 2024

Gave an invited talk on "Indigenously developed Pulsed power sources for Nonequilibrium Plasma Applications" at DAE-BRNS 1st National Conference on "Pulsed Power Science, Technology & Applications" (PPSTA-2024), BARCF Facility, Atchutapuram, Visakhapatnam, 12-14 September 2024 [Co-authors: Keena Kalaria, Naresh Vaghela, Ghanshyam Jhala, Akshay Vaid, Alphonsa Joseph, Purvi Dave, S. K. Nema and Subroto Mukherjee]

Gave an invited talk on "Emerging role of Plasma Technology in Multidisciplinary Research" at Samvaad 2024: Annual Symposium, Silver Oak University, Ahmedabad, 5th December 2024

Gave an invited talk on "ESD and its detrimental effects on spacecraft charging and arc mitigation techniques" at 7th Latin American Workshop on Plasma Physics, Santiago, Chile, 20-23rd January 2025 [Co-authors: Keena Kalaria, Naresh Vaghela et al.]

DR. S. SUNIL

Gave an invited talk on "Role of vacuum in Gravitational wave detection" at 2nd National Seminar on Discovery and Detection of Gravitational Waves, Jaipur National University, Jaipur, 14th September 2025

Gave an invited talk on "LIGO-India: Vacuum Equipment Layout" at the Meeting with LIGO-India nodal institutes and LIGO-US personnel visiting IUCAA, IUCAA, Pune, 6th March 2025

DR. SHANTANU KARKARI

Gave an invited talk on "Coaxial Plasma Accelerator: Applications in Fusion Technology" at DAE-BRNS 1st National Conference on Pulsed Power Science, Technology and Applications (PPSTA-2024), Bhabha Atomic Research Centre Facilities, Visakhapatnam, 12-14 September 2024

MR. HIMANSHU TYAGI

Gave plenary talks on "Assessment of signal reconstruction techniques for critical signals in high power negative ion based plasma sources" and on "Plasma Density estimation using Machine Learning for High power Ion Source" at 9th International Symposium on Negative Ions, Beams and Sources (NIBS2024), ITER-India, Institute for Plasma Research, Gandhinagar, 19-22 November 2024

MR. UPENDRA PRASAD

Gave an invited talk on "High temperature superconducting magnets for magnetic fusion: R&D update and plan" at 29th National Conference on Cryogenics and Superconductivity (NCCS-29), Inter-University Accelerator Centre, New Delhi, 26 -29 November 2024

MR. NITIN SHAH

Gave an invited talk on "India's Contribution to the ITER Cryogenic System and Present Status" at 29th National Conference on Cryogenics and Superconductivity (NCCS-29), Inter-University Accelerator Centre, New Delhi, 26-29 November 2024

Invited talks given at 39th National Symposium on Plasma Science and Technology (PLASMA 2024), Pandit Deendayal Energy University (PDEU), Gandhinagar, 17-20 December 2024

DR. SHANTANU KARKARI, gave a talk on "Revisiting the Basics in Fusion Research through Linear Plasma Devices"

DR. SHISHIR DESHPANDE, gave a talk on "A Staged Approach to Indian DEMO: The Role of an Integrated Test Facility and QE ≤ 1 Pilot Plant"

DR. JOYDEEP GHOSH, gave a talk on "Tokamak Operation with Low-Edge Safety Factor (Qedge < 2) Value: Can It Be Scaled to a Fusion Reactor?"

MR. ARUN CHAKRABORTY, gave a talk on "India in ITER – Technical and Management Perspectives from a Collaboration of 18+ Years"

DR. SUBROTO MUKHERJEE, gave a talk on "Laser Interferometer Gravitational Wave Observatory (LIGO) - Developments in India"

DR. RAKESH TANNA, gave a talk on "Confinement improvement, disruption and runaway electron mitigations experiments in ADITYA/ADITYA-U tokomaks"

DR. T. K. BORTHAKUR, gave a talk on "ELM relevant Heat Loading Studies using Pulsed Plasma Accelerator at CPP-IPR"

DR. S. K. NEMA, gave a talk on "Development of Plasma Technologies for Industries and Society"

DR. DEVENDRA SHARMA, gave a talk on "Magnetized Plasma Modes with Ion Participation in Space, Laboratory and Computer Simulations"

MR. SAROJ DAS

Gave an invited talk on "Balancing the Shrink and Surge: Challenges for Libraries" at the National Conference on Reimagining Libraries (ReIL-2025): Balancing Tradition and Innovation in a Digital Era, organized by the Tata Memorial Hospital in collaboration with Bombay Science Librarians' Association (BOSLA) on 10 January 2025

DR. RAJIV SHARMA

Gave an invited talk on the topic "Glass Fiber Composites Material for Vacuum, Cryogenic, Space, and Fusion Applications" at the 5th International Conference on Recent Advances in Mechanical Infrastructure (ICRAM 2025), IITRAM, Ahmedabad, 10-12 January 2025

DR. P. A. RAYJADA

Gave an invited talk on "Electron Spectroscopy and Electronic Structure of Materials" at National Symposium on Advanced Material Processing and Characterization (NSAMPC-2025), Sardar Patel University, Vallabh Vidyanagar, 4th March 2025

D5. TALKS DELIVERED BY VISITORS AT IPR

DR. ROHIT KUMAR SRIVASTAV, Jaypee Institute of Information Technology (JIIT), Noida, gave a talk on "Excitation of terahertz surface plasmons by lasers and electron beam" on 12th April 2024

DR. DEBKUMAR CHAKRABORTY, University of Calcutta, Kolkata, gave a talk on "Analytical and computational studies of some nonlinear wave processes in plasmas" on 19th April 2024

DR. JAYANTA DUTTA, Harish-Chandra Research Institute, Prayagraj, gave a talk on "Formation and Evolution of the very First Stars (Primordial Stars) in the Universe" on 26th April 2024

DR. MANOJ KUMAR, National Institute of Technology, Rourkela, gave a talk on "Design and Development of Cryogenic Turboexpander, Indigenous Helium Liquefier and its Major Components" on 3rd May 2024

DR. AKHIL KHAJURIA, Dr. B.R. Ambedkar National Institute of Technology, Jalandhar, gave a talk on "Effect of boron modification on microstructure in HAZ of P91 steel for better resistance to type IV cracking" on 10th May 2024

DR. BARTI MALVI, Indian Institute of Technology, Gandhinagar, gave a talk on "Use of stable isotopes for failure detection and tracing of biomaterials" on 13th May 2024

DR. DEBASHRITA MAHANA, Academy of Scientific and

Innovative Research (AcSIR), CSIR-HRDC Campus, Ghaziabad, gave a talk on "Development and characterization of CuO thin films and ZnO/CuO heterostructure by PVD process for CO gas sensing application" on 07th June 2024

DR. D. K. ASWAL, Group Director of Health, Safety, and Environment at BARC, Mumbai, gave a talk on "Radiation, Nuclear Energy, and Environment" on 13th June 2024

DR. KAMALAKKANNAN, University of Madras, Chennai, gave a talk on "Defects Studies in Low Energy Ion-Implanted Silicon Carbide" on 14th June 2024

DR. AMBA SANKAR K N, PSG College of Arts and Science, Coimbatore, gave a talk on "Carbon-based Nanomaterials for Applications in Energy Generation & Storage" on 21st June 2024

MR. ANAND PRAKASH, Raman Research Institute, Bangalore, gave a talk on "End-Cap Type Paul Trap for Precision Spectroscopy and Ion-crystal Experiments" on 28th June 2024

DR. DEPANSHU VARSHNEY, Aligarh Muslim University, Aligarh, gave a talk on "Effect of nanomaterials on the dielectric and electro-optical properties of liquid crystals and their applications" on 02nd July 2024

DR. VINEET KUMAR SHUKLA, University of Allahabad, Prayagraj, Uttar Pradesh, gave a talk on "Relative abundance of elements in geological material using Spectroscopic Techniques" on 05th July 2024

DR. SATISH KUMAR, Indian Institute of Technology, Kanpur, gave a talk on "High strength and ductile mixed phase steels from Modified 9Cr1Mo steel with enhanced wear and corrosion resistance" on 12th July 2024

PROF. SANAT KUMAR TIWARI, Indian Institute of Technology, Jammu, gave a talk on "Turbulent vortex flow in dusty plasma" on 16th July 2024

SHRI. P R DANI, Member-Secretary, DAE Intellectual Property Rights Cell, gave a talk on "Overview on Intellectual Property & HBNI IP Policy" on 18 July 2024

PROF. ARCHANA LAKHANI, UGC-DAE Consortium for Scientific Research (UGC-DAE-CSR), Indore, gave a talk on "Introduction to Quantum Materials at the Interface of Physics and Technology: A Magneto-transport study" on 19th July 2024

DR. SANTANU BANERJEE, Princeton Plasma Physics Laboratory, USA, gave a talk on "The role of edge neutrals in exciting tearing mode activity and achieving flat temperature profiles in LTX-β" on 30th July 2024

DR. NIMITHA K VIJAY, Mahatma Gandhi University, Kottayam, Kerala, gave a talk on "On the Growth and Structure of Nano-structured Zinc Oxide Thin Films in Sol-gel Spin Coating" on 14th August 2024

PROF. NIGAM DAVE, Pandit Deendayal Energy University, Gandhinagar, gave a talk on the theme "Anti-Ragging" on 16th August 2024

DR. ANKIT MATHUR, Bharathiar University, Coimbatore, gave a talk on "Dynamic Cellular Plasticity in Cancer: EMT Transitions and Stem Cell Differentiation Strategies" on 23rd August 2024

DR. MITESH SOLANKI, PDEU, Gandhinagar, gave a talk on "Experimental and Theoretical Characterization of Plasma Facing XCrCu (X=Zr, Nb, Mo, and Tc) for Corrosion-Resistant Material" on 30th August 2024

DR. AMIT KUMAR, Modern Institute of Technology and Research Centre, Alwar, Rajasthan, gave a talk on "Study of Electrostatic and Electromagnetic Waves Instabilities in Plasma and Complex Plasma" on 06th September 2024

DR. SANJU RANI, National Physical Laboratory, New Delhi, gave a talk on "Gas Sensing Performance Based on Tin Selenides" on 20th September 2024

DR. ANKITA SAXENA, Aligarh Muslim University, Uttar Pradesh, gave a talk on "Spectral investigation of multiply ionized silver atoms: Ag III-IV" on 20th September 2024

DR. NAVIN SHARMA, Devi Ahilya University, Indore, gave a talk on "Investigation of Dielectric barrier discharge based Cold Plasma Sources for the generation of Reactive oxygen and Nitrogen Species and Vacuum Ultraviolet VUV)/Ultraviolet (UV) Radiation" on 27th September 2024

PROF. SANTANU BHATTACHARYYA, National Institute of Technology, Rourkela, gave a talk on "Ceramic Technology: Art, Science, Technology, or Innovation?" on 30th September 2024

DR. R K SHARMA, Bhabha Atomic Research Centre (BARC), Mumbai, gave a talk on "High Voltage Energy Storage Capacitors" on 16th October 2024

