वार्षिक प्रतिवेदन 2021-2022

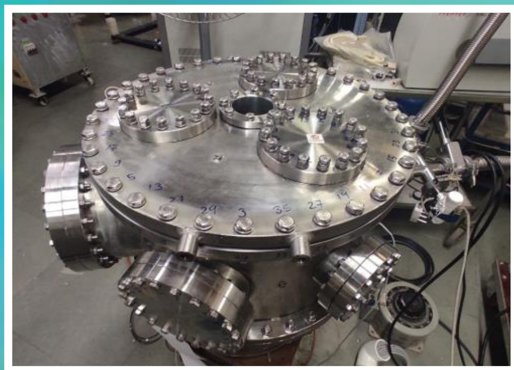
ANNUAL REPORT 2021-2022

प्लाज़्मा अनुसंधान संस्थान

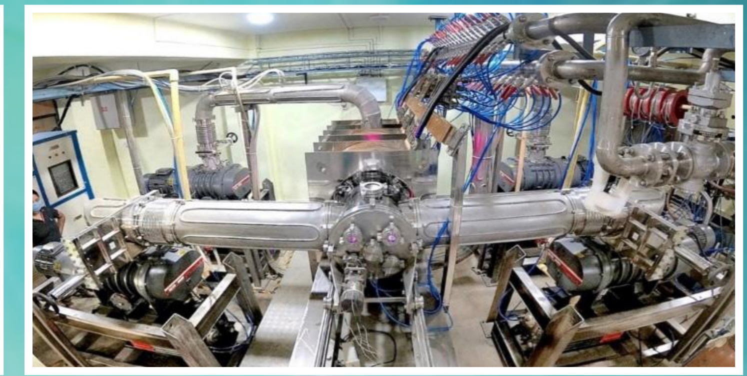
Institute for **Plasma Research**

भाट, निकट इन्दिरा पुल, गांधीनगर - ३८२ ४२८ (भारत)

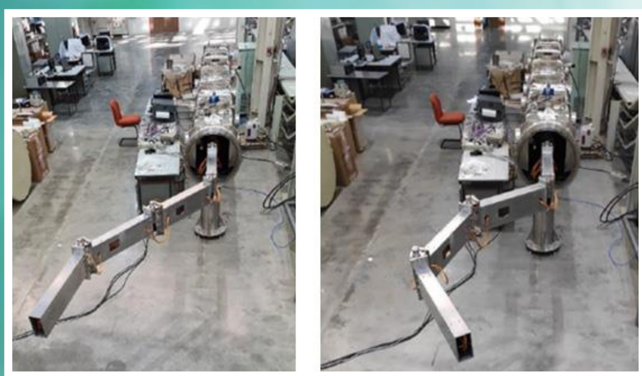
Bhat, Near Indira Bridge, Gandhinagar 382 428, Gujarat (India)



SMARTEX-C प्रयोग के लिए नए निर्वात पात्र का निर्माण
Construction of new vacuum vessel for SMARTEX–C experiment

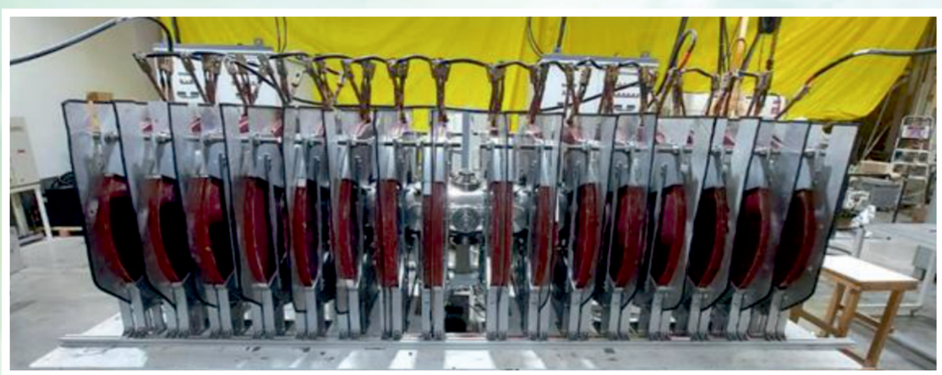


सीपीपी-आईपीआर में CIMPLE-PSI उपकरण
CIMPLE-PSI device at CPP-IPR

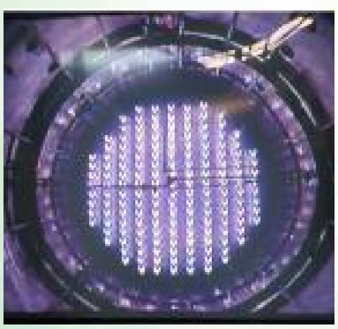


टोकामॅक घटकों के दूरस्थ निरीक्षण हेतु इन-वेसल निरीक्षण प्रणाली (आईवीआईएस)
In-vessel Inspection System (IVIS) for remote inspection of Tokamak components

14-MeV न्यूट्रॉन जनरेटर का सेटअप
14-MeV Neutron Generator Setup



एपीपीईएल उपकरण के लिए प्रायोगिक सेटअप
Experimental setup for APPEL device



अपने सभी 162 फिलामेंट के साथ संचालनरत बड़े क्षेत्र का बहु-फिलामेंट वाला प्लाज़्मा स्रोत (LAMPS)
Large Area Multi-filamentary Plasma Source (LAMPS) in operation with all its 162 filament

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2021-2022

प्लाज़्मा अनुसंधान संस्थान

Institute for **Plasma Research**

Bhat, Gandhinagar 382428

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EXECUTIVE SUMMARY

The activities of the Institute are nearly back to normal, overcoming the disruptions caused by the pandemic over the past two years. A large number of import substitute products have been developed in-house, as a contribution to "Atmanirbhar Bharat". The Institute's R&D activities broadly cover three areas, viz., (1) Plasma Based Technologies & Applications in the fields of medical/health, space, agriculture, waste disposal, defence, textiles, etc; (2) Nuclear Fusion experiments and indigenous development of various Fusion technologies, including in-kind contributions towards the international projects – ITER and LIGO, and (3) Fundamental plasma physics studies based on theory, experiments, and computational modelling.

An import substitute microwave-based space type plasma (LEO and GEO) source has been developed and integrated in the SPIX facility for ground-based satellite solar panel testing. Based on this facility, experimental data have been supplied to ISRO for developing futuristic high voltage satellite solar panels. An indigenous helicon plasma thruster, able to produce thrust ~ 90 mN has been developed, and a higher thrust system is under development. The Institute is developing an indigenously built plasma pyrolysis system for biomedical waste disposal at the Homi Bhabha Cancer Hospital, Varanasi. This fully-indigenous, environment-friendly plant, making use of three 100 kilowatt graphite-electrode based plasma arcs, is a contribution to Atmanirbhar Bharat. This is the first time that such high-power arcs have been developed in the country for 24 x 7 operation. In a major milestone, these arcs and associated power supplies have been tested continuously for 120 hours.

IPR had earlier developed an AI-based software for high-speed automated detection of abnormalities in chest X-rays. That software is now at the heart of an ICMR-organized national programme. 20 Labs/hospitals are uploading CXR data + diagnosis, which is then being used for training IPR's software. In a recent test, the software gave good results for CXR obtained from a portable X-ray system in a remote tribal area of MP. IPR has also developed & will be distributing a low-cost x-ray digitizer. An Indian patent has been granted to IPR on a novel apparatus for production of microwave atmospheric plasma for the applications in coal gasification, waste disposal, diamond synthesis, and biomedical tools/equipment sterilization. Atmospheric dielectric barrier discharge-based plasma activated water (PAW) technology license has been transferred to a company. PAW is well known for its antimicrobial activity due to having numerous reactive oxygen-nitrogen based radicals, which helps to prevent bacterial and fungal infections. IPR, in collaboration with the Tata Memorial Cancer (TMC) Mumbai, has studied the use of cold atmospheric plasma (CAP) jet for treatment of oral cancer, and early results are promising.

Both Aditya-U and SST-1 tokamaks made significant progress in terms of plasma operation and physics understanding. Consistent discharges with plasma current of about 170 kA and duration ~370 ms were obtained in Aditya-U using a parallel configuration of vertical magnetic field (BV) coils. Several new diagnostics were added. Gas-puff induced cold pulse propagation has been observed, and experiments have been performed for controlling the rotation of drift tearing modes by electrode biasing. The effect of divertor coils on plasma shaping was studied in Aditya-U. Lithium wall conditioning technique was established for impurity and fuel control. On the Steady State Superconducting Tokamak-1 (SST-1), a multipoint Thomson scattering diagnostics system was commissioned for the measurement of plasma density and plasma temperature. An RF-based novel spiral antenna system was developed for low loop voltage current start-up, as an alternative technique to the routinely used electron cyclotron resonance (ECR) current start-up method. Electron Cyclotron Resonance Heating (ECRH) experiments with two-pulses (breakdown and heating) were also successfully carried out both on SST-1 and Aditya-U tokamaks.

A number of fusion related technologies are being developed indigenously. (a) On the fusion blanket technology front, IPR has developed a Lead Lithium Eutectic (Pb-16Li) ingot production system of capacity ~75kg per batch, Lead-Lithium (Pb-Li) loop having 60 litre inventories with flow rate up to 8 kg/s for thermo-fluid MHD studies, an electromagnetic pump for high temperature (~ 300^{o}C) electrically conducting liquids, and a few diagnostic systems including a flow meter for characterizing such high temperature conducting fluids. (b) Under superconducting magnet technology development, IPR is developing a high-temperature (~ 77K) superconducting (HTS) cable and also solenoid magnet coils. (c) A remote in-vessel inspection system for Tokamak components has been developed. This includes a 4 m long articulated arm having 6-degrees of freedom. . An interactive virtual reality CAVE facility has been established. Using this facility, users can instantly view and interact with virtual 3D models of any machines/systems and feel the actual environment, eliminating the need for physical expensive prototypes. (d) A new 300keV 20mA D+ ion accelerator based 14-MeV neutron generator having capacity of 5×10^{12} n/s has been established in IPR, the most powerful 14-MeV neutron source in India. In early testing, it has yielded 7×10^{11} n/s. (e) An import substitute co-axial ceramic-based vacuum barrier for high power RF systems has been successfully developed indigenously in collaboration with Non-ferrous Materials Technology Development Centre (NFTDC). (f) Electro-deposition technology on large area for manufacturing NBI accelerator grids has been developed and successfully tested in collaboration with RRCAT on a 300mm x 300mm Cu substrate. (g) A 500 kV, 2 A DC power supply is being designed and developed for future NNBI systems. (h) Plasma of density ~10^{17} m^{-3} has been created in an indigenously built TWIN source by igniting two RF drivers simultaneously for the first time, using a 40kW, 1MHz solid-state RF generator.