DR. MUKESH JEWARIYA, Council of Scientific and Industrial Research (CSIR), New Delhi, gave a talk on "Terahertz Computed Tomography and its Prospectus" on 17th October 2024

DR. THIYAGARAJAN MAADHU, Vellore Institute of Technology, Tamil Nadu, gave a talk on "Synthesis, growth and physic- chemical investigations on Morpholinium based crystals for non-linear application" on 18th October 2024

MR. VIVEK JOSHI, Rashtriya Raksha University, Gandhinagar, gave a talk on "Cyber Security Awareness" on 18th October 2024

DR. SHASHANK SINGH, Panjab University, Chandigarh, gave a talk on "Fragmentation, multiple ionization and dehydrogenation of PAHs molecules by the impact of swift protons" on 25th October 2024

DR. SHYAMAPADA PATRA, Indian Institute of Technology, Bhubaneswar, gave a talk on "Ion Beam Induced Modification of Wetting and Optoelectronic Properties of Functional Nanomaterials" on 25th October 2024

DR. SHARVIL PATEL, Pandit Deendayal Energy University (PDEU), Gandhinagar, gave a talk on "Study of Sawtooth Crash Induced Heat Pulse Propagation and Fast Doppler Spectroscopy Diagnostic for ADITYA-U Tokamak" on 07th November 2024

DR. VIBHUTI R VASHI, M S University Baroda, Vadodara, gave a talk on "Study of Reaction Cross-Sections for Advanced Reactors and Astrophysical Applications" on 08th November 2024

DR. KOUSIK MAKUR, Indian Institute of Technology, Hyderabad, gave a talk on "Fast electron transport in the laser-plasma interaction: Studies of the ion acceleration and X-rays" on 29th November 2024

DR. YOGITA DAHIYA, Malaviya National Institute of Technology, Jaipur, gave a talk on "MOF-derived Transition Metal Compounds as Anode Materials for All-Solid-State Lithium-Ion Batteries" on 29th November 2024

DR. AADIL RASHID, Aligarh Muslim University, Uttar Pradesh, gave a talk on "Atomic Structure studies of ionized mercury atoms: Hg III - Hg VI" on 05th December 2024

DR. NEELAM KUMARI ARYA, Aligarh Muslim University, Uttar Pradesh, gave a talk on "Spectral Studies of Moderately Ionized Bismuth Atoms: Bi (III-VI)" on 06th December 2024

DR. ROHIT JAIN, High Temperature Superconductors Inc., California, gave a talk on "Metalorganic Chemical Vapor Deposition of REBCO on various substrates and correlation of its superconducting properties for high frequency and functional applications" on 09th December 2024

PROF. ARCHANA BHATTACHARYYA, Former Director, Indian Institute of Geomagnetism, Mumbai, gave a talk on "Evolution of equatorial plasma bubbles as seen through ionospheric scintillation observations" on 10th December 2024

DR. MANOJ KUMAR, CSIR-National Physical Laboratory, New Delhi, gave a talk on "Exploring Tin-Selenide for Optoelectronic and Thermoelectric Applications" on 13th December 2024

DR. SIBA PRASAD ACHARYA, Saha Institute of Nuclear Physics, Kolkata, gave a talk on "Nonlinear waves and chaos in different plasma systems" on 03rd January 2025

DR. MAHESH CHOUDHARY, Banaras Hindu University, Varanasi, gave a talk on "Study of uncertainty quantification and parameter estimation through nuclear reactions" on 10th January 2025

DR. HARISH CHARAN, Durham University, United Kingdom, gave a talk on "What causes a transition from Static to Dynamic Friction?" on 13th January 2025

MR. PATRYK NOWAK VEL NOWAKOWSKI, Department of Microelectronics and Computer Science (DMCS), Lodz University of Technology, Poland, gave a talk on "First testing results of the prototype ITER HXR-Monitor on Aditya-Upgrade tokamak" on 16th January 2025

DR. THANGJAM RISHIKANTA SINGH, Pondicherry University, Puducherry, gave a talk on "Interplay between Electron and Ion Plasma Waves" on 17th January 2025

DR. K M RAKHI, Indian Institute of Technology Ropar, Punjab, gave a talk on "Dynamical Evolution of Self-organized Nanostructures Produced by Unconventional Ion Beam Irradiation Techniques" on 27th January 2025

DR. IPSITA CHINYA, CSIR-Central Glass and Ceramic Research Institute (CSIR–CGCRI), Kolkata, gave a talk on "Development of Polymer Nanocomposites as Self-powered Sensors, Optoelectronics, and Flexible Energy Harvester and Storage" on 21st February 2025

DR. AMIT K BHOJANI, Institute of Infrastructure Technology Research and Management (IITRAM), Ahmedabad, gave a talk on "Advancing Energy Materials through Computational and Experimental Synergy" on 28th February 2025

DR. IPSITA DAS, Indian Institute of Technology, Kharagpur, gave a talk on "Design aspects of High-Temperature Superconducting power cable" on 07th March 2025

DR. JOHN PAUL, National Institute of Technology Tiruchirappalli, Tamil Nadu, gave a talk on "Graphene Oxide Incorporated, Post-Transition Metal Doped Zinc Oxide Thin Films and Nanorods for Efficient Dye Degradation" on 21st March 2025

DR. JYOTI PANDEY, Extreme Light Infrastructure - Nuclear Physics (ELI-NP), Romania, gave a talk on "Nuclear Data for fusion and astrophysical applications" on 28th March 2025

D6. COLLOQUIA PRESENTED AT IPR

PROF. RAGHUNATH CHELAKKOT, Department of Physics, IIT Bombay, gave a talk on "Non-equilibrium phases in active Brownian particles" on 11th June 2024 (Colloquium #336)

DR VISHWA BANDHU PATHAK, School for Advanced Sciences, VIT, Vellore, gave a talk on "All-optical control on acceleration length to optimize laser wakefield acceleration" on 25th June 2024 (Colloquium #337)

PROF. AVINASH KHARE, Indian National Science Academy, New Delhi, gave a talk on "Shell stabilized spherical tokamak" on 03rd October 2024 (Colloquium # 338)

PROF. RAMIT BHATTACHARYYA, Physical Research Laboratory, Ahmedabad, gave a talk on "Data-constrained magnetohydrodynamic simulation of solar coronal transients" on 06th December 2024 (Colloquium #339)

PROF. SADIQ RANGWALA, Raman Research Institute, Bengaluru, gave a talk on "Interactions with trapped ions" on 10th December 2024 (Colloquium #340)

PROF. U. A. YAJNIK, Indian Institute of Technology, Gandhinagar, gave a talk on "Cosmic conundrums and their Particle Physics solutions" on 20th February 2025 (Colloquium #341)

D7. SCIENTIFIC MEETINGS HOSTED BY IPR

Academic Visits to IPR (April-May 2024)

On 5th April 2024, 21 students of BSc/MSc and 3 faculty members of Shri Guru Govind University, Godhara, Gujarat, visited IPR; on 8th-9th April 2024, 67 students of BE (Electrical) and 6 faculty members of L.D. College of Engineering, Ahmedabad, visited IPR; on 23rd April 2024, 17 students of BE (Metallurgy) and 2 faculty members from Government Engineering College, Gandhinagar, visited IPR.

Student participants of ISRO's YUVIKA (YUva VIgyani KAryakram (Young Scientist Programme) program visited IPR on 20th May, 2024. These 50 students, picked from the western states of India, get to spend a few weeks at ISRO centers. At IPR, YUVIKA students were given an introductory lecture on plasma by Dr. A V Ravi Kumar and then they were shown the various exhibits on plasma by the Outreach team. They were also taken to visit both Aditya and SST-1 tokamaks.

Seminar cum Workshop on Plasma Physics and its Applications @ CPP-IPR

CPP-IPR's Outreach Cell conducted a "Seminar cum Workshop on Plasma Physics and its Applications" on 5th April, 2024 at Madhabdev University, Narayanpur, Assam. The programme was attended by around 10 teachers and 90 students of the university, including few students from Kaziranga University, Jorhat, Assam and North Eastern Regional Institute of Science and Technology (NERIST), Itanagar, Arunachal Pradesh. During the technical session I, Dr. Rakesh Moulick gave a talk on introduction to plasma physics, followed by a talk by Dr. S. S. Kausik on negative ion production in dusty plasma. Technical session I concluded with a talk on basics of experimental plasma physic by Dr. Ngangom Aomoa. During technical session II, the participants were shown glow discharge plasma, arc plasma, DBD plasma, Jacob's ladder and a plasma globe. The working principle of these plasmas and their applications were explained to the participants.

Plasma Exhibition @ Udaipur (Rajasthan)

Institute for Plasma Research (IPR), Gandhinagar (Gujarat), in association with Geetanjali Institute of Technical Studies (GITS), Udaipur (Rajasthan), organized an exhibition on Plasma, the fourth state of matter during 15-19 April, 2024. This program is part of IPR's scientific outreach activity in various states of India under the auspices of "70 years of DAE" celebrations. The event was inaugurated by the Director of GITS, Dr. Narendra Singh Rathore.

The programme consisted of an exhibition on plasma, its applications as well as introductory talks on plasma for visiting students and training program for teachers. Sixty one students of 1st year engineering from GITS were trained by IPR staff to explain the various exhibits to visiting public. In the training program on plasma and its applications for science teachers, over 60 teachers from Udaipur participated and were provided with resource materials and tokotoy. A quiz program was also conducted for school students and Tokamak assembly competition was conducted for the volunteers. Over 4000 students from over 50 schools and colleges in Udaipur visited the exhibition. The event was coordinated by Dr Hina Oza and Dr. Vishal Jain of GITS.

MoU between IPR and PDEU

A Memorandum of Understanding (MoU) has been established between the esteemed Institute for Plasma Research (IPR) and Pandit Deendayal Energy University (PDEU), for advancing academic and scientific research for progressive exploration and development of plasma science, technology, and associated disciplines. IPR has a comprehensive R&D roadmap for fostering indigenous expertise in fusion and plasma technologies, with a view to addressing societal needs. Notably, the establishment of an Atal incubation center at IPR further strengthens its support framework for startups and innovators, facilitating the accelerated maturation of plasma technologies for fusion and broader societal applications. Pandit Deendayal Energy University (PDEU), known for its wide-ranging academic offerings in engineering, arts, and management, boasts a strong research and development setup. PDEU's emphasis on cutting-edge areas like Energy, Environment, Additive Manufacturing, and 3-D printing highlights its commitment to innovation and sharing knowledge. The collaboration between IPR and PDEU will deliver substantial mutual benefits, fostering synergies in research endeavors, academic pursuits, and the expeditious implementation of plasma technologies and development of skilled human resource for achieving these objectives. This collaboration holds great potential for transformative progress in academic, technological, and societal spheres.

National Technology Day 2024

Institute for Plasma Research (IPR), Gandhinagar (Gujarat), in association with Gujarat Science City, Ahmedabad and GUJCOST celebrated the National Technology Day by organizing a series of events at the Gujarat Science City, Ahmedabad on 11th May, 2024 with the theme "Technology for Viksit Bharat". This program is a part of IPR's scientific outreach activity under the auspices of "70 years of DAE" celebrations. The event was inaugurated by Dr. Narottam Sahoo, Advisor and Member Secretary, GUJCOST.

The programme consisted of an exhibition on plasma, its applications as well as introductory talks on plasma for visiting students and training program on plasma, its applications and nuclear fusion for science teachers, students and public. UG students of MG Science College Ahmedabad participated as student volunteers for the exhibition. Over 1500 people visiting the science city also visited the exhibition.

Orientation to Summer School Program (SSP-2024) Students

The summer school program for the year 2024 (IPR SSP - 2024) has started from 27th May, 2024 at the institute with the welcome and registration ceremony conducted at the seminar hall. The summer school students joined in the program have came from all across the country from various Universities, national institute etc. A total number of 25 students have joined in this program out of which 19 students are from Physics, 2 students are from electrical, 2 students from Electronics & Instrumentation and 1 student each from Mechanical and Computer disciplines. The students were given orientation about overall IPR activities, IPR Library and IPR Outreach programs. The program students were also addressed by the Director, IPR on overall activities and goals of the institute and followed by the talks from Dean Academic & Students Affairs, Dean Administration and Dean R & D. The students have attended popular lectures given by experts in the respective R & D fields in the institute along with lab visits including SST - 1, ADITYA-U, BETA, ITER India and FCIPT. The students also visited Vikram Sarabhai Space Exhibition (VSSE) Center in Ahmedabad to know more about the space research activities at ISRO. The students are currently engaged in various R&D labs and theory and simulation groups for project work on their respective fields.

The program concluded with oral presentations on 3rd July 2024 followed by poster presentations by students on 4th July 2024. The poster session was open for IPR staff members. The concluding ceremony was held on 5th July 2024 with prize distribution to the winners of the poster presentation, and certificates and mementoes to the participating students.

World Environment Day - 2024

World Environment Day (WED) 2024 was celebrated at IPR on 5th June 2024. Special invited guests, Shri R.D. Kamboj and Shri Indersinh K. Barad, both retired IFS attended the WED. A special talk on "Biodiversity - Causes and Consequences of its Loss" by Shri R.D. Kamboj, retired IFS, was organized at IPR. Distribution of Saplings and Plantation were also arranged by the IPR Staff Club.

MoU between IPR and Nirma University

Memorandum of Understanding (MoU) has been signed between the IPR and Nirma University (NU) on 7th June 2024 to foster scientific research collaboration and academic partnership. This collaboration aims to address mutual interests and develop skilled human capital in plasma science, technology, and allied fields. IPR has a comprehensive R&D roadmap focused on development of indigenous expertise in fusion and plasma technologies to meet societal needs. IPR also has established a separate section-8 company (AIC-Plasmatech Innovation Foundation, AIC recognized by Atal Innovation Mission, NITI Aayog) for providing mentoring and infrastructure support for startups and innovators, promoting the rapid development of plasma technologies for fusion and broader applications. NU is renowned for its diverse academic programs in engineering, science, arts, and management, and its robust research and development infrastructure. NU has been actively engaged in research areas such as biotechnology, pharmaceuticals, life sciences, the space sector, engineering, technology, and design. Previously, NU has collaborated with IPR on various scientific projects funded by government agencies such as BRFST/BRNS and DST. The objective of this collaboration is to leverage the strengths of both organizations for the accelerated development of plasma technologies for societal applications and to cultivate a skilled workforce to achieve these goals. This partnership holds significant potential for transformative advancements in academic, technological, and societal spheres.

International Day of Yoga (IDY) - 2024

International Day of Yoga (IDY-2024) was celebrated at IPR on 21st June 2024. A large number of employees energetically participated by performing Yoga and pranayama. Mr. Amrutsinh Mali, Yoga trainer from Gujarat State Yog Board and his team conducted a guided session. The session included practicing of various types of Asanas by the participants.

Academic Visits to IPR (June - July 2024)

On 5th June 2024, 52 students of B.Sc. / M. Sc. Physics / Applied Physics of St. Xavier's College, Ahmedabad, visited IPR; on 12th June 2024, 57 students of B.E. Computer Engineering and 2 faculty members of L.D.R.P Institute of Technology and Research, Gandhinagar, visited IPR; on 19th June 2024, 56 students of B.E. /M.E. and 4 faculty members of University College of Engineering, Banswara, Rajasthan, visited IPR; on 21st June 2024, 65 student of 11th & 12th Standard and 3 faculty members of Shivashish World School, Ahmedabad, visited IPR.

On 02nd July 2024, 25 faculty members of Nirma University, Ahmedabad, visited IPR; on 18th July 2024, 50 students of B.E. and 2 faculty members of Vidush Somany Institute of Technology and Research (VSITR), Kadi, Gujarat, visited IPR; on 23rd July 2024, 35 Students of B.E.(EC) and 3 faculty members of LDRP-Institute of Technology and Research, Gandhinagar and 27 students of B.E.(IT) and 2 faculty members of Sardar Vallabhbhai Global University - UCP Institute of Technology, Ahmedabad visited IPR; on 24th July 2024, 75 students of B.E. (CS) and 2 faculty members; on 25th July 2024, 75 students of B.E. (IT) and 2 faculty members and on 26th July 2024, 77 students of B.E. and 2 faculty members of Shree Swaminarayan Institute of Technology, Bhat, Gandhinagar, visited

IPR.

Academic Visit of Cotton University students at CPP-IPR (June 2024)

Four students from Cotton University visited CPP-IPR from 25th to 27th June, 2024 and participated in various activities. Dr. Rakesh Moulick, delivered a talk on Basic Plasma Physics and Dr. Ngangom Aomoa on Experimental Plasma Physics. In the newly established outreach exhibition hall of CPP-IPR, the students were shown glow discharge plasma, arc plasma, DBD plasma, Jacob's ladder and a plasma globe. The working principle of these plasmas and their applications were also explained to them. They also conducted experiments on plotting of Paschen curve and I-V characteristics of gas discharge using the glow discharge set up. Finally, they visited various laboratories and interacted with research scholars and scientist of CPP-IPR

Plasma Exhibition @ Smt. P.D. Shroff Sanskardeep Vidhyalaya, Ankleshwar

Institute for Plasma Research (IPR), Gandhinagar (Gujarat), in association with Smt. P. D. Shroff Sanskardeep Vidhyalaya, Ankleshwar (Gujarat) organized an exhibition on Plasma, "The Fourth State of Matter" during 09-11 July, 2024. This program is part of IPR's scientific outreach activity in various states of India under the auspices of "70 Years of DAE" celebrations. The event was inaugurated by the District Collector, Mr. Tushar Sumera. The programme consisted of an exhibition on plasma, its applications as well as introductory talks on plasma for visiting students and training program on plasma, its applications and nuclear fusion for science teachers. Thirty two students of 9th and 10th standard from the host school were trained by IPR staff to explain the various exhibits to visiting public. Over 1700 students and teachers from over 17 schools and colleges in Ankleshwar and Bharuch visited the exhibition.

Talk on "Overview on Intellectual Property & HBNI IP Policy"

A Talk on "Overview on Intellectual Property & HBNI IP Policy" by Shri Dani Rajiah, Member-Secretary, DAE IPR Cell, was organized on 18 July 2024. The speaker gave an overview on IP and highlighted the importance of protecting inventions through Patenting. He also discussed the HBNI IP Policy. More than 60 participants attended the interactive session.

Academic Visits to IPR (August - September 2024)

On 1st August 2024, 92 students of std. 9 & 10 and 5 teachers of Divya Jyot School, Shela, Ahmedabad, visited IPR; on 5th August 2024, 39 students of B.E. (Chemical) and 2 faculty members and on 7th August 2024, 38 students of B.E. (Electrical) and 2 faculty members of Silver Oak University, Ahmedabad, visited IPR; on 12th August 2024, 8 students of std. 11 & 12 and 2 teachers from the Millennium School, Surat, visited IPR.

On 21st August 2024, 73 Students and 02 Teachers of Delhi Public School (DPS), Bopal, Ahmedabad, visited IPR; on 22nd August 2024, 25 Students of B. Sc. and 02 Faculty of National Forensic Science University, Gandhinagar, visited IPR; on 06th September 2024, 12 Students of B. Tech and 02 Faculty of Gandhinagar Engineering College (GEC), Gandhinagar, visited IPR; on 12th September 2024, 45 Students of B. Tech (Electrical) and 02 Faculty of Charotar University of Science and Technology, Changa, visited IPR; on 18th September 2024, 47 Students of B. Tech (Mech) and 02 Faculty of Charotar University of Science and Technology, Changa, visited IPR.

Plasma Exhibition @ Parvathaneni Brahmayya Siddhartha College of Arts & Science, Vijayawada, Andhra Pradesh

IPR Gandhinagar, in association with Parvathaneni Brahmayya Siddhartha College of Arts & Science, Vijayawada (Andhra Pradesh) organized an exhibition on "Plasma: The Fourth State of Matter" during 05-09 August, 2024. This program was part of IPR's scientific outreach activity in various states of India under the auspices of "70 Years of DAE" celebrations. The programme consisted of an exhibition on plasma, its applications as well as introductory talks on plasma for visiting students and training program on plasma, its applications and nuclear fusion. Seventy two students from the host college were trained by IPR staff to explain the various exhibits to visiting public. Over 5000 students and teachers from over 72 schools and colleges in and around Vijayawada visited the exhibition.

AIC - IPR Plasmatech Innovation Foundation Awareness Program in North East

An awareness programmne on "Plasma Technologies for Entrepreneurship" was organized by AIC – IPR Plasmatech Innovation Foundation, in collaboration with North East Centre for Technology Application and Reach (NECTAR) at the National Institute of Technology (NIT) Meghalaya at Shillong and the Cotton University at Guwahati on 6th and 8th August, 2024 respectively. At NIT Meghalaya, Prof. Pinakeshwar Mahanta, Director, NIT Meghalaya gave the welcome address and at Cotton University, Prof. Ramesh Chandra Deka, Vice Chancellor of Cotton University gave the welcome address.

During these programmes, Dr. Arun Kr. Sarma, Director General, NECTAR gave an introduction about the program in which he highlighted various potential applications of plasma in North East India. Dr. Nirav Jamnapara, explained about the Atal Incubation Centre at IPR and various plasma based technologies which can be used by startups. Mr. Saroj Das, talked about Information Management and the activities of the IPR TTIP committee. Shri. Dani P. Rajiah, Member Secretary, DAE IPR Cell, talked about Intellectual Property Rights and patents. Dr. Nirav Jamnapara talked about various plasma based technologies which can be used by startups while Dr. Ngangom Aomoa, CPP-IPR gave an overview of the application based research activities being carried out at CPP-IPR.

The programme at NIT Meghalaya was attended by around 70 participants, including students and faculties from various colleges of Shillong, NIT Meghalaya and North Eastern Hill University. At Cotton University around 60 participants, including students and faculties from various colleges and Universities in and around Guwahati attended the programme.

An awareness programme on startups and patenting was held at CPP-IPR on 7th August 2024. During the programme, Shri. P. R. Dani, Member Secretary, DAE IPR Cell, gave a talk on Patents and also discussed about the DAE's experience with patenting. Dr. Nirav Jamnapara discussed about the Atal Incubation Centre at IPR while Mr. Saroj Das discussed about the patenting and publication processes at IPR. The programme was attended by about 40 participants, including Research Scholars, PDFs and Scientist from CPP-IPR.