In fundamental science IPR is involved in many experimental, theoretical and computational modelling activities. Cluster science is an active field of research due to its applications in nanotech & colloidal science. Dusty plasmas can be employed to study cluster science by creating self-organized 1-D, 2-D or 3-D finite classical Coulomb clusters following thermodynamic nature of a Coulomb clusters. A DC dusty plasma device in IPR has established the relationship between configurational ordering and thermodynamics of strongly coupled Coulomb cluster systems, which could be helpful in analysing and controlling the dynamics of micro and nano-particle clusters. This understanding has applications in medicine, sensor, electronics, etc. Major up-gradations have been or being carried out in the devices like LVPD, SMARTEX, APPEL, and IMPED. Theoretical simulation studies have made progress in various areas. (i) combined effect of a resonant magnetic perturbation (RMP) and a sheared toroidal flow on the characteristics of edge localized modes (ELMs); (ii) deep-learning-based major disruptions prediction in ADITYA Tokamak; (iii) finite electron temperature gradient effects on blob formation in the Scrape-Off Layer (SOL) of a Tokamak plasma, and (iv) studies on impurity seeding and transport in edge and SOL of Tokamak plasma have significant impact on tokamak plasma science understanding. (v) Electromagnetic wave energy absorption in over-dense plasma is a matter of research in laser-based inertial fusion. A fundamentally new ponder motive pressure-driven mechanism of excitation of electrostatic waves in an over-dense magnetized plasma by a finite laser pulse has been identified. When Mie-plasma frequency matches the laser frequency linear resonance absorption occurs in a laser-irradiated atomic cluster. (vi) In electronegative plasma, a parametric investigation by solving nonlinear Schrodinger equation has identified a universal parabolic relationship between the critical density ratio of negative to positive ions and the average ionic mass ratio for excitation of modulation instability, responsible for large amplitude soliton.

The ANTYA High Performance Computing (HPC) facility, rated at 1 Peta flop, achieved an uptime of more than 99% in this year. A GPU-based HPC facility is under procurement considering the growing importance of Artificial Intelligence (AI) and Deep Learning (DL) in scientific research. A dedicated newsletter "GAṆANAM" containing information on available HPC tools, ANTYA software updates and new research articles based on the works done using the HPC resources, is being regularly published every month. Some of the recent works of simulations performed on ANTYA are: (i) Numerical simulation study on rocket propulsion with detonations, (ii) Turbulence Study in a 3D Complex Plasma using MPMD-3D, (iii) Impact of Plasma Flows on Tokamak In-stabilities, (iv) Multi-GPU Acceleration of 3-D pseudo-spectral MHD code for large scale plasma simulation.

ITER-India continued timely and quality-adherent supplies to ITER related to the 9 procurement packages. While 100% deliveries of the four important ITER first plasma packages, viz cryostat, in-wall shields, cooling water systems and cryo-lines systems have been completed, technology development and performance demonstration of the complex first of kind systems related to ICRH, ECRH, DNB and various diagnostics are the new focus areas. Construction activities at the ITER Site in France are in full swing. Till date ~80 % of work has been completed. This includes the installation and acceptance of the components of the cryostat, the cooling water system, the various sections of the multi-feed cryo cold and warm lines supplied by India to ITER and the in-vessel shields supplied by ITER India to EUDA and KODA to be installed in the vacuum vessel sectors. IPR has indigenously developed a software suite called ACTYS for neutron transport and nuclear activation calculations. The ACTYS codes are faster than existing codes. Recently, the codes have been approved by the Nuclear Integration Unit of ITER for all ITER-related nuclear activation calculations.

The LIGO-India project envisages the construction, installation and commissioning of a 4 km long laser interferometer based Gravitational Wave detector in India in collaboration with LIGO Laboratory, USA. The LIGO India project is jointly executed by RRCAT Indore, IPR Gandhinagar, DCSEM Mumbai and IUCAA Pune. After successful factory acceptance tests of two critical prototype chambers (BSC and HAM) of 1:1 size, these were delivered to RRCAT and accepted. The procurement process for setting up LIGO-India – Vacuum Integrated System Test Assembly (LI-VISTA) facility has been initiated. As a part of prototyping activities for control and data system for LIGO India, the CDS test rack and vacuum control and monitoring system (VCMS) rack for vacuum setups are being developed at IPR.

DIRECTOR,
IPR.

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APRIL 2021 TO MARCH 2022

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 1 peta-flop High Performance Computing (HPC) facility has also been established. Over these years, the institute has trained a large number of man power to pave the way to reach India's "self-reliant/Atmanirbhar" goal in the field of plasma technology and fusion power. Institute is now 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 now 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

A.1 Plasma Based Technologies & Applications

Plasma based technologies and applications is a key area with far reaching technological and societal benefits. New projects in these areas continue to be added while good progress continues. The highlights this year have been following,

A.1.1 Plasma Surface Engineering Applications

<u>*An Import Substitute Plasma Source for Ground Testing of Satellite Solar Panels:*</u> The increasing power requirement in satellites requires operation at progressively higher bus voltages. This can lead to arcing on the satellite solar panel and may limit the operational lifetime (figure A.1.1).

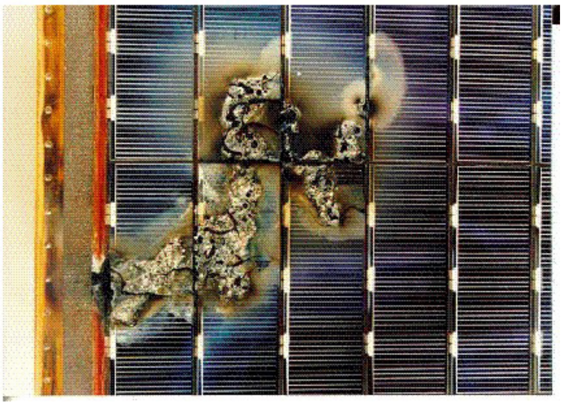


Figure A.1.1: An image of a satellite solar panel damaged due to arcing.

To study this effect, institute had set up an indigenous Spacecraft Plasma Interaction eXperiment (SPIX) facility (figure A.1.2), where the plasma resembles Low Earth Orbit (LEO) and Geosynchronous Equilateral Orbit (GEO) like space environment. Space environment data are provided by URSC-ISRO. An ECR plasma source has now been indigenously developed and integrated with SPIX, yielding performance at par with imported systems. This is a contribution to Atmanirbhar Bharat. Earlier a filament source was used in the facility. To validate the performance of indigenously developed LEO source, experimental results of Filament plasma source and ECR plasma source have been compared together. These experimental findings will be helpful in developing high voltage satellite solar panels for the ongoing and future space program of ISRO.

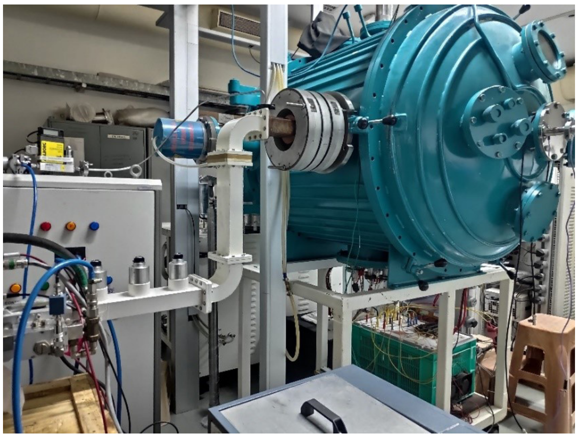


Figure A.1.2: An indigenously developed SPIX facility with ECR plasma source for the ground testing of satellite solar panels before launching into the space.

Feasibility study on surface activation of polystyrene using low pressure plasma: Amongst the polymers, polystyrene (PS) has served as the fundamental substrate for adherent animal and human cell culture. However, the simple polymer lacks appropriate surface chemistry for cellular recognition. Hence surface modification of polystyrene surface is necessary to facilitate cell anchorage by incorporating surface functionality, on which cells will attach and grow. The feasibility study project was done with a private enterprise in Gandhinagar in which plasma activation study is carried out on polystyrene surfaces using low pressure glow discharge plasma. The process for plasma treatment has been developed to increase the cell adhesion on the polystyrene surface. The argon/oxygen plasma is generated inside the polystyrene flask to treat the inside surface of the flask. The cells adhesion on the plasma treated surface was found to be higher in comparison with untreated surface. Figure A.1.3 shows cell growth of RAW 264.7 cells on untreated and plasma treated surface.

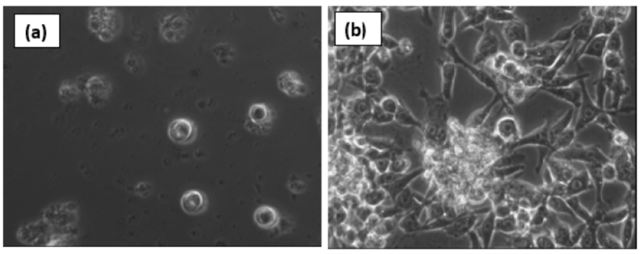


Figure A.1.3: Cell growth on (a) untreated and (b) plasma treated polystyrene surface.

A.1.2 Atmospheric Plasma Applications

Plasma Pyrolysis for Biomedical Waste Disposal: Institute is establishing a common biomedical waste treatment facility along with Homi Bhabha Cancer Hospital, Varanasi. This facility will cater hospitals and health care facilities located in and around Varanasi and will include 5 Tons/day plasma pyrolysis plant, autoclave, shredder, ETP and various other systems to treat all categories of biomedical waste. This upcoming facility is the first of its kind in India to use home grown plasma pyrolysis technology for safe disposal of biomedical waste. This facility will be established as per recent guidelines of Biomedical Management Rules 2016 using advanced plasma technology to dispose bio medical waste**.** The major sub systems of the plasma pyrolysis plant were indigenously designed at the institute and are in the stage of fabrication and procurement. Integration of various sub systems of plasma pyrolysis plant and its testing & demonstration is planned by the end of 2023. One of the major milestones of this activity is development and testing of three graphite electrode based thermal plasma arc system along with its individual high efficient power source. Atmospheric Plasma Division has successfully tested the three power supplies for operation of 120 hours continuously.

Antifouling Properties on Silicone Catheter Surface by Plasma Treatment: The most common bacterial species responsible for causing Catheter-Associated Urinary Tract Infection (CAUTI) is Escherichia Coli (E-Coli). Systematic experimental investigation of plasma-induced physico-chemical changes on silicone catheter surfaces and their influence on biofilm formation by uropathogenic E-coli bacterial cells for 7 days incubation period. Results of this study convey that plasma induced morphological parameters such as average surface roughness, the average distance between local peaks, and average slope of the morphological features play dominant role over surface chemistry for reduction in bacterial colonization and biofilm formation. The effectiveness of plasma treatment was evaluated for next 30 days after plasma treatment. Results confirm that oxygen plasma-treated catheter surface is successfully able to prevent biofilm formation with maximum 99.4 % reduction in bacterial adhesion having 10 minutes plasma exposure. The study also suggests that oxygen plasma treatment alone can be considered as a simple and eco-friendly solution for the prevention of E-coli biofilm formation on silicone catheter surfaces without involving the use of antibiotics or any other complex coat*i*ng chemistry. Results of bacterial adhesion studies on bare and plasma treated catheter surfaces and their effectiveness after plasma treatment are shown in below figure A.1.4 [A - sample is analyzed immediately after plasma treatment, B - analyzed after15 days, C - after 30 days.].