Plasma Exhibition @ Bhavan's Vivekananda College, Secunderabad, Telangana

IPR Gandhinagar, in association with Bhavan's Vivekananda College, Secunderabad (Telangana) organized an exhibition on "Plasma: The Fourth State of Matter" during 12-14 August, 2024. This program was part of IPR's scientific outreach activity in various states of India under the auspices of "70 Years of DAE" celebrations. The programme consisted of an exhibition on plasma, its applications as well as introductory talks on plasma for visiting students and training program on plasma, its applications and nuclear fusion. 76 students from the host college were trained by IPR staff to explain the various exhibits to visiting public. Over 1750 students and teachers from over 19 schools and colleges in and around Secunderabad visited the exhibition.

Anti-Ragging Observation Week

To bring the awareness on prevention of ragging among the students, faculty and staff, IPR had observed Anti Ragging Day/week during 12-18 August 2024. The Dean Academics, Dean Admin, Dean R & D along with the Anti-Ragging Committee and Hostel Committee of IPR had administered the oath against ragging practice on the Anti-ragging day. During the week different competitions were conducted, such as Slogan writing, Logo and Poster making. The Anti-Ragging Day/Week was concluded with an awareness talk by Prof. Dave followed by prize distributions for the winners and runners of the competitions.

Plasma Exhibition @ Muktajivan English School, Maninagar, Ahmedabad

IPR Gandhinagar, in association with Muktajivan English School, Maninagar, Ahmedabad organized an exhibition on "Plasma: The Fourth State of Matter" during 21-23 August, 2024. This program was part of IPR's scientific outreach activity in rural areas across Gujarat under the auspices of "70 Years of DAE" celebrations. The event was inaugurated by the Director, Muktajivan group of Education. The programme consisted of an exhibition on plasma, its applications as well as introductory talks on plasma for visiting students and training program on plasma, its applications and nuclear fusion. 32 Students of 11th and 12th Standard from the host school were trained by IPR staff to explain the various exhibits to visiting public. Over 1200 students and teachers from nearby schools visited the exhibition.

Popular Talk on Plasma at Gujarat Vidyapeeth

A popular talk in Hindi, on the Introduction to Plasma, was delivered by Mr. Manu Bajpai of Outreach Division, IPR at Gujarat Vidyapeeth on National Space Day, 23rd August 2024 to commemorate the first anniversary of the landing of Vikram Lander on the lunar surface. The talk included the abundance of plasma in the universe, its domestic and industrial applications and future prospects especially the fusion power. The dignitaries present on the occasion, were Prof Nikhil S. Bhatt (Registrar), Prof Niraj T. Sheth (Dean), Prof Kaushik R. Patel, Prof D. Sriniwas Murthy, and other faculty members. The audience also included, research scholars and the students from bachelors and masters courses of science, mostly microbiology and biogas research.

Workshop on Plasma Physics and its Applications by CPP-IPR Outreach

CPP-IPR's Outreach Cell conducted "Workshop on Plasma Physics and its Applications" at two colleges of Jorhat, Assam on 3rd September 2024. In the morning session, the workshop was conducted at Devicharan Barua Girls' College, which was attended by 8 faculties and 40 students of the college and 12 students from Nanda Nath Saikia College, Titabar, Assam. In the afternoon session, the workshop was conducted at Jagannath Barooah University (formerly JB College) which was attended by 10 faculties and 100 students of the college. During the workshops, Dr. B J Saikia addressed the audience about a brief history of CPP-IPR and the activities of CPP Outreach cell. Dr. Rakesh Moulick gave a talk on introduction to plasma physics, followed by a talk on basics of experimental plasma physics by Dr. Ngangom Aomoa. The participants were shown glow discharge plasma, arc plasma, DBD plasma, Jacob's ladder and a plasma globe. The working principle of these plasmas and their applications were explained to the participants.

Induction Programme for newly joined staff members

The Outreach Division - IPR has an Induction Programme for the newly joined staff members on 13th September 2024. The induction programme was aimed to bring awareness about the activities going on in the Institute and also about the roles and responsibilities that we will have to adhere as a staff of the Institute.

Swachhata Pakhwada 2024

IPR celebrated 'Swachhata Hi Seva' campaign from 17th September to 1st October 2024. As per the guidelines of DAE, the

Institute organized various programs in all the campuses- IPR, FCIPT, ITER-India and CPP-IPR which included Pledge taking, walkathon, Health awareness lecture for sanitation workers, tree plantation, awareness talks etc.

IPR AIC-Plasmatech Foundation AGM and Incubation Agreements

IPR has established a Section-8 company, AIC-IPR Plasmatech Innovation Foundation (AIC-Plasmatech). The first Annual General Meeting (AGM) of the Board was held on 25th September 2024. Following the AGM, incubation agreements were signed with two start-ups: Exxcarbon Private Limited and Ecoplaswa Technology Private Limited. Exxcarbon focuses on waste-to-energy applications and is incubated for the commercialization of IPR's RAUDRA Plasma Pyrolysis technology. Ecoplaswa aims to develop products based on IPR's patented Plasma Activated Water technology for disinfecting and cleaning of containers used in the dairy industry, as well as for agricultural applications such as bio-nutrition and bio-fertilizers for crops. In addition to these, AIC-Plasmatech had earlier signed an incubation agreement with LBIS Research Private Limited for developing glass-like coatings on biodegradable fibres using plasma processing. By doing so, the aim is to have sustainable food packaging solution which will solve the problem of contamination of food due to leaching out of the coating material from packaging containers. A total of three start-ups are now incubated at IPR's incubation centre, all focused on commercializing plasma-based technologies for various applications. Incubation applications from 6 other Start-ups are presently at an advanced stage of processing.

Plasma Exhibition @ Sir Pratap School, Idar, Gujarat

IPR Gandhinagar, in association with Sir Pratap School, Idar, Gujarat organized an exhibition on Plasma, "The Fourth State of Matter" during 25-27 September 2024. This program is part of IPR's scientific outreach activity in various states of India under the auspices of "70 years of DAE" celebrations. The programme consisted of an exhibition on plasma, its applications as well as introductory talks on plasma for visiting students. Fifty students from the host school were trained by IPR staff to explain the various exhibits to visiting public. Over 2000 students and teachers from over 22 schools in and around Idar visited the exhibition.

Hindi Pakhawada – 2024 @ CPP-IPR

CPP-IPR observed Hindi Pakhawada - 2024 between September 26 and October 1, 2024. Several competitions among staff members were held, including Hindi Poem Recitation, Self-composed Hindi Poem Writing, Storytelling Telling in Hindi, and Dictation. Mr. Devendra Modi, Scientific Officer-F, IPR delivered an invited talk on 26th September, 2024 on general safety guidelines. Dr. Sharmila Taye, Assistant Director (Language), Department of Official Language, Maligaon, Guwahati delivered an invited talk on the importance of Hindi as an official language during the closing ceremony on October 1, 2024.

Academic Visits to CPP-IPR (September - October 2024)

On 27th September 2024, 06 Students of MSc, from Department of Physics, Guwahati University, visited CPP-IPR; on 29th October 2024, 39 students of MSc & BSc and 4 faculty of Department of Mathematics, Royal Global University, Guwahati, Assam, visited CPP-IPR

Workshop on Basic Plasma Physics at CPP-IPR

A Workshop on Basic Plasma Physics was organized at CPP-IPR on 27th September 2024. 38 Students and 3 Faculty members from five Institutions of the Don Bosco University, Assam participated in the workshop. During the workshop, the students visited the CPP-IPR Outreach Exhibition Hall and the Basic Plasma Physics Lab

Plasma Exhibition @ Noble University, Junagadh, Gujarat

IPR Gandhinagar, in association with Noble University, Junagadh, Gujarat organized an exhibition on Plasma, "The Fourth State of Matter" during 8-10 October 2024. This program is part of IPR's scientific outreach activity in various states of India under the auspices of "70 years of DAE" celebrations. The programme consisted of an exhibition on plasma, its applications as well as introductory talks on plasma for visiting students. Fifty students from the host school were trained by IPR staff to explain the various exhibits to visiting public. Over 4300 students and 151 teachers from over 31 schools in and around Junagadh visited the exhibition.

Basic Training for Students in Plasma Physics at CPP-IPR

Five students from University of Science and Technology Meghalaya, Baridua, visited CPP-IPR from 14 - 25 October 2024. The students were given lectures on plasma physics and visited exhibition hall and laboratories. The students also conducted various experiments with plasma devices in the exhibition hall.

The experiments include plotting of Paschen curve, experimental proof of deviations from Paschen law, plotting of I-V characteristics of a gas discharge, measurement of plasma resistance, nanoparticles synthesis using plasma and plasma treatment of dye solutions.

Talk on Cyber Security Awareness

A talk on Cyber Security Awareness was organized at IPR on 18 October 2024. The talk was delivered by Mr Vivek Joshi, School of Information Technology, Artificial Intelligence and Cyber Security, Rashtriya Raksha University, Ahmedabad. The speaker discussed various aspects of cyber security with case studies on phishing. He also highlighted the measures to tackle cyber threats.

Academic Visits to IPR (October - November 2024)

On 15th October 2024, 60 Students (Power Electronics) and 02

Faculty of Vishwakarma Government Engineering College, visited IPR; on 16th October 2024, 55 Students (9-12 Std) and 03 Teachers of GEMS Genesis International School, Ahmedabad, visited IPR; on 23rd October 2024, 33 Students (Electrical Engg.) and 03 Faculty of Institute of Infrastructure, Technology, Research and Management, Maninagar, Ahmedabad, visited IPR.

On 23rd November 2024, 101 students (8th, 9th and 10th grade) and 6 teachers of Bhavika-Gujcost, Ahmedabad, Gujarat, visited IPR; on 26th November 2024, 56 students (10th grade) and 3 teachers of Jawahar Navodaya, Vadnagar, and 38 students (10th and 12th grade) and 2 teachers of Shri School Jawahar Novodaya Vidyalaya, Kathlal, Kheda, Gujarat, visited IPR.

ITPA MHD, Disruption and Control Topical Group (ITPA-MDC-TG) Meeting

IPR hosted the 44th Meeting of the International Tokamak Physics Activity Magnetohydrodynamics (MHD), Disruption and Control Topical Group (ITPA-MDC TG) from 22-25 October 2024. The meeting was attended both in-person and remotely through Videoconferencing. There were a total of 34 in-person participants – 27 from IPR/BARC and 6 from abroad, while 38 participants from all ITER Partners joined remotely through videoconferencing. There were 42 presentations in total over 3.5 days, that included 3 special sessions – on VDE and Disruption modelling (5 presentations), on Optimization of Shattered Pellet Injection (SPI) for disruption and Runaway Electron (RE) mitigation (4 presentation) and on Disruption Prediction and Avoidance (9 presentations). Apart from these, there were 11 presentations on ITPA-MDC joint experiments and joint activities and 9 contributed presentations, which included 4 presentations from IPR (2 by faculties and 2 by senior Research Scholars) and one presentation from BARC on electromagnetic pellet injector development. All the presentations were of very high quality and there were intense discussions after each session, where local Indian participants also participated actively. The opening session of the meeting was dedicated to the Memory of Dr. Michael Lehnen, who passed away in June 2024 and was one of the deputy Chairs of the ITPA-MDC-TG. Presently Dr. Indranil Bandyopadhyay from ITER-India, IPR is the Chair of the ITPA-MDC-TG from 2024-2026 and he also chaired this meeting. One of the main reasons of holding the ITPA MDC meeting in IPR was to facilitate a larger number of local participants from IPR to take part in the deliberations and it succeeded in that objective.

Vigilance Awareness Week at IPR

The Institute observed Vigilance Awareness Week -2024 during 28 October - 3 November 2024. It started with the Integrity pledge, administered by the Director and Chief Vigilance Officer (CVO) on 28th October 2024. A talk was delivered by the CVO detailing the functions and responsibilities of the CVO along with Do's and Don'ts and hence the importance of vigilance clearance. The various events and programmes were conducted during the VAW 2024 and it was extended till 15th November 2024 to accommodate the festival holidays in between. Competitions like Quiz, Cartoon making, Debate (along with experience sharing about corruption), Slogan writing etc. were also conducted to sensitize and bring awareness about Vigilance among the employees. A talk by Mr. G.Venkatesan (ex-director, ATI, DAE) was arranged on CCS conduct rules on 14th November 2024. Finally, a Nukkad Natak "Yam pe Bhari - Ghapla lal ki Anokhi kahani" was performed by IPR Staff in the porch area on 14th November 2024, which was well received by the audience.

Plasma Exhibition @ Indian Institute of Technology, Gandhinagar

IPR Gandhinagar participated in "Amalthea 2024", Annual Technology exhibition organized by Indian Institute of Technology (IIT), Gandhinagar during 9-10 November 2024. Amalthea is a student-run annual technical summit. The event consisted of several tech exhibitions including robotics, AI and mobility based innovations. Several industry and national R & D institutions participated in the event. IPR exhibited working and static models related to Tokamak, ITER, Wiggler Experiment, Plasma for Grooming and Ion thruster. Around 800 visitors from schools, colleges and industry visited IPR exhibition stall during the event.

Plasma Exhibition @ B. C. Roy Engineering College, Durgapur, West Bengal

IPR Gandhinagar in association with B. C. Roy Engineering College, Durgapur, (West Bengal), organized an exhibition on Plasma, "The Fourth State of Matter" during 12-14 November, 2024. This program is part of IPR's scientific outreach activity in various states of India under the auspices of "70 years of DAE" celebrations. The programme consisted of an exhibition on plasma, its applications as well as introductory talks on plasma for visiting students and teachers. Over 1000 students and teachers from over 12 schools and colleges in and around Durgapur visited the exhibition.

Plasma Exhibition @ Rani Durgavati Vishwavidyalaya, Jabalpur, Madhya Pradesh

IPR Gandhinagar in association with Rani Durgavati Vishwavidyalaya, Jabalpur (Madhya Pradesh), organized an exhibition on Plasma, "The Fourth State of Matter" during 18-21 November, 2024. This program is part of IPR's scientific outreach activity in various states of India under the auspices of "70 years of DAE" celebrations. The event was inaugurated by Member of Parliament (Jabalpur), Shri Ashish Dubey. The programme consisted of an exhibition on plasma, its applications as well as introductory talks on plasma for visiting students and teachers. Over 1600 students and teachers from over 40 schools and colleges in and around Jabalpur visited the exhibition.

State Level Workshop on Plasma Physics at CPP-IPR

CPP-IPR's Outreach Cell conducted a "State Level Workshop on Plasma Physics" at Morigaon College, Morigaon, Assam on 26th November, 2024 in collaboration with Physics and Mathematics department of the college. The workshop was attended by the principal, vice principal, 8 faculties and 91 students of the college. During the workshop, Dr. Rakesh Moulick gave a talk on introduction to plasma physics, followed by a talk on basics of experimental plasma physics by Dr. Ngangom Aomoa. Thereafter, the participants were shown glow discharge plasma, arc plasma, DBD plasma, Jacob's ladder and a plasma globe. The working principle of these plasmas and their applications were explained to the participants.

Plasma Exhibition @ Shri Sardar Patel and Swami Vivekananda High School, Maninagar, Ahmedabad

IPR Gandhinagar in association with Shri Sardar Patel and Swami Vivekananda High School, Maninagar, Ahmedabad (Gujarat) organized an exhibition on Plasma, "The Fourth State of Matter" during 28-29 November, 2024. This program is part of IPR's scientific outreach activity in various states of India under the auspices of "70 years of DAE" celebrations. The programme consisted of an exhibition on plasma, its applications as well as introductory talks on plasma for visiting students and training program on plasma, its applications and nuclear fusion for science teachers. Students of 9th and 10th standard from the host school were trained by IPR staff to explain the various exhibits to visiting public. Over 2150 students and teachers from over 20 schools and 7 colleges visited the exhibition and highly appreciated.

CPP-IPR's participation at the India International Science Festival (IISF) 2024

CPP-IPR participated in the Science-Technology-Defence-Space Exhibition of India International Science Festival (IISF2024) organized from 30 November – 03 December 2024 at IIT Guwahati, Assam. India International Science Festival (IISF) is an initiative of the Ministry of Science and Technology and the Ministry of Earth Science of Government of India in association with Vijnana Bharati. Various plasma devices exhibiting different production mechanisms and plasma applications were shown. In addition to these, posters on various activities of CPP-IPR were also displayed with posters. The stall was visited by around 500 visitors including students, teachers, scientists from other institutes and common visitors and was well appreciated for the demonstration of various plasma production mechanisms.

Academic Visits to CPP-IPR (November 2024 - February 2025)

On 19th November 2024, 44 students of Class 11 & 12 and 3 faculty from Sankardeb Shishu Bidya Niketan, Malaybari, Assam, visited CPP-IPR; on 21st November 2024, 9 students of BSc and 1 faculty of Department of Physics, Rangia College, Assam, visited CPP-IPR. On 21st February 2025, 32 students of MSc and 2 faculty from Department of Physics, Royal Global University, Guwahati, Assam, visited CPP-IPR.

Two-Days Hands-on Basic Science Camp at IPR

First 2-day Hands-on Basic Science Camp for School students from class 10th to 12th was conducted by Outreach Division on 7th and 8th December 2024 (Sat & Sun) at Outreach Hall, IPR. The theme for this hands-on camp is Electricity, Electromagnetism and Electromagnetic Induction. For the first camp, the children of IPR staff were invited. 22 students registered and 20 students participated on both the days. The students were provided with practical booklet, writing materials, brief explanation about each experiment. The experiments were conducted in four half-day sessions supervised by scientists of IPR: Mr. Sunil Belsare, Mr. Prakash Parmar, Dr. Jyoti Sankar Mishra, Ms. Pramila, Ms. Praveena, Ms. Minsha Shah, Mr. Deepak Kumar, Mr. Abhishek, Mr. Rahul Kumar, Mr. Pritesh Kumar Ray, Mr. Saurav Kumar, Ms. Priyanka Patel and members from Outreach Division: Dr. Nirav Jamnapara, Mr. Manu Bajpai, Mr. Narendra Chauhan, Mr. Rahul Vishwkarma, Mr. Anand Kumar and Mr. Gattu Ramesh Babu. Special thanks to Mr. Dasharath Sonara and Ms. Aneesh for developing superconducting and temperature dependency experiment for this science camp.

39th Symposium on Plasma Science & Technology (PLASMA - 2024) at PDEU

The 39th Symposium on Plasma Science and Technology was organized at Pandit Deendayal Energy University (PDEU), Gandhinagar jointly by Institute for Plasma Research (IPR), Gandhinagar and Plasma Science Society of India (PSSI) during 17th December to 20th December 2024. A pre-conference workshop was organized for the university students and early stage researchers/faculties working in the field of plasma science and technology on 16th December 2024. The inaugural session was attended by Sh. K N Vyas, Former Secretary & Chairman, Department of Atomic Energy, Dr. Shashank Chaturvedi, former Director, IPR, Dr. S. Sundar Manoharan, Director General, PDEU, Gandhinagar, Dr. R. K. Shrivastava, Registrar, PDEU, Dr. Dhaval Pujara, Director, SOT, PDEU, Dr. G P Pandey, HOD, ECE, PDEU, Dr. Pawaan Sharma, HOD, ICT, PDEU, Dr. Abhishek Kumar (Co-Convenor), Dr. Manish Kumar (Convenor) and Dr. Amulya Kumar Sanyasi, Secretary, PSSI.

The Session -1 (Astrophysical & Space Plasma) was dedicated to the memory of Prof. Bimala Buti and homage to distinguished plasma physicists Prof. A N Iyengar and Prof. M S Sodha who passed away in 2024. There were nine (9) sessions covered during the symposium with a total number of 19 invited talks and 28 oral presentations. A total of 319 posters were also presented at the symposium. Apart from these topical sessions, 5 young prospective applicants for the BUTI Young Scientist Award presented their work on 17th Dec 2024. This was followed by Parvez Guzdar Award presentations in online mode.

Academic Visits to IPR (January - February 2025)

On 02nd January 2025, 25 students (MSc Physics) and 4 faculty from the Maharaja Sayajirao University of Baroda, visited IPR; on 17th January 2025, 74 students of EE and 3 faculty from Nirma University, Ahmedabad, visited IPR; on 20th January 2025, 80 students of EE and 2 faculty from Nirma University, Ahmedabad, visited IPR; on 21st January 2025, 35 students of BSc. (Phys) and 3 faculty from Lalan College, Bhuj, Kutch, visited IPR; on 22nd January 2025, 60 students of Class 7th and 2 Teachers from Sakar English School, Chandkheda, Ahmedabad, visited IPR; on 03-February 2025, 145 students of CSE and 4 faculty (2 batch) from Pandit Deendayal Energy University, Gandhinagar, visited IPR; on 4th February 2025, 149 students of CSE and 4 faculty (2 batch) from Pandit Deendayal Energy University, Gandhinagar, visited IPR; on 05th February 2025, 79 students of CSE and 2 faculty from Pandit Deendayal Energy University, Gandhinagar, visited IPR; on 17th February 2025, 87 students of ME/MC/AE and 3 faculty from U.V. Patel College of Engineering, Ganpat University, visited IPR; on 18th February 2025, 71 students of EE and 2 faculty from U.V. Patel College of Engineering, Ganpat University, visited IPR.

Workshop to Enhance Knowledge of Quality Assurance at IPR

To strengthen the understanding and implementation of Quality Assurance (QA) practices among IPR staff members, IPR and ITER-IN collaboratively organized a dedicated workshop. The initiative aimed to foster a deeper appreciation for QA principles, standards and practices, critical to achieving excellence in project execution and organizational operations.

A Pre-Workshop Session for Division Heads and Section Heads:

As a precursor to the main event, a special session was organized on January 17, 2025, for Division Heads and Section Heads at IPR. This session provided a comprehensive briefing on the workshop's objectives, agenda, and the critical role QA plays across various projects and divisions.