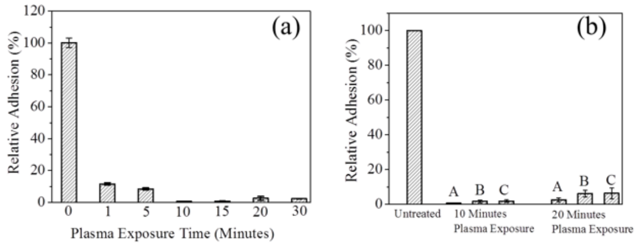


Figure A.1.4: (a) Relative adhesion of bacterial cells on untreated and plasma treated catheter surfaces, (b) effectiveness of treatment on 10 and 20 minutes plasma exposed silicone catheter surfaces.

<u>*Use of Plasma Activated Water (PAW) in Food Sector:*</u> The cold plasma when interacts with water it forms numerous reactive oxygen-nitrogen species in water. These species include NO_2^-, NO_3^-, H_2O_2, HO·, $ONOO^-$, and dissolved O_3, etc. The dissolution of these reactive species in water makes it active and it can be used in applications like microbial inactivation (bacteria, fungi, viruses, and pests), food preservation, selective killing of cancer cells, seeds germination and plant growth. Microbial (bacteria and fungi) infections and diseases are the major cause of food spoilage all over the world. Therefore, PAW can prove to be a potential eco-friendly and green alternative to conventionally used chemicals to enhance the shelf-life of food products. The effect of PAW on lemon (Citrus limon) shelf-life (figure A.1.5). The washing of lemon with PAW substantially enhances the self life of lemon storage. The colour, texture, weight, and sensory (odour, appearance, taste, and overall acceptability) characteristics of PAW washed lemon remain intact over time (30 days study), however, control (Ultrapure Milli-Q water) washed lemon showed significant degradation. In addition, PAW washed lemon showed enhanced soluble sugar and protein, flavonoid, vitamin C, antioxidant activity (total phenol and DPPH assay) compared to control.

Figure A.1.5: Pictures of control washed and PAW washed lemon after 30 days of storage period.

<u>*Treatment of Pea Seeds using PAW: Faster Germination & Growth:*</u> The effect of PAW on pea seeds germination and plant growth was explored. The PAW exposure of white dried pea seeds (Pisum sativum L.) significantly enhance pea seeds germination and plant growth (figure A.1.6). This was due to PAW exposure with seeds remove the naturally occurring wax from seeds surface that results in enhancement of wettability properties and rapid absorption of water by seeds (figure A.1.7). Hence, higher agronomy traits (height, fresh and dry weight, germination index, etc.) observed in PAW grown pea plant compared to control. Moreover, PAW grown plants showed higher chlorophyll ‘a’, sugar, and protein, enhanced antioxidant enzyme (SOD, CAT, APX, and POD) activity compared to control.

Figure A.1.6: Picture of PAW (PAW – 5 min and PAW - 10) and control (Ultrapure Milli-Q water, DM water) grown pea plant.

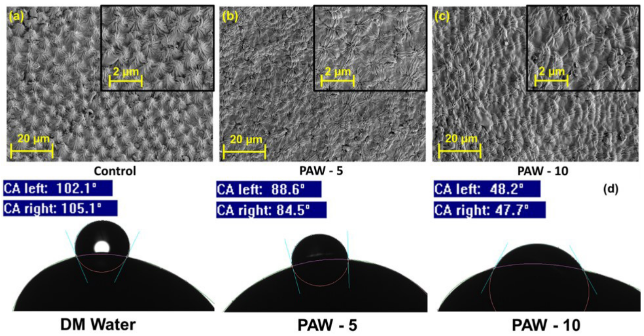


Figure A.1.7: Change in morphology and wettability of pea seeds surface after PAW treatment in terms of contact angle, a parameter to show wettability.

Technology license transfer for generation of Plasma Activated Water: A technology knowhow and license agreement was signed between the institute and M/s Persapien Innovations Pvt. Ltd. for a prototype system to generate Plasma Activated Water.

Development of a system for the degradation of pesticides from fruits and vegetables: An experimental system is developed for the degradation of pesticides from fruits and vegetables. The system is sent to Dr. Y.S. Parmar University of Agriculture and Horticulture, Solan, Himachal Pradesh for further testing. The system is designed in such a way that at any given time two vegetables having size of 75 mm and 20 mm can be placed and treated. The overall dimensions of the system are length 500 mm x width 250 mm x Height 482 mm (figure A.1.8). In the first test the pesticides Malathion and Chloropyriphos are sprayed on tomato and its degradation is being studied.

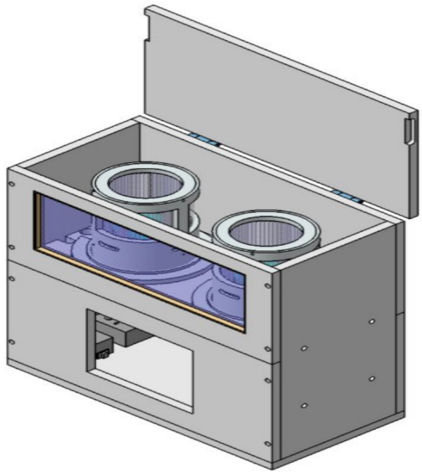


Figure A.1.8: Schematic view of the system for reduction of pesticides.

Apparatus for Production of Microwave Plasma: Institute has developed a novel apparatus for production of atmospheric-pressure plasma using microwaves (figure A.1.9), and this has been granted an Indian patent. This low-cost system is also simpler than conventional systems, since there is no need for matching components like isolator, circulator and stub-tuner for matching the source to the plasma. This system can be used in a variety of industrial applications, such as microwave plasma arc in coal gasification, waste disposal, diamond synthetization, and sterilization of biomedical tools/equipment.

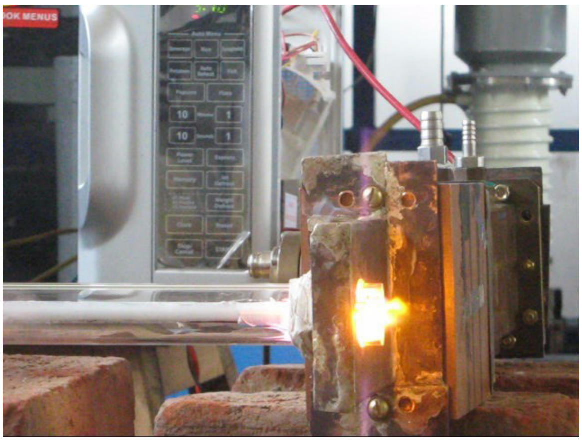


Figure A.1.9: Microwave plasma arc at atmospheric pressure.

A.1.3 Plasma Thruster Technologies

Indigenous development of Helicon Plasma Thruster: A helicon plasma thruster and its characterization facility has been indigenously developed at the institute (figure A.1.10). Such thrusters offer higher specific impulse and long lifetimes as compared to many other thrusters for space applications. The facility uses a 5 kW, 13.56 MHz RF source coupled to the plasma using a helicon antenna. Thrust measurement is done using an indigenously-developed & calibrated strain gauge thrust sensor. Three types of magnetic nozzle configurations are employed for thrust performance studies. By using only electromagnet with an axial magnetic field of 1.5 kG, with argon gas feed and a 50 mm dia plasma source, the thruster has so far yielded 40-60 mN thrust. Only permanent magnet operation with magnetic field (axial field ~ 1.2 kG & surface field ~6 kG) with different configuration appears to be yielding higher thrusts (50-70 mN). Further, combination with permanent magnets and electromagnets with axial magnetic field ~2kG, thrust above 90 mN is achieved.

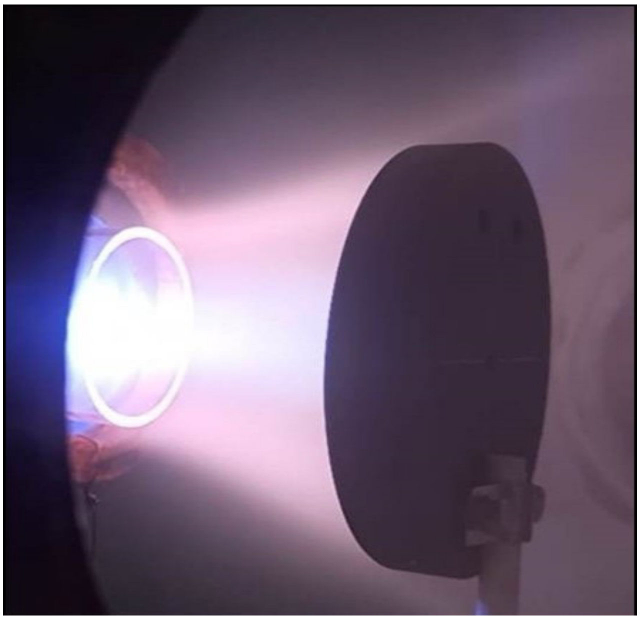


Figure A.1.10: Helicon Thruster under operation.

A variety of plasma diagnostics are under installation & testing phase, Langmuir probes for measuring axial profiles of plasma density and temperature, Mach probe for ion velocity, retarded field energy analyzer (RFEA) for ion energy distributions and optical emission spectroscopy. A new 10 kW helicon source device is now under development.

Plasma erosion characterization of anode liner material for plasma thruster: Plasma Thrusters are used in satellites for changing orientation, changing orbits, etc. Currently used thrusters are coated with Boron Nitride ceramic. Ceramic erosion by ions is a major problem in thruster. Hence a material erosion study is crucial. This requires in-depth understanding of Plasma Physics and Material Science. Under an IPR-VSSC MoU, institute has set up a low-energy ion beam facility. Under this MoU a Low Energy Ion Beam facility (figure A.1.11) equipped with Kaufman ion source of 100-1200 eV energy was developed for in-situ erosion measurement using QCM sensor to test the ceramic material developed by VSSC under Hall Effect Plasma Thruster (HEPT) operating conditions.