The workshop featured two expert speakers: Shri Pankaj Mokaria (QA, ITER-IN) and Shri Jigar Raval (IQS, MESD, IPR). They conducted engaging sessions, explaining key concepts such as Quality Control, Quality Assurance, and the application of QA through real-world case studies. These sessions highlighted the importance of QA in maintaining consistency, ensuring compliance, and achieving operational success.

Two-Day Workshop Highlights

The main workshop, held at IPR during 20–21 January 2025, was specifically designed for SO-C and TO-C staff members to deepen their knowledge of QA methodologies. The program began with opening remarks by Prof. Subroto Mukherjee (Dean – Administration), who emphasized the significance of QA in achieving organizational excellence. Shri Ujjwal Kumar Baruah (Director – ITER-IN) followed with an insightful address, outlining the workshop's goals and objectives while setting the tone for the sessions ahead.

Over the course of two days, a total of eight sessions were conducted, covering the following key topics:

Introduction to Quality Assurance and Quality Management Systems (QMS) – Fundamentals of QA and the role of QMS in maintaining standards.

Quality Perspectives for Specification Development – Best practices for defining quality-related specifications in projects.

Quality Audits – Strategies for planning and conducting audits to ensure compliance.

ISO 9001 and ASME NQA-1 Requirements – An overview of international QA standards and their implementation.

Documentation Management During Contract Execution – Best practices for maintaining documentation integrity throughout contract lifecycles.

Material Inspection and Acceptance Procedures – Methods to ensure material quality through systematic inspection processes.

General Safety Regulations as per IAEA GSR-2 – Understanding safety protocols and regulatory compliance in projects.

A total of 51 staff members attended the workshop, actively participating in discussions and practical exercises designed to build their QA competencies.

The workshop concluded with closing remarks by Dr. Paritosh Chaudhuri (Dean – R&D), who underscored the importance of embedding QA practices into the organization's culture and daily operations. He commended the participants for their enthusiasm and urged them to apply their learnings in their respective roles.

The successful execution of the workshop was made possible through the invaluable support of Dr. Rajesh Kumar

(Associate Dean – R&D) and Dr. (Er.) Manoj Kumar Gupta (Head – MESD), who played a pivotal role in planning and organizing the event. Their efforts ensured that the workshop was not only informative but also impactful for all attendees.

Basic Training for Students in Plasma Physics at CPP-IPR

The outreach cell of CPP-IPR conducted basic training for students in plasma physics. The programme consist of lectures on plasma physics and python programming language, conducting experiments with various plasma devices and laboratory visits. The experiments include plotting of Paschen curve, experimental proof of deviations from Paschen law, plotting of I-V characteristics of a gas discharge, measurement of plasma resistance, nanoparticles synthesis using plasma and plasma treatment of dye solutions. Students from Jagannath Barooah University, Jorhat, Assam and St. Joseph University, Dimapur, Nagaland, attended training during 9-20 December 2024; and students from St. Edmunds College, Shillong, Meghalaya, attended training during 6-22 January 2025.

National Startup Day 2025

National Startup Day 2025 was celebrated at Entrepreneurship Development Institute of India (EDII) on 16th January 2025 with a resounding focus on fostering entrepreneurial spirit, technology commercialization, and connecting industry with innovation. The event brought together esteemed dignitaries, entrepreneurial leaders, researchers, and startup founders to create a vibrant platform for knowledge exchange, networking, and showcasing cutting-edge technologies. Esteemed Guest Speakers included Shri Hitesh S Makwana, IAS, Surveyor General of India; Shri R D Barhatt, Jt. Commissioner of Industries – Govt. of Gujarat; Dr. Arvind C. Ranade, Director – National Innovation Foundation (NIF), Dr. Nirav Jamnapara, Head – AIC-IPR and Dr. Suresh Kumar Mojjada, Chief Technical Officer – Mariculture, ICAR-CMFRI. Dr. Nirav Jamnapara gave an introduction about the technologies developed at the Institute for Plasma Research and the incubation support being offered to startups through Atal Incubation Centre of IPR (AIC-IPR). Event witnessed participation from over 100 attendees, including aspiring entrepreneurs, researchers, and industry leaders. It served as a powerful platform for cross-sectoral knowledge exchange, offering participants actionable insights and potential collaborations

Plasma Exhibition at the Charutar Vidya Mandal (CVM) University, Vallabh Vidyanagar, Anand, Gujarat

IPR, Gandhinagar (Gujarat), in association with the Charutar Vidya Mandal (CVM) University, Vallabh Vidyanagar, Anand, Gujarat organized an exhibition on Plasma, "The Fourth State of Matter" during 31 January-01 February, 2025. This program is part of IPR's scientific outreach activity in various states of India under the auspices of "70 years of DAE" celebrations. The programme consisted of an exhibition on plasma, its application and fusion technology for visiting students and general public. Forty eight students from the host college were trained by IPR staff to explain the various exhibits to visiting public and students. Over 12000 students, teachers and general public in and around Vallabh Vidyanagar, Anand, Gujarat visited the exhibition.

One Day Seminar on Surface Modification using Plasma Technologies (SMPT-2025)

As a part of ongoing efforts for commercializing plasma-based technologies, Institute for Plasma Research and AIC-IPR Plasmatech Innovation Foundation, in association with Gujarat Chamber of Commerce & Industries (GCCI) have organized One Day Seminar on the theme "Surface Modification using Plasma Technologies (SMPT-2025)" on 4th February 2025 at FCIPT, Gandhinagar. The aim of the seminar was to give a platform to researchers and industries for showcasing their ongoing activities and results in the field of surface modification using plasma-based technologies. The topics covered in the seminar were Plasma Nitriding, Plasma carburizing process, Plasma assisted physical and chemical vapour deposition, Nano textured surfaces for super hydrophobicity, Plasma surface modification of textiles and polymers and Plasma surface modification for agricultural applications etc.

The seminar was inaugurated by the Chief Guest Shri. R.D. Barhatt, Joint Commissioner of Industries, Government of Gujarat, and the Guest of Honor was Shri. Rajeshbhai Gandhi, Senior Vice-President, GCCI. In the inaugural session, the guests were felicitated by Dean (Admin), Dr. S. Mukherjee, and Dean (R&D) Dr. Paritosh Chaudhuri. There were total 02 sessions held on plasma surface modification for various applications. One additional session covered the funding opportunities for startups, AIC-IPR and Incubation at AIC-IPR etc. Around 60 participants from industries, universities, research institute participated in this event. There were 12 invited talks (06 from outside + 06 from IPR) in the seminar. After the technical sessions, panel discussion was organized where delegates representing from industries, academic institutes, start up, actively interacted with the audience and gave valuable feedback and suggestions. A Lab visit was conducted after the panel discussion.

National Science Day 2025 at CPP-IPR

Centre of Plasma Physics – Institute for Plasma Research (CPP-IPR) celebrated the National Science Day on 5th February, 2025 with day-long activities. To mark the occasion, several competitions like essay writing, drawing, quiz and extempore speech were organized for school students. Around 70 students and teachers from 8 schools visited the campus and participated in various events. Slogan writing competition was also organized for the CPP-IPR staff. Dr. Rakesh Moulick also gave a popular talk on plasma physics. Professor Deepali Sarkar, Head, Physics Department, Gauhati University was the chief guest of the event.

Talk on Corporate Social Responsibility (CSR) funds

A talk on "Advancing R&D through Corporate Social Responsibility (CSR)" by Mr. Manuj Tripathi (Principal Scientist at CSIR-IMTECH), was organized in FCIPT on 05 February 2025. Talk was focused on the underutilization of CSR funds in India's Research & Development (R&D) ecosystem. The talk enhanced the knowledge of CSR landscape in context of R&D, CSR project proposals, funding cycle, and carve out a path to learn from some of the best practices across the organizations.

National Science Day 2025

The National Science Day, conducted under the aegis of the Platinum Jubilee Celebrations of the Department of Atomic Energy (DAE) was conducted as an offline event at IPR main campus during 15-16 February 2025. Over 350 students and 60 teachers from 57 schools participated in this 2-day event. The program was inaugurated by Dr. Subroto Mukherjee, Dean Admin, IPR. Seven competitive events were conducted in which 21 prizes were awarded. Apart from the competitive events, the NSD also had open house visits to various labs of IPR as well as a solar observation event using the high resolution solar telescope of IPR outreach. Around 45 students and 7 teachers participated in the science model competition. St Xavier's High School, Gandhinagar was awarded the IPR NSD 2025 Rolling trophy for scoring the maximum points in the competitive events. Over 2000 people visited IPR during the two-day scientific extravaganza.

Swachhata Pakhwada 2025

The Institute observed Swachhata Pakhwada from 16th February to 28th February 2025. Various events were organised as a part of this celebration, which were carried out by the Swachhata Committee members in close co-ordination with and active participation of all the staff members. The Pakhwada started with Swachhata Pledge taking ceremony followed by a Plog-a-thon within the campus on 17th February 2025. Other events like Essay competition, Best out of Waste Competition were organized during the fortnight, and Swachhata banners were displayed across all the three campuses to enhance awareness about the campaign. Tree plantation was carried out near the ST Plant behind the second security gate. DAE Joint Secretary - Finance graced the occasion with his presence, and saplings were planted by Swachhata Committee members as well as volunteers. Safai Sevaks (housekeeping and gardening staff) were served refreshment, as a token of appreciation for their continued efforts in maintaining clean and beautiful surroundings. A signature campaign and a sanitation drive was carried out at CPP-IPR Guwahati. The committee members and staff at CPP-IPR also carried out a Swachhata Walkathon. A painting competition was also organized for the children of staff members. The concluding session of Swachata pakhwada was held on 28th February. Mr. Utsav Modi, Program Officer, CEE (Centre for Environment Education) Ahmedabad, was invited, who delivered a special lecture on "Sustainable Waste Management, RRR (Reduce, Reuse, Recycle) and Circular Economy". During this program, prizes were awarded to the winners of the competitions. Swachhta Committee Chairman Shri Dilip Rawal proposed Vote of Thanks. Dean-Administration in his concluding speech stressed on the importance of cleanliness and praised everyone for successfully organising the Swacchata Pakhwada. He also motivated everyone to continue working for cleanliness.

CPP-IPR Outreach Programme at Bhattadev University, Assam

An outreach programme on the theme of "Plasma Science and Technology" was conducted by CPP-IPR's Outreach Cell at Bhattadev University, Bajali, Assam on 19th February, 2025. The workshop was attended by 5 faculties and 112 students of the college. Dr. Rakesh Moulick and Dr. Ngangom Aomoa gave talks on plasma physics followed by live demonstration of glow discharge plasma, arc plasma, DBD plasma, Jacob's ladder and a plasma globe.

Plasma Exhibition at Jagiroad College, Assam

CPP-IPR's Outreach Cell participated at the Science Exhibition programme conducted at and by Jagiroad College, Jagiroad, Assam to celebrate the National Science Day on 28th February, 2025. Various plasma devices exhibiting different production mechanisms and plasma applications were shown. The stall was visited by around 200 students and teachers from various schools and colleges.

54th National Safety Week 2025 at IPR

The 54th National Safety Week was celebrated at IPR from 4-10 March 2025. This year's theme was "Safety and

Well-being Crucial for Viksit Bharat." During the week, Institute organized various events and competitions to create safety awareness among its employees at IPR, FCIPT & ITER-India. Competitions such as Slogan, Quiz and Essay Writing were conducted in Gujarati, Hindi & English languages, based on the decided theme. Good response was received from the employees for various competitions.

During the week, demonstration of fire fighting equipment was conducted at IPR and FCIPT for employees as well as security personnel. A Safety Awareness Talk by Shri Devendra Modi, Safety Officer, was also organised.

The Concluding Session was conducted on 10th March 2025, included a talk on "Safety Measures in High Pressure High temperature Experimental Helium Cooling Loop at IPR" delivered by Shri Ankit Gandhi. Dr. Subroto Mukherjee, Dean (Admin) shared his thoughts on safety. He emphasized that safety should be an integral part of the working culture. He also informed that appropriate safety measures are to be taken care, if any system does not operate for quite long time. He congratulated the winners of various competitions and safety committee for organizing this event. Safety Pledge was administered by Dr. Rajesh Kumar, Co-Chairperson of the Safety Committee. This was followed by prize distribution to the winners of various competitions. Shri Sudhirsinh Vala, Member, Safety Committee gave the vote of thanks.

Academic Visits to IPR (March 2025)

On 5th March 2025, 12 students of BSc. and 5 faculty from Bahauddin Science College, Junagadh, Gujarat, visited IPR; on 12th March 2025, 66 students of CSE and 3 faculty from BVM Computer Engineering College, Anand, visited IPR; on 17th March 2025, 141 students of ICT and 4 faculty from Pandit Deendayal Energy University, Gandhinagar, visited IPR; on18th March 2025, 129 students of ICT and 4 faculty from

Pandit Deendayal Energy University, Gandhinagar, visited IPR; on 20th March 2025, 137 students of ECT and 4 faculty from Pandit Deendayal Energy University, Gandhinagar, visited IPR; on 21st March 2025, 59 students of ECT and 2 faculty from Pandit Deendayal Energy University, Gandhinagar, visited IPR; on 28th March 2025, 38 students of CSE and 2 faculty from Pandit Deendayal Energy University, Gandhinagar, visited IPR.

Expert Talk on "Can a Researcher be a Good Entrepreneur?"

As part of ongoing efforts to promote innovation and entrepreneurship within the academic community, AIC-IPR Plasmatech Innovation Foundation in association with HBNI Institute Innovation Council have organized an insightful talk on the topic "Can a Researcher be a Good Entrepreneur? – A Technology Translation & Design Perspective" on 13th March, 2025. The session aimed to spread awareness about the importance of technology translation and the journey from lab-based innovations to market-ready products.

The session was delivered by Dr. Suresh Nair, Managing Director, Amara Raja Design Alpha Pvt. Ltd., an accomplished domain expert and entrepreneur, who shared his extensive experience in the fields of technology development and commercialization. During his address, Dr. Suresh elaborated on the crucial role that researchers play in bridging the gap between laboratory research and market needs. He provided a detailed overview of the product development process, highlighting essential components such as technology readiness, market assessment, design strategies, and the pathways to successful commercialization.

The talk witnessed active and enthusiastic participation from students, faculty members, and staff, who engaged in meaningful discussions and gained valuable insights on how research-driven ideas can be transformed into impactful entrepreneurial ventures. The session served as a valuable platform to encourage researchers to consider entrepreneurial avenues for the practical application of their innovations.

Plasma Exhibition at IIT Jammu

IPR, Gandhinagar, in association with IIT-Jammu (J&K) organized an exhibition on Plasma, "The Fourth State of Matter" at IIT-Jammu during 17 -21 March 2025. This program is a part of IPR’s scientific outreach activity in various states of India under the auspices of “70 years of DAE” celebrations. Over 1500 students and teachers from 19 schools and general public visited exhibition. 30 teachers were trained from host institute to explain the static and working models and resource materials during this exhibition..

E. Other Activities

E1. Official Language Implementation

The 22nd Half-yearly meeting of the Town Official Language Implementation Committee, Gandhinagar, was held on April 30, 2024, at the Baroda Apex Academy, Gandhinagar. In this meeting, the Institute for Plasma Research was awarded the Second Prize (Official Language Shield) in the Autonomous Institutions/Educational Organizations category for its outstanding work in the implementation of the Official Language during the year 2023–24.

Under the ATOLIS Incentive Scheme of the Department of Atomic Energy (DAE), staff members of the Institute were continuously encouraged to work in Hindi. As part of this scheme, a total amount of ₹41,500 was awarded in cash for the April–June 2024 quarter, ₹41,900 for the July–September 2024 quarter, ₹42,400 for the October–December 2024 quarter, and ₹42,200 for the January–March 2025 quarter to employees who carried out their official work in Hindi.

A two-day Regional Hindi seminar on the theme "Viksit Bharat 2047 – Contribution of Your Institute/ Organization" was organized by the Institute on August 8 and 9, 2024. Representatives from member offices of the Town Official Language Implementation Committees (TOLIC) of Gandhinagar, Ahmedabad (Offices), and Ahmedabad (Banks) participated in the seminar. A total of 41 presentations were made, including 2 keynote talks, 8 invited talks, 12 oral presentations, and 19 poster presentations. The seminar was also broadcast live on YouTube and around 450 audience attended online.

The Institute observed Hindi Fortnight from September 17 to 27, 2024. During this period, a variety of competitions were organized across all three campuses of the Institute. These included technical/non-technical article writing, dictation, noting, letter writing and translation, crossword puzzles, Hindi computer typing, Hindi quiz, presentation of interesting incidents, video competition, recitation of self-composed poems, and singing. Employees of the Institute participated in these events with great enthusiasm.

During this period, the Hindi Section organized Hindi workshops every quarter with the objective of training staff members to work in Hindi. On April 26, 2024, a workshop on "Cyber Security Awareness" was held in the Seminar Hall, which saw active participation from many officers and staff of the Institute. The speakers of the workshop were Mrs. Kirti Mahajan and Mr. Govind Lokhande from the Institute's IT Division. As part of the Hindi Fortnight 2024 celebrations, a special talk was organized under the Hindi Workshop on September 20, 2024, on the topic "Expression – Creative Writing and Effective Presentation." In this session, Ms. Vrinda Rathi (Creative Trainer – Storyteller) provided training. Additionally, on November 28, 2024, the Hindi Section conducted a workshop for employees newly appointed in the year 2024. The session covered the Official Language Policy, drafting and correspondence, useful tools for using Hindi on computers, and the incentive schemes implemented by the Institute for working in Hindi.

The 32nd and 33rd issues of the Institute's in-house Hindi magazine *Plasma Jyoti* were **e-published**, along with all 12 monthly issues (from April 2024 to March 2025) of the Hindi newsletter *Plasma Samachar*. All these e-publications are available on the Institute's website.

Under the Hindi Training Scheme, five staff members of the Institute received training, out of which one qualified the *Pragya* level and four qualified the *Praveen* level examination. In addition, the Hindi Section provided regular training to employees nominated for various Hindi language examinations. The IPR officials have been nominated for Hindi examination (Prabodh-2, Praveen-2, Pragya-1, Parangat-3) training for the Hindi language training from July to November, 2025.

On World Hindi Day on 10 January 2025, a Hindi talk was delivered by Dr. Kulwant Singh of Bhabha Atomic Research Center, Mumbai on the topic "Contribution of Material Science in Indian Nuclear Program" at the Institute.

As part of the Platinum Jubilee celebrations of the Department of Atomic Energy (DAE), the Institute organized National Science Day on February 15–16,

2025. The event witnessed participation from over 350 students and 60 teachers representing 57 schools. During the two-day programme, competitions such as poster making, essay writing, skits, and debates were conducted in English, Hindi, and Gujarati languages.

As part of the Hindi Talk Series, retiring officials delivered talks based on their experiences. On May 24, 2024, Dr. A.V. Ravi Kumar delivered an inspiring talk on the topic "My Fascinating Journey in Plasma." On December 12, 2024, Scientific Officer Dr. Pramod Kumar Sharma delivered a motivational talk titled "My Pleasant Journey of Three and a Half Decades at IPR."

Under the talk series "Taknik ke sath Vigyan ki baat", two notable talks were organized during the year 2024–25. On July 4, 2024, Mr. Rajesh Kumar Trivedi delivered a talk on the topic "ICRF Source – Outcomes from the Research and Development Phase," and on March 19, 2025, Mr. Vinay Menon delivered a talk on "Fundamental Principles of Tokamak Operation and Their Application in Fusion."

On October 1, 2024, under the aegis of the Town Official Language Implementation Committee, an online workshop was organized by the IPR to provide proper guidance on accurately filling out the Parliamentary Committee on Official Language Inspection Questionnaire. Hindi Officers, Translators, and Hindi Coordinators from various offices of TOLIC Gandhinagar participated in the workshop. In this session, Mr. Achaleshwar Singh, Director (Official Language), Department of Atomic Energy, Mumbai, provided training on the Parliamentary Committee Inspection Questionnaire.

On September 19, 2024, an interactive talk session on the topic *"Contract Labour Laws and Procedures"* was organized at the IPR. In this session, Mr. Sanjeev, Labour Enforcement Officer (Central), briefed the attending officers and staff on the processes, enforcement, and practical aspects of labour laws.

The Institute observed Swachhta Pakhwada from February 16 to 28, 2025. As part of the campaign, an essay writing competition and a talk in Hindi on the topic of waste management were organized.

On International Women's Day 2025, a Hindi talk was delivered by Prof. Neerja Gupta on March 12, 2025, on the topic "Spiritual Geography of India."

On August 27, 2024, the *All India Hindi Scientific Seminar–2024* was organized at Raja Ramanna Centre for Advanced Technology, Indore (M.P.) on the theme *"Amrit Kaal: The Role of Science and Technology."* In this Seminar, Dr. Suryakant Gupta from the Institute, delivered a talk.

On September 27, 2024, during the Hindi Fortnight celebrations at the National Institute of Occupational Health (NIOH), Mr. Raj Singh delivered a talk in Hindi on the topic *"Net Zero Emissions and the Role of Nuclear Energy in Achieving It."*

In the Hindi workshop organized by the Central Public Works Department (CPWD), Gandhinagar on September 6, 2024, the Hindi Officer of the Institute provided training to the staff on the topic *"Hindi Noting, Drafting, and Use of Hindi on Computers."*

In the Hindi workshop organized by Software Technology Parks of India (STPI), Gandhinagar on September 25, 2024, the Hindi Officer of the Institute provided training to the staff on the topic *"Software/ Tools for Using Hindi on Computers."*

During this period, with the coordination of TOLIC Gandhinagar, staff members of the Institute enthusiastically participated in various workshops, quizzes, symposiums, and competitions organized by different member offices such as CPWD, NFSU, Institute of Hotel Management, Baroda Apex Academy, and others. Their active participation earned them several awards and recognitions.