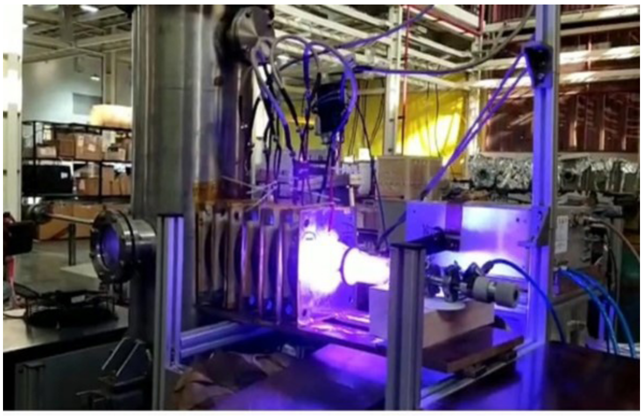


Figure A.1.11: Thruster facility.

A large number of long duration experiments were performed, and erosion behaviour & sputtering yield was noted along with other surface characterisations at various ion energies, angles of incidence, temperature & fluence for various materials developed by VSSC/ISRO. This helped to validate & qualify the developed material for indigenously developed plasma thrusters by ISRO, which will be used in forthcoming missions.

The eroded surfaces are characterized in terms of surface roughness and compositional changes in material both at room and high temperature upto 650°C (figure A.1.12). ISRO has been working to indigenise the anode liner material since long time. With joint efforts the material is finally developed and showed 20% less erosion compared to the imported anode liner material maintaining all other required properties. To celebrate this achievement, a technology handover ceremony was arranged on 27.12.2021 by VSSC in presence of Director VSSC, Director LPSC (Bangalore and Thiruvananthapuram), Director CEERI, M/s Bhukhanvala Pvt.Ltd and Dean, Head PSED and APD of the institute.

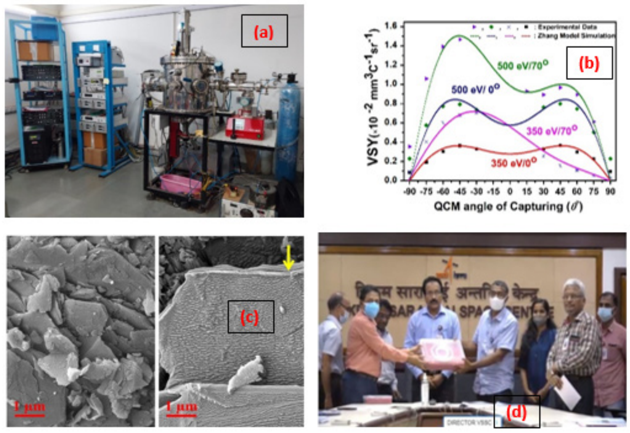


Figure A.1.12: Low Energy Ion Beam Facility (a), Volumetric Sputtering Yield (VSY) profiles (b), SEM images of sample before and after irradiation, and Variations in Erosion rate with temperature, Machined Anode Liner material for the annular channel for 300 mN SPT (c), Technology handing over ceremony to LPSC in presence of Director VSSC (d).

A.1.4 Other Technologies

<u>Nanomaterial Development:</u> A novel, clean plasma technique is developed, for high-rate production of molybdenum-oxide nanomaterials with controlled phase/stoichiometry and surface oxygen-vacancies, through a one-step, integrated oxidation/hydrogenation process. Oxygen radicals in a thermal-plasma beam, promote rapid oxidation of a molybdenum target and sublimation of the oxides, out of which metal-oxide nanostructures are nucleated through gas-phase condensation process. The beam is also seeded with low-energy H radicals that intercalate

into the top layer of the condensing molybdenum-oxides, producing dark-blue coloured, nano-flake and nano-ribbon structured MoO_3-x up to 194 g/h. Stoichiometric α-MoO_3 is produced maximum up to 750 g/h while using only oxygen.

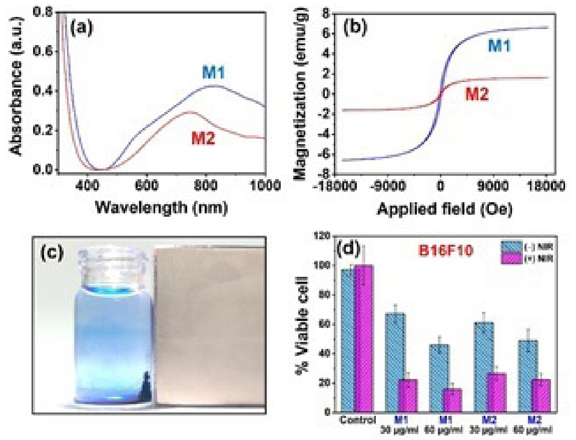


Figure A.1.13: (a) UV-Vis spectra of sample MoO_3-x M1 (7.8 kW, O_2: 5 lpm, H2: 2.5 lpm) and M_2 (17.3 kW, O_2: 5 lpm, H_2: 5 lpm); (b) Hysteresis loop of M1 and M2; (c) Magnetic separation after MB dye adsorption by MoO_3-x and (d) Bar graph representing cell viability of melanoma (B16F10) treated with MoO_3-x nanomaterials.

The nanometric MoO_3-x is very stable against oxidation under atmospheric exposure, perfectly dispersible in a solution even without a surfactant, and characterized with intense absorption of light over the near infrared (NIR) attributed to the localized surface plasmon resonance (LSPR) (figure A.1.143(a)). The controlled surface hydrogenation endows the nanomaterials with robust room-temperature ferromagnetic behaviour (saturation-magnetization 6.58 emu/g), which is one of the strongest reported for nanomaterials induced through surface engineering of defects (figure A.1.13 (b)). The as-synthesized nanomaterials are characterized with large negative Zeta potential (maximum up to -54 mV), which can very efficiently remove cationic dyes from an aqueous solution, both with fast rate and large maximum adsorption capacity (1044 mg/g) (figure A.1.13 (c)). Being ferromagnetic, the nanoadsorbents may be separated from wastewater by a simple magnet. In-vitro experiments, carried out at National Institute of Pharmaceutical Education & Research (NIPER) Guwahati, confirm that the photonic nanomaterials may be most ideal for treatment of melanoma cancer through the photothermal therapy (PTT) (figure A.1.13 (d)). They are perfectly compatible in animal physiological environments, and can be manipulated with a magnetic field for targeted delivery to a tumour. The light induced degradation behaviour of this nanomaterial ensures that they are easily excreted out of the body, avoiding the chances of long-term toxicity to other healthy body parts.

<u>Linear Induction Motors (LIM) for Electro Magnetic Launching (EML):</u> Electromagnetic launchers (EML) are being developed to accelerate various projectiles to high velocities which are generally difficult and less efficient to achieve by conventional system. Technologically matured EMLs may find wide use in defense applications like aircraft (~45 Ton) launching from naval ships and in industry for conveyer belts, mass transit systems, hyper-loop, rock pulverizing in mines etc. Institute is developing an Electro Magnetic Launching (EML) system (figure A.1.14) with an objective to accelerate a 100 kg payload to the speed of 20 m/s with an acceleration of ~60 m/s^2. The required force (8kN) for launching the payload, is generated by Linear Induction Motor (LIM), which is the major component of the system. Prototype development of 12N and 150N LIM based EMS have already been successfully tested in two phases. Final phase EML design using 8kN LIM sets, has been completed. Procurement of LIMs, components and outdoor experimental site preparation are initiated.

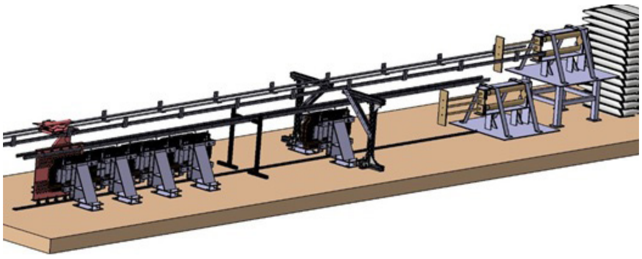


Figure A.1.14: Major Components and assembly of the EML system.

Pulsed Disk Alternator (or Fly wheel based compulsators): Compulsators (Pulsed Alternators) are popular choice as power source for high-end railguns, Reluctance Coil Guns (RCG), central Solenoid for tokamak etc. The Compulsators can also be used to power other pulsed energy applications in R&D. Flywheel is the technology to meet sudden load demand. The kinetic energy of a rotating object depends on the mass of the object, the shape of the object and the square of the speed of rotation. Hence, compulsators are designed for high speed and to have very light rotors. The windings of a compulsator are designed for minimal inductance compared to that of normal alternator. Air core is used as they do not operate in continuous mode. The pulse shape is controlled by controlling the phase angle at which each of the phases is triggered into the load.

The prototype development of compulsator is planned in 3-Phases. In Phase-1, low power input drive motor (5.5 kW) drives a flywheel (made of carbon steel) of mass 230 kg to 3000 rpm in about 1000 seconds which would supply pulse power of 1.7 MW for 6 ms pulse duration resulting in 10.6 kJ of energy. Any series and parallel combination can be used to achieve desired AC voltage and current. The estimated technical parameters are listed in Table-A.1.1.

Table A.1.1: List of typical parameters of Compulsator system in 3 phases.

Sr.No.	Pulsed Power required	Extracted electrical Energy (kJ)	Time Duration	Current (I)	Voltage (V)	Change in the speed	Remarks
Phase-1	1.77 MW	10.6	6 mS	4277 A	415 V	6.87 RPM	230 kg (Mild Steel flywheel) at 3000 RPM.
Phase-2	5.4 MW	32.4	6 mS	13012 A	415V	15.66 RPM	110 kg (Carbon Composite Flywheel)at 7000 RPM
Phase-3	10.8 MW	64.8	6 mS	26024 A	415V	15.66 RPM	Operation of two # Phase-2 systems together.

The objective of prototype development of Compulsator is aimed at understanding of electrical parameters inductance and resistance, optimization of air gap and permanent magnetic field strength, solid state switching devices for high current, operational difficulties, use of carbon composite material for flywheel, dynamic behavior of flywheel, weight optimization for deflection of shaft, impact of braking torque on shaft, safety concerns etc. COMSOL simulation has been carried out for Phase-1 Compulsator for estimation of output voltage and current.

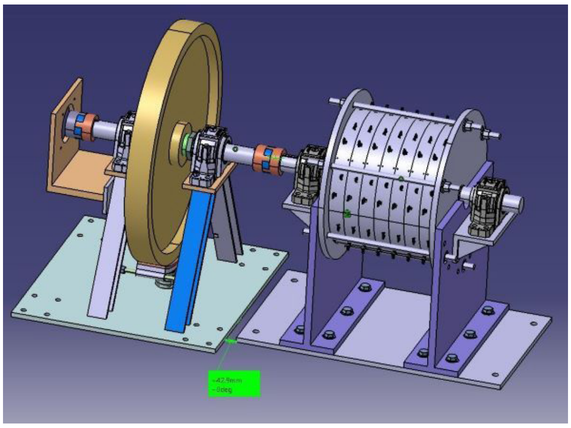


Figure A.1.15: Configuration of the Flywheel with Pulsed Alternator system in Phase-1.

The configuration of the Flywheel with Pulsed Alternator of phase-1 is shown in figure A.1.15. For the phase-1 system, Flywheel with Variable Frequency Drive (VFD) has been procured and installed in Pulsed Alternator laboratory. Procurement process is initiated for the Pulsed Alternator.

Application of Cold Atmospheric Plasma Jet for Oral Cancer Treatment: Institute in collaboration with the Tata Memorial Cancer (TMC) Mumbai, has studied the use of Cold Atmospheric Plasma (CAP) Jet on oral cancer cells. The active radicals generated in CAP Jet treatment have been found to shrink cancerous cells and showed potent effects. The study has recently been published in “Effect of Cold Atmospheric Plasma Jet and Gamma Radiation Treatments on Gingivobuccal Squamous Cell Carcinoma and Breast Adenocarcinoma Cells”, in the journal Plasma Chemistry and Plasma Processing (2021). More detailed studies are in progress to see if this can become a new tool in the fight against cancer.

Rapidly-reconfigurable plasma antenna array: Plasma is well known for its re-configurability and dynamic behavior. Because of this, plasma has several commercial applications. One of them is to use plasma column as a conductor in antenna for wireless communication. Instant on/off capability, highly re-configurability, electrically controlled and variable impedance has lead to use of plasma- for application in normal antenna, Wi-Fi communi-

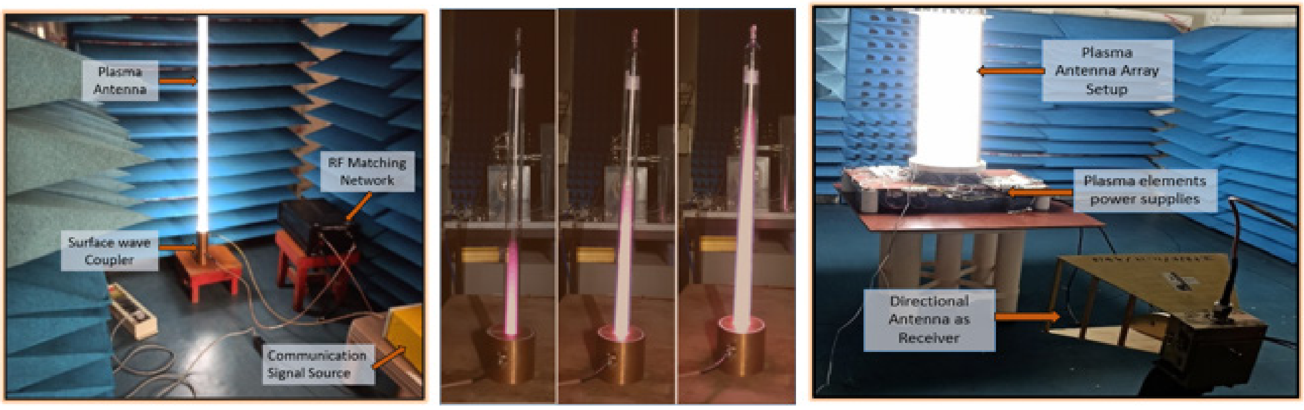


Figure A.1.16: Reconfigurable plasma antenna system and Plasma antenna array system.

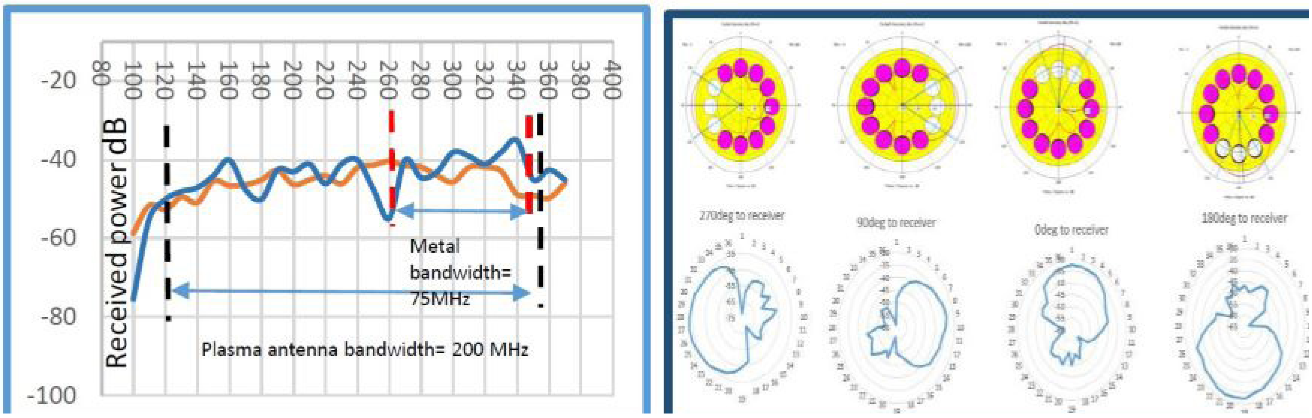


Figure A.1.17: [L] Bandwidth of monopole metal antenna and plasma antenna, [R] Plasma antenna array steering 360^0.

cation, radar application and wide band frequency antennas. Institute has successfully developed reconfigurable plasma antenna system for wireless communication. The plasma column in the system acts as monopole antenna and transmits and receives the signal successfully. The surface wave coupling method used for producing the plasma helps for better communication and efficient power coupling.

Plasma antenna system developed in the institute has no electrodes and therefore no plasma contamination. The surface wave can be excited by a very compact wave launcher which covers a very small portion of the discharge tube, the RF power being carried to the rest of the column by the propagating wave. A system with glass tube is developed with electrode less discharge at 13.56MHz by the RF power supply and is capable to transmit through the plasma antenna system (figure A.1.16). Experiments are performed with glass tube of different diameters. Finally a compact 12V battery operated plasma antenna system is developed where all the parameters are flexible. Institute has developed plasma antenna array also to scan 360^0 for communication without physically moving the system (figure A.1.17). This will help to find direction of communication by steering the communication window.

Application of Cold Atmospheric Plasma Jet for Oral Cancer Treatment: Institute in collaboration with Tata Memorial Cancer Center (TMC), Mumbai, has studied the use of cold atmospheric plasma (CAP) jet on oral cancer cells. The active radicals generated in CAP jet treatment have been found to shrink cancerous cells and showed potent effects. The study has been recently published in a reputed journal dealing with plasma chemistry and processing. More detailed studies are in progress if this can become a new tool in the fight against cancer.

A.1.5 External Projects

A) PROJECTS COMPLETED				
Sr. No	**Organisation**	**Description**	**Deliverables**	**Status**
1	Persapien Innovations Pvt. Ltd.	Technology transfer for Plasma activated water generation system	Transfer of knowhow & licence	Technology transfer agreement was executed on 6th Sept, 2021.
2	TBRL, DRDO	Modelling of pulsed detonation engine.	Code development & validation against literature & TBRL expts – handing over the code to TBRL	A simulation code was developed and delivered to TBRL.
3	CCMB, Hyderabad	Testing of portable plasma jet for anti-viral properties against COVID-19 virus	Prototype for testing	Reports from CCMB received. The portable plasma jet device found effective for sterilizing bacterial species (E. Coli, P. Aeruginosa) (10^6 log reduction) and covid-19 viruses (89% reduction).
4	IIT Gandhinagar (IMPRINT – MHRD)	Advanced nano tracers for product life cycle assessment & product monitoring	Process development of isotopic nanoparticles. Delivery of iNP.	Institute's scientific aspect of the project work is complete.
5	Science and Engineering Research Board (SERB), New Delhi	Development indigenous Technology for CZTS absorber based solar cell using industry friendly magnetron sputtering and RTP sulphurization process	Scientific/Technical report	Project completed in March 2022.
6	VSSC, ISRO	Plasma erosion Characterization of anode liner materials	Material Characterization report with erosion studies.	All the tasks as per the scope specified are completed successfully. Final report prepared and submitted to VSSC.

B) PROJECTS STARTED

Sr. No	Organisation	Description	Deliverables	Status
1	ITER Organization	EMC3-Eirene simulations of main chamber recycling on ITER	Simulation reports for recycling	All the tasks for the main service contract completed. As per the requirements from ITER organization, the scope of work in the original agreement is increased with duration.
2	Accumax Lab Devices Private Limited	Feasibility study on surface activation of polystyrene using low pressure plasma	Feasibility study report	Experiments and characterization are in progress.
3	ITER Organization	Radiation calculation support for penetration working groups	Report on activation	Subtasks 1 & 3 are delivered and reports are submitted. Activities on subtasks 2 & 4 are initiated and in progress.
4	Science and Engineering Research Board (SERB), New Delhi	Design and development of anti-UAV (Unmanned Aerial Vehicle) system	Anti-UAV system	Conceptual design of the system is completed. Procurement is under progress.
5	Indian Council of Medical Research (ICMR)	Development and validation of Artificial Intelligence Tool for Screening/detection of pulmonary TB and other lung disease using chest X-ray	Artificial Intelligence software for Screening/detection of pulmonary TB and other lung disease	NIRT has provided the data for training of software. The Software optimization has progressed well and is further being implemented.

A.2 Fundamental Plasma Physics

Naturally occurring plasma is found in abundance in our universe and interacts with us directly or indirectly in our day to day life. Plasma is also being created in laboratories, characterized in various conditions so as to explore its fundamental nature, properties which can be later used for various applications in society, industry and power plants. Here, it is being studied in starting from very small scale laboratory experiments as well as in moderately bigger size systems like Large Volume Plasma Device. Apart from these, several fundamental plasma experiments have come up with versatile ideas to cater various physics issues.