Poems and articles written by officers and staff of the Institute for Plasma Research were published in the April 2024 and September 2024 issues of Gandhinagari, a magazine published by the Town Official Language Implementation Committee, Gandhinagar. The April issue featured the poem "*Hisab Kya Rakhna*?" by Mr. Parag Panchal, the article "*Mahilaon Ki Gauravshali Gatha*" by Mr. Amit Maurya, the article "*Aam Jeevan Mein Plasma Ka Mahatva*" by Mr. Nirav Jamnapara, and the poem "*Zindagi Ka Safar*" by Mr. Ayush Mani Tripathi. The September issue included the poem "*Srijan Chakra*" by Ms. Pratibha Gupta.

During the year 2024–25, Official Language Implementation inspections were carried out for Administration Section–2 (on May 31), Purchase Section (on September 18), and Administration Section–3 (on March 18, 2025). During these inspections, the status of Hindi documentation, correspondence, and use of Hindi on computers was reviewed, and necessary instructions were given for improvements.

Five articles authored by Ms. Pratibha Gupta, Scientific Officer–F of the Institute, were published in the quarterly Hindi magazine *"Vaigyanik"*, issued by the Hindi Science Literature Council.

Translation Work: The Hindi Section carried out the translation of the *Annual Report 2023–24*, the *Outcome Budget*, documents falling under Section 3(3) of the Official Language Act, and various official correspondences.

The Institute has made good progress in making Hindi a permanent part of its work culture through promotion efforts.

Figure E.1.1: Members of the Library Section receiving inter-departmental shield from the Director for outstanding implementation in the field of Official Language (Rajbhasha) .

Figure E.1.2: Release of the summary booklet of Sthaniya Hindi Sangoshthi at the institute, (left to right) Dr. Shashank Chaturvedi, Director; Dr. Anil Bhardwaj, Director, PRL; Mr. Yashwant U. Chavan, Prin. Ch. Comm. of Income Tax, Gujarat and Chairman, TOLIC (Ahmedabad); Mr. Ashwini Kumar, Gen. Manager and Zonal Head, Ahmedabad, Bank of Baroda and Chairman, TOLIC (Ahmedabad–Bank); and Mr. Sunil Sinha, Head of Baroda Apex Academy and Chairman, TOLIC (Gandhinagar).

Translation Work: The Hindi Section carried out the translation of the Annual Report 2023–24, the Outcome Budget, documents falling under Section 3(3) of the Official Language Act, and various official correspondences.

Through these efforts undertaken for the promotion and propagation of the Official Language, the process of integrating Hindi as a permanent part of the work culture at the institute has been further strengthened.

E2. Outreach

Institute's Outreach conducted several scientific outreach activities (both in rural and urban locations) across the country during this period. As part of the outreach activities, plasma exhibitions were conducted at 16 locations across the country in the states of Rajasthan, Gujarat, West Bengal, Madhya Pradesh, Jammu, Telangana and Odisha. These events consisted of an exhibition on plasma, its applications and nuclear fusion with over 25 exhibits, most of which being working, interactive exhibits, interactive and popular talks on plasma & its application for general public. Training program in plasma science & technology for science teachers was also conducted during many of these events

Figure E.2.1: Organization of solar week.

Over 800 students from the host institutions were trained to explain the exhibits to visitors during the exhibitions. These events have seen a net footfall of over 4 lakh visitors, which includes around 50,000 students and teachers from over 800 schools and colleges. Around 50 teachers were trained in plasma and its applications during the outreach events.

To involve participation from more students, competitions such as quiz, Tokamak gaming as well as Tokamak assembly competitions were organized during the outreach events which were received with great enthusiasm. Institute's outreach also celebrated the Technology Day event in association with the Gujarat Science City, Ahmedabad during May 2024. This event saw participation of over 1500 engineering students from across the state of Gujarat.

Popular talk in Hindi on plasma was delivered by Outreach at Gujarat Vidyapeeth on National Space Day (23 Aug 2024), commemorating Vikram Lander's lunar landing. The talk covered plasma's abundance, applications, and fusion prospects. Nearly 200 attendees included faculty, researchers, and students from microbiology and biogas disciplines.
The Outreach website also has up-to-date information about the events and a repository of resource materials and details about the exhibits for students to download and use.

A solar observatory has been established by the institute's Outreach. Solar observation was organized in institute's campus as well as at the campuses of rural schools. About 1000 students and 70 teachers from 6 schools participated in the Solar Observation Week and viewed prominences (glowing red loops of gas), filaments (dark, thread-like structures that are prominences seen against the Sun's face), and spicules (tiny, jet-like spikes of gas) (Figure E.2.1).

Figure E.2.2: Snapshots of the event Amalthea.

During this period, Institute's Outreach facilitated academic visits to main campus/FCIPT from 56 schools/colleges with over 3000 students in more than 60 academic visits. Additionally, a plasma awareness week was held in the institute whereby about 300 students from **5** schools participated.

Outreach participated and displayed exhibits and posters in 16th Edition of the student-led technical summit 'Amalthea' on 10 November 2024 in IIT Gandhinagar (Figure E.2.2). In the following month (December 2024) plasma exhibition was organized during 39th National Plasma Symposium in PDEU Gandhinagar.

For the first time in the institute, induction program for new recruits was organized in September 2024, covering administrative responsibilities and lab-visits. A basic science camp was also organized for the first time in the institute, in December 2024 where about 20 students from 10th-12th grade participated in hands-on experiments on electricity and magnetism.

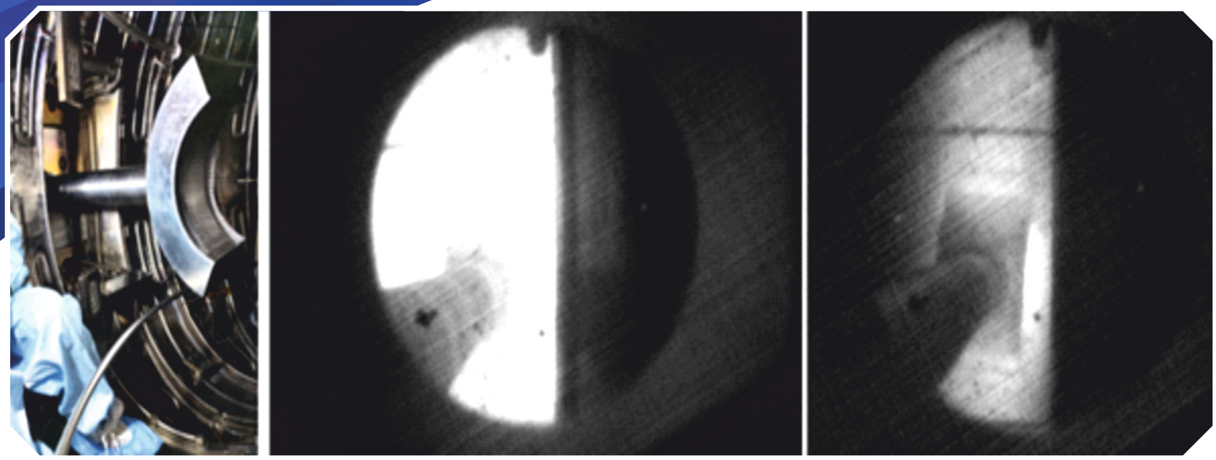
Figure E.2.3: Celebration of national science day 2025.

In February 2025, institute organized the National Science Day for school students from across Gujarat state. More than 2500 students and teachers from 57 schools participated in the event which covered essay competition, quiz, skit, eloquence and the competitions of scientific models from both students and teachers in their respective categories (figure E.2.3).

Virtual Reality contents related to plasma and fusion are being developed by the Outreach for showcasing various experimental systems as well as concepts of fusion to students. On a regular basis the in-vessel and the outer view of SST-1 is shown to the students and visitors on outstation events in order to provide the viewers with a general understanding of a Tokamak. Outreach participated in DAE Conclave held at NISER Bhubaneswar in October 2024.

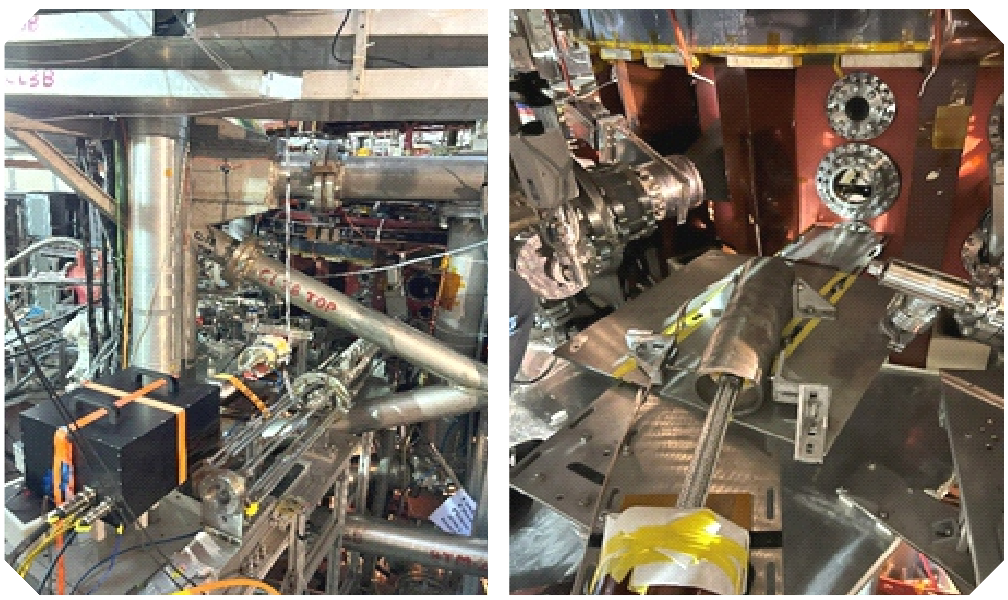
E3. Right to Information

During the report period 2024-2025, a total of 101 RTI applications were received, out of which 89 were of new RTI Application, while the other 12 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.



एसएसटी-1 में स्थापित एंटीना का दृश्य तथा दृश्य कैमरे द्वारा कैद किए गए प्लाज़्मा उत्पादन का स्नैपशॉट

A view of installed antenna in SST-1 and snapshot of plasma production by visible camera



आदित्य- अपग्रेड टोकॉमक पर स्थापित प्रोटोटाइप ईटर एचएक्सआरएम

Prototype ITER HXRM installed on the ADITYA-Upgrade tokamak

हीलियम-शीतित ब्रीडिंग ब्लैंकेट और डायवर्टर मॉक-अप से ऊष्मा निष्कर्षण के अध्ययन हेतु बनी प्रायोगिक हीलियम शीतलन लूप ईएचसीएल सुविधा

Experimental Helium Cooling Loop (EHCL) facility for studies on heat extraction from helium cooled breeding blanket and divertor mock-ups

प्रधानमंत्री श्री नरेंद्र मोदी फ्रांस के राष्ट्रपति श्री इमैनुएल मैक्रोन के साथ फ्रांस स्थित ईटर स्थल के दौरे पर

Prime Minister Shri Narendra Modi along with his French counterpart
President Emmanuel Macron during their
visit at the ITER site, France on 12 February 2025