A.2.1 Large Volume Plasma Device (LVPD) – Upgrade

This year has been eventful for Large Volume Plasma Device (LVPD) as it has seen major developments towards its transition to LVPD – Upgrade. Recent up-gradations include new installations and operation of large area multi-filamentary plasma source (LAMPS) (figure A.2.1), discharge power supply (DPS) (1kA-100V) and solenoid power supply (SPS) (2.5kA-175V). The plasma pulse duration has been enhanced by more than 5 times to 50 ms from existing 9.2 ms. The DPS and the SPS are successfully tested for the desired pulse duration of 50 ms and 55 ms respectively. The plasma density in LVPD-U is envisaged to increase from ~10^{11} cm^{-3} to typically ~10^{12} cm^{-3} by the augmentation of LAMPS. Beside these developments, LVPD has move further in automation of its plasma source operation, temperature monitoring and controls by adding new features in LabVIEW platform. Major initiatives have been taken in consolidation of system parameters, experimental requirements, real time feed-back scenarios, I/O selection towards the procurement PLC - SCADA system for process system automation of LVPD-U. Apart from these, the device has produced some interesting physics results, firstly, identifying whistler waves as a tool for the mitigation of high energy electrons and secondly, novel observation of density depletion with time in the domain of cross field transport. Our study and results on the mitigation of energetic electrons in LVPD with whistlers in low temperature plasmas have parallels and has

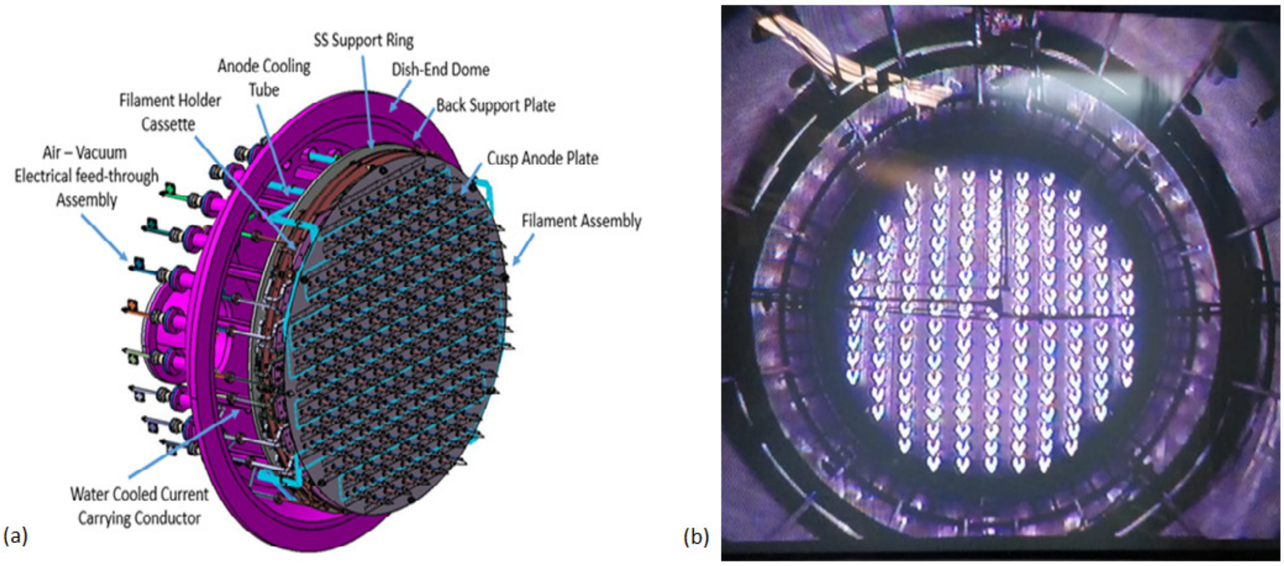


Figure A.2.1: The 3-D model of the LAMPS(a) and the photograph of LAMPS in operation with all its 162 filaments(b).

physics significance to physics of runaway mitigation in tokamaks.

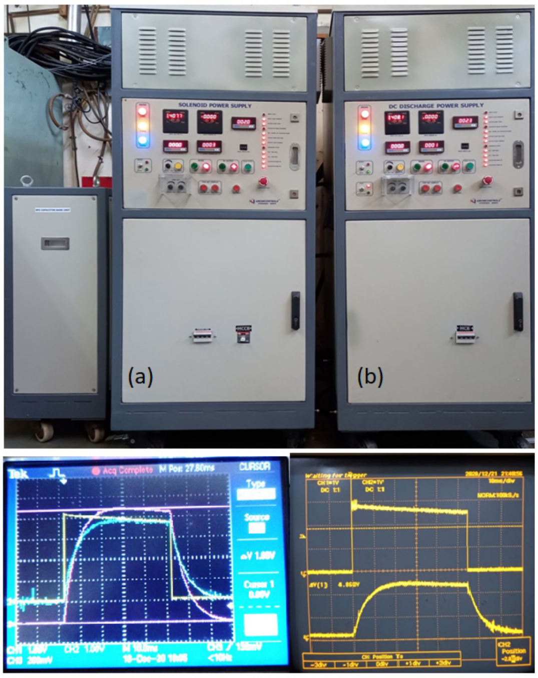
The LAMPS has produced circularly symmetric plasma and the source consists of 162 numbers of tungsten filaments (dia= 0.5 mm and L=180 mm) mounted on 324 numbers of Molybdenum current feedthroughs. The water cooled copper anode plate (dia =1.8 m, d=2 mm), holds magnet channels containing samarium cobalt permanent magnets (B~0.4 T). A matrix (X-Y) of 15 numbers of K- type thermocouple is mounted to monitor the temperature distribution on the back of the anode plate due to the plasma source.

The first plasma discharge in LVPD-U is produced by charging filaments to 3.2kA current at a voltage drop of 15V feeding net 48kW of electrical power. The filaments are heated by using filament power supply of rating 10kA/20V. The Argon plasma discharge current of 1kA is obtained for a time duration of 50 ms. A SCADA system for supply, installation, development and commissioning of Process Automation System for Large Volume Plasma Device Upgrade (LVPD-U) has been designed and tendered. The LVPD operations have been shifted to e-logbook mode. For this a digital platform is developed for meeting the requirement.

LVPD has already reported excitation of Quasi-Longitudinal (QL) whistler turbulence driven by reflected (energetic) electrons from a magnetic mirror like configuration. This work was aimed to correlate the physics of whistler's interaction with runaway electrons although the energy levels are significantly differing.

The results focussed on saturated whistler mode (normalised) growth parameter with the electron energy. The discharge potential is systematically varied between 50V<VD≤90V in the experiments to control the energy of electrons. Within the experimental limitations on applying the discharge potential, shifting and narrowing of the whistler

mode frequency towards low-frequency side is observed when the energy of the electrons is increased.



(c) (d)

Figure A.2.2: Two LVPD_U power supplies are shown in (a) and (b) respectively. The figures (c) and (d) shows testing results of power supplies with dummy loads.

It is also observed that the value of the perpendicular wave vector (k_perp) reduces while parallel wave vector (k_para) increases with increase of particle energy in accordance with whistler wave dispersion (figure A.2.3). This suggests that the whistler mode propagation is becoming less oblique. The wave amplitude also has shown the similar trends which leads to the deviation in the resonance condition of wave-particle interaction for different discharge voltages. We found that mode growth rate is inversely proportional to the square root of electron temperature ($\gamma_i \;\alpha\; T_e^{-0.5}$) whereas in tokamaks, analytical models predicted the growth rate threshold on a larger power of the background plasma temperature ($\gamma_i \;\alpha\; T_e^{-1.5}$). The measurements to obtain energy scaling of runaway electrons with whistler instability is rare, we provided an analytical comparison of the threshold provided in past reported work for tokamaks was provided.

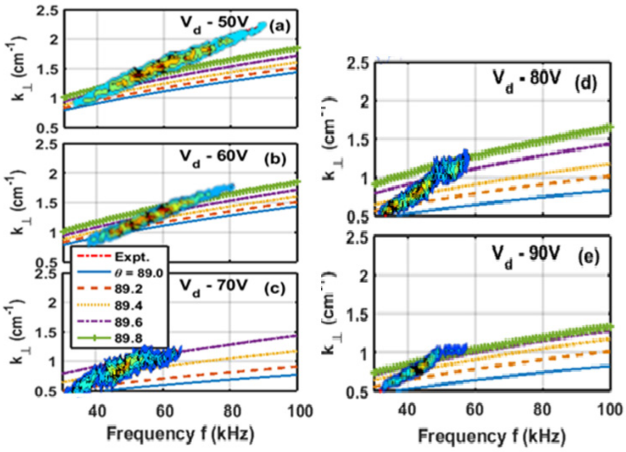


Figure A.2.3: A comparison of the estimated value of perpendicular wave number with experimentally obtained values (red line) is plotted for different wave frequencies at different propagation angles.

A.2.2 Non-Neutral Plasma Device (SMARTEX-C)

SMARTEX-C experimental setup has been operated at low injection energies of 50V to 100V at an improved background neutral pressure of 4.0 x 10^{-10} mbar and a B-field of 200 Gauss. Injector shield box has been re-designed for improved inter-electrode insulation and has been installed in the trap. Confinement time experiments at these parameters have been carried out by finding total stored charge evolution using excitation of diocotron waves. These experiments have been performed with finest reproducibility to bring error-bar in confinement time to be less than 5%. Dependency of confinement time with background neutral pressure, filament potential and B-field has been carried out for some range of parameters and is still in progress.

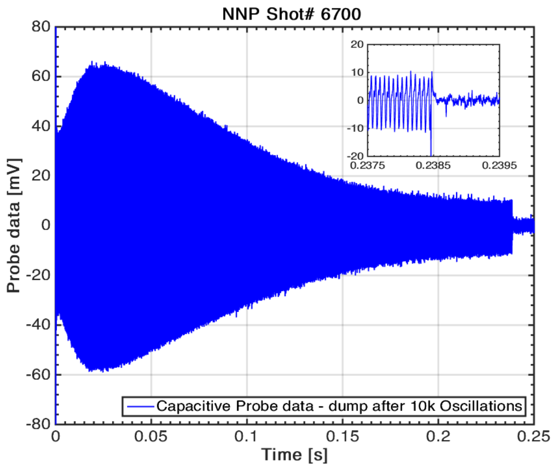


Figure A.2.4: Plasma dump after 10k oscillations assisted by feedback from capacitive probe diagnostics.

In addition to this, charge collector diagnostics has been revived for this long-lived plasma. With the help of FPGA based trigger-box, plasma dumping can now be executed by feedback from capacitive probe diagnostics. This feedback based dump is based on the detection of zero-crossing of capacitive probe data and thus allows the phase locked dump of the plasma. This is expected to provide high reproducibility of charge measurement on charge collection diagnostics. Figure A.2.4 shows an example plasma shot, where plasma is dumped after 10k oscillations.

Efforts to develop a preliminary electronics circuit to measure ion current of few pA with 2pA of noise floor was developed and tested on the experimental set-up. In the presence of large leakage current from the filament assembly, the ion current could not be delineated. Measurement of injection current from filament has been carried out in SMARTEX-C device. Emission current from filament, injector grid current, inner wall current and collector grid current are measured using resistive technique corroborated by measurement on current transformer. The measured current is a function of filament bias, magnetic field and filament current. Transparency of injector grid has been estimated to be >50%. High impedance Langmuir probe diagnostics has been tested for electron plasma and estimation of injected electron cloud potential is underway. Measurement at different radial positions has been carried out and data-analysis is under progress.

Development of PLC Based baking system: PLC based controlled baking system for SMARTEX-C is developed and integrated with the system. Baking system is tested for 36 hours of steady baking of the vacuum vessel at 175 ^{0}C with ramp-up time of 6 hours and ramp-down time of 5 hours. RTD sensors are used to monitor the temperature of the vacuum vessel at multiple locations. The uniformity of the temperature with the help of Silicone based rubber heaters have aided to improve the vacuum of the system to 1.0 x 10^{-10} mbar.

Development of a test setup for the imaging of the trapped charge: The test setup consists of a vacuum chamber, rotary pump, tungsten Filament, power supply to heat the filament, a phosphor biasing HVAC transformer, current, voltage and vacuum measuring instruments, a stainless-steel lookalike of Phosphor target (151mm × 282mm × 2mm) as anode (figure A.2.5).

Construction of a new vacuum vessel for SMARTEX-C: A new vacuum vessel for SMARTEX-C is designed and fabricated (In-house) for performing electron plasma experiments with improvised pumping port targeting for vacuum better than 10^{-10} mbar. The vessel is vacuum tested for leak rate < 1.0×10^{-8} mbar litre per second (figure A.2.6).

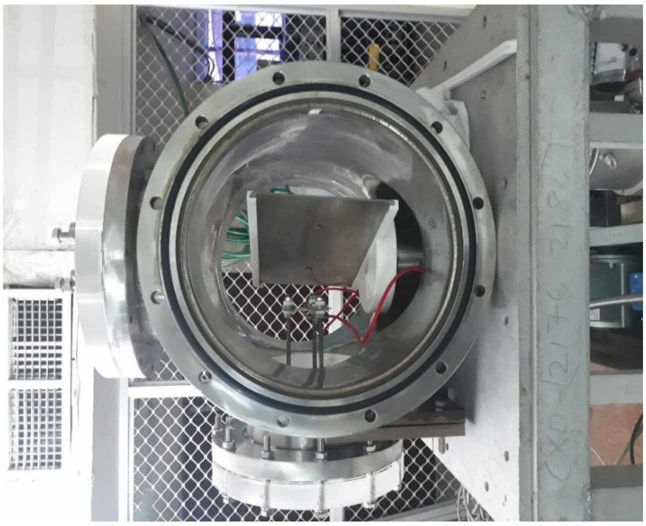


Figure A.2.5: Photograph of a test-setup for imaging diagnostics.

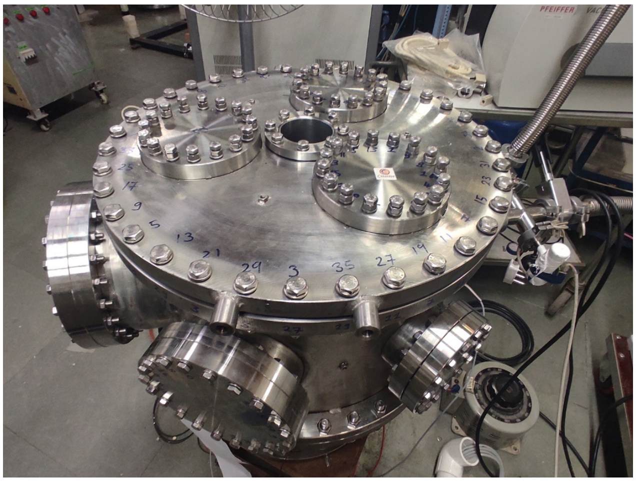


Figure A.2.6: Construction of new vacuum vessel for SMARTEX – C experiment.

Support structure for this vacuum vessel, compatible with copper bus-bar based TF coil is also designed and is under fabrication.

A.2.3 Multi-Pole Plasma Device (MPD)

In typical filamentary produced argon plasma in Multi-pole Plasma device, perturbation studies are being done to explore the nonlinear regimes. For this, a high amplitude perturbation voltage (~20V) is applied to the exciter with a frequency of 90kHz. The propagation of this perturbation is observed to have solitary nature. This propagation is then studied by varying the various system parameters. Plasma was perturbed by different types of waves, i.e., single-pulse sinusoidal wave, half-sine wave, and continuous sine wave. Since the solitons are governed by a nonlinear wave equation called Korteweg de Vries (KdV) equation, the propagation of above mentioned solitary wave was characterized accordingly. The velocity and width of these solitons are measured experimentally and compared with the 1-D Korteweg-de Vries equation. The soliton velocity is obtained by time of flight technique from the data obtained in the set of probes placed at known distances and the width is calculated from the Full Width at Half Maximum (FWHM) of the measured temporal evolution. To further confirm the solitary nature of the propagation, two identical solitons were excited simultaneously and their interaction was studied. For this, two exciters were kept such as to excite two solitons are counter-propagating towards each other. The interaction zone of these perturbations was studied using the similar set of probes and the solitary nature of the waves was confirmed as the two solitons were found to overlap, collide, and pass through each other without losing their identities. In these experiments, the soliton was excited in the field-free region of the device where all the plasma parameters are uniform, and the applied cusp magnetic field value is minimum or zero. In addition, ions are also unmagnetized in this region. It is experimentally observed in MPD that the excitation and propagation of solitons are influenced by the value of the field at pole cusps. The amplitude of the solitons are found to increase with field up to some value (~0.6kG with = 80A) and then it is found to be decreasing with the further increase in field values.

A.2.4 Basic Experimental Toroidal Assembly (BETA)

In BETA, the plasma discharge current is about 5 Amperes. Hence, the magnetic field produced by plasma current is negligible and hence is often called as "current-less" toroidal plasma device. Here the confinement of particles and energy is only due to external magnetic fields :- toroidal and vertical fields. In BETA (aspect ratio R_0/a = 45cm/15cm) device, there are presently two plasma sources (a) hot cathode (tungsten filament) and (b) electron cyclotron resonance (ECR) sources. Presence of toroidal geometry, radial gradients in plasma density, electron temperature and toroidal magnetic field (B_phi) naturally provide free energy sources for the instabilities and transport. Presently, toroidal confining magnetic field lines and absence of rotational transform (B_theta = 0) of low temperature (T_{e0} = 5eV) plasma in BETA produces main features of the magnetic field geometry at tokamak scrap-off-layer. External rotational transform or external-q ($q_{ext} = rB_{phi}/RB_{theta}$) experiments have been planned in BETA to study electrostatic instabilities in presence of externally produced quasi-concentric current-less flux surfaces by charging a toroidal current-carrying copper conductor at the minor axis (r = 0) of the vacuum vessel. To generate the external poloidal magnetic field (B_{theta}), a toroidal conductor and its support structure has been designed. For these experiments, a 1kW/2.45GHz magnetron source based ECR system has been developed. In addition to this, a Reynolds-stress probe has been installed for the measurements of fluctuations induced flows during these experiments. Currently, fabrication of copper conductor is underway, and Reynolds-stress probe and its biasing circuits are being tested.

A.2.5 Dusty Plasma Experiment Device (DPED)

Thermodynamics and self-organization of classical 2-d coulomb clusters – an experimental study: Atomic or nanoparticle clusters have properties very different from bulk materials. Cluster science is an active field of research due to applications in nanotech & colloidal science. Dusty plasmas can be employed to study cluster science by creating 1-D, 2-D or 3-D finite classical Coulomb clusters. Dusty plasma is a multi-component system consisting of neutrals, electrons, ions & highly charged massive dust particles. The thermodynamics and self-organization of classical 2-D Coulomb clusters are studied as function of cluster size. Experiments were carried out in DC glow discharge argon plasma, for clusters with different numbers of particles. Hexagonal symmetry around each individual particle is quantified using local orientation order parameter for different particle configurations. The screened Coulomb coupling parameter, which plays a key role in determining the thermodynamic nature of a Coulomb cluster, is estimated using Langevin dynamics and found to be sensitive to the cluster size. The process of self-organization and dynamics of plasma cluster, while changing from metastable to ground state, are studied. These findings may provide an intimate link between configurational ordering and thermodynamics of strongly coupled Coulomb cluster systems, and could be helpful in analysing and controlling micro-dynamics of micro and nano-particle clusters having applications in medicine, sensing, electronics, etc. This work has been recognized and put on the cover page of the journal Physics of Plasmas in July 2021 (figure A.2.7).

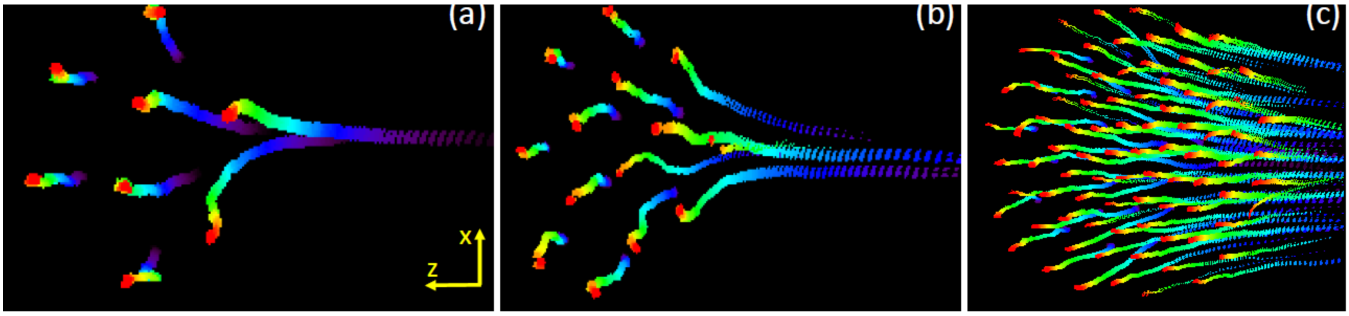


Figure A.2.7: Addition and self-organization of dust particles in a dusty plasma produced by DC glow discharge.

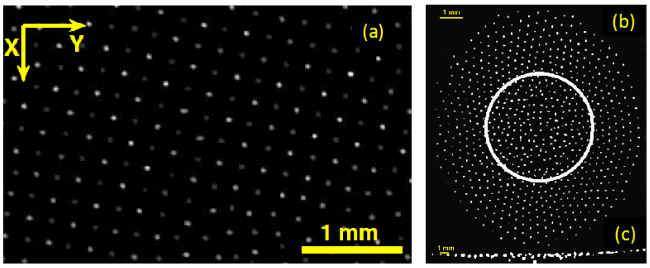


Figure A.2.8: Typical camera images of a) the formation of square lattice, and b) coexistence of crystal-liquid states.

Experiments in DC Coulomb Crystal: The unique asymmetric electrode configuration of Dusty Plasma Experimental (DPEx-II) device facilitated to create spatially extended stable large sized DC complex plasma.

a) Formation of square lattice: First observations of a square lattice formation in a mono-disperse complex plasma system - a configuration transition phenomenon that has long been an experimental challenge in this field is studieded in the system. By carefully controlling the vertical potential confining the charged particles as well as the strength of the ion wake charge interactions with the dust particles the system could be steered towards a crystalline phase that exhibits a square lattice configuration (figure A.2.8a). The transition occurs when the vertical confinement strength is slightly reduced below a critical value leading to a buckling of the mono-disperse hexagonal 2D dust crystal to form a narrowly separated bilayer state (a quasi-2D state). Some theoretical insights into the transition process are provided through Molecular Dynamics (MD) simulations carried out for the parameters relevant to this experiment.

b) Phase-Coexistence: In this experiment the transition of a 2D dust crystal to non-equilibrium solid-liquid phase coexistence is observed. The experiments have been carried out in an L-shaped Dusty Plasma Experimental (DPEx-II) device in a DC Argon glow discharge plasma environment. Initially, a monolayer of crystalline structure is formed which later transforms to a two-phase coexistence state using pressure as a control parameter. It is observed that a molten centre coexists with a solid periphery. Various structural and thermodynamics quantities are used to define the phase state of the system. Self-excited horizontal oscillations are found in the centre of the monolayer prior to the appearance of coexistence state. To investigate the ranges of phase coexistence, a detailed parametric study is also undertaken. It is found that the combination of non-reciprocity and presence of few stray particles beneath the top layer is responsible for this observed phenomenon.

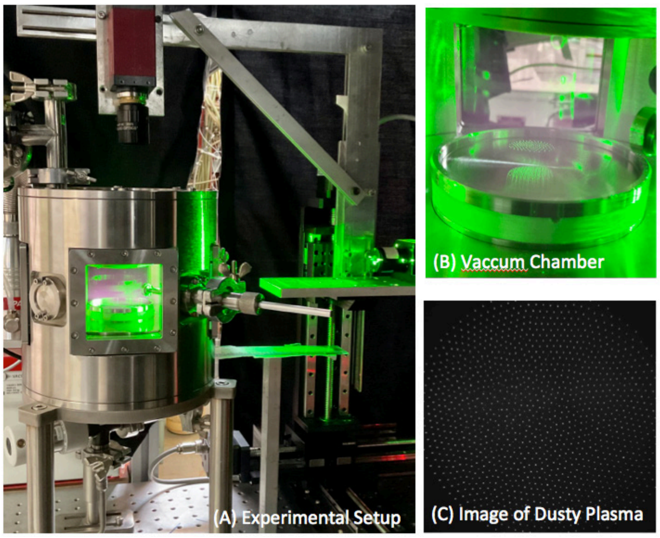


Figure A.2.9: a) An image of RF device, b) The close view of vacuum chamber and the levitation of dust particles and c) camera image of dust lattice.

Experiments in RF dusty Plasma: A new experimental device to study complex plasmas in radio frequency (RF) discharges is designed, fabricated and commissioned at the institute (figure A.2.9). The glow discharge plasma is produced by applying an RF power between two parallel plate electrodes in the Argon gas environment. The complex plasmas are then produced by introducing mono-dispersive micron sized Melamine Formaldehyde dust particles into the plasma. These particles get negatively charged due to high mobility of electrons and forms complex plasma interacting via shielded Columbic interaction. The system is equipped with fast imaging camera for recording the time and space dynamics of complex plasma from particle level. The objective of the device is to study various problems involving statistical physics of fluids and non-equilibrium processes at microscopic scales.

Experiments in flowing dusty Plasmas: In another set of experiments with flowing dusty plasma in DPEx device, the flow is generated in the dust fluid by using single gas injection technique. This is carried out by using a gas pulse valve. Two detailed experiments on the trapping of waves and the KH instability were performed, which are discussed below in more details:

a) *Trapping of waves:* An experiment to demonstrate the trapping of dust acoustic waves in flowing dusty plasma is performed. The experiments are carried out in DPEx device in which the plasma is created in a DC Argon glow discharge plasma using micron size Kaolin particles. Two copper wires are installed radially on the cathode, one of the wire is used to generate flow in the dust cloud by changing its potential and waves are excited in the downstream direction of the flow when the dust fluid flow over the another wire. The potentials on these two wires serve as obstacles for the waves, which get trapped in between two wires. The amplitude of the waves and the distance between them are independent of the dust fluid velocity. The numerical solution of the forced Korteweg-de-Vries equation in which two source terms are used to trap the waves is explaining the experimental observation theoretically. Molecular dynamic simulation is also carried out to provide more theoretical support to the experimental observations.

b) *KH instability:* A controlled experiment is carried out to study the flow induced KH instability in a dusty plasma. A gas pulse valve is used to initiate a directional motion of the dust particles in a particular dust layer. The shear generated at the interface of the moving and the stationary layers leads to the formation of KH-vortices. Figure A.2.10 shows the velocity vector field along with the magnitude of velocity and a prominent vortex can be seen at the interface of two layers. An MD simulation is also carried out to compare the experimental results.

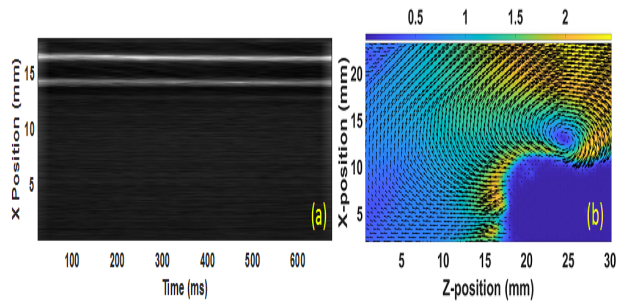


Figure A.2.10: a) The periodogram shows the two dust acoustic wave crests get trapped over the time, b) The formation of KH-vortex in a flowing dusty plasma.

A.2.6 Applied Plasma Physics Experiments in Linear Device (APPEL-Device)

The linear plasma devices are known as an open trap machines. They are cost-effective and a popular research tool, hence they are used world-wide to experimentally simulate edge plasma conditions. A variety of plasma physics studies can be conducted in linear plasma devices; such as: plasma detachment experiments, recombination, and plasma-wall interaction in the magnetic fusion device, turbulence studies can be performed in linear devices. Unlike in tokamaks, the linear device simplifies the geometrical complexities of the particle trajectories. Besides the open field line configuration provides a natural diverter at both ends, hence loading external components are much simpler. The new support structures for APPEL magnets are installed (figure A.2.11). Axial magnetic field for mirror and linear configurations is measured up to magnet current 400 A. Peak axial magnetic field of 0.2 T found at the centre of the device for magnets current 400 A. Magnetic field simulation has been conducted to optimize the external electromagnet coil configuration for the APPEL device. The simulation has been validated by measurements. A 3.5m helium plasma column has been produced in this setup using cold hollow cathode source and characterized using Langmuir probe diagnostics and electron density of the order of ~$10^{18}m^{-3}$ achieved in the device with magnetic field 50 mT. The device will be used for the basic plasma physics experiments such as electrode biasing effects on the E×B instabilities in magnetized plasma column.

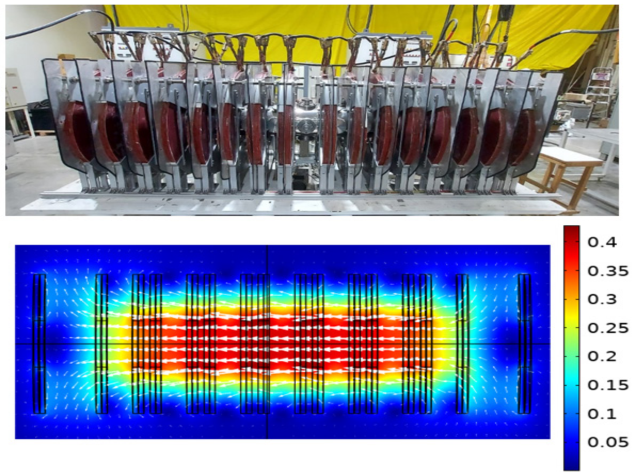


Figure A.2.11: Photograph for actual experimental setup for APPEL device (top), simulated magnetic field (T) configuration and photograph of actual plasma are shown (bottom pictures).

A.2.7 Basic Experiments in Axially Magnetized Plasma (BEAM Device)

Low temperature plasmas confined by axisymmetric magnetic fields of few 10's to 100mT in linear devices are considered to be highly favourable for studying wide range of plasma physics in laboratories. These plasmas have applications in material surface processing to the generation of positive/negative ion beams for plasma heating in fusion devices or used in interplanetary spaceship propulsion.

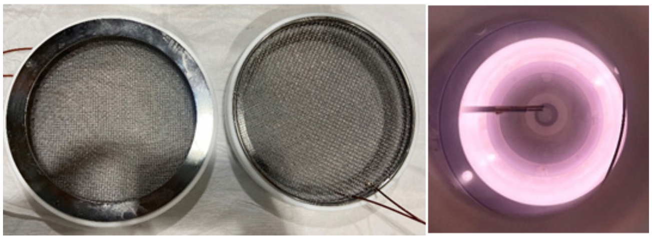


Figure A.2.12: Grid components and photograph of actual plasma in BEAM experimental system.

Besides complex plasma physics problems associated in fusion technologies such as magnetized plasma interactions with material electrodes or with background gas molecules, turbulence physics, charge particle confinement in magnetic fields can be exclusively studied in linear devices. In Magnetized Plasma Development laboratory, a novel plasma source based on capacitive coupled radio-frequency discharge with external magnetic field applied parallel to the RF sheaths has been developed. By increasing the magnetic field strengths, the positive ion flux and electron temperature distribution across the cross-section can be controlled. The device can be useful for extracting low energy ion beam for surface modifications on delicate substrates and also for enhancing volume production of negative ions. The above experiment is conducted in the BEAM experimental device (Basic Experiments in Axially Magnetized Plasma Device) (figure A.2.12) which has a Mass and Energy resolve analyser to study the energy distribution of ion beams extracted from this device.

A.2.8 Stimulated Phenomena in Negative Ion Plasma Experiments (SPIN-eX Device)

Plasma containing negative ions has very distinct characteristics than ordinary electron / positive ion plasma. To study the properties of such plasma, pulsed laser photo-detachment technique has been developed to diagnose negative oxygen ions in the SPIN-X experimental device (Stimulated Phenomena in Negative Ion Plasma Experiments (SPIN-X Device) (figure A.2.13). The photo-detached electrons are detected by a resonance hairpin probe placed in the laser illuminated channel.

Figure A.2.13: Experimental setup for SPIN-eX experiment.

A.2.9 Inertial Electrostatic Confinement Fusion (IECF) Device

X-ray emission from the IECF device and its application in radiography: Although, neutrons are the primary product of the IECF device, x-rays can also be produced from it while applying either positive or negative bias to the central grid. During the conventional operation in negative polarity of the central grid, the electrons are accelerated towards the chamber wall and as a result the bremsstrahlung radiation, or continuous x-rays, is produced due to electron-wall interaction. The emitted x-ray has been detected by using the NaI scintillator-based photomultiplier tube. The x-ray photon count is found to be increasing with the applied cathode voltage. Moreover, the spectrum seems to be broadened and the maximum photon energy extends all the way up to the applied potential range. On the other hand, in order to increase the x-ray emission from the device, the polarity of the central grid is reversed, i.e., positively biased. In this configuration of the device, the electrons are the ones that re-circulate across the grid openings just like the ions do during the negative polarity of the grid. These high energetic electrons accelerate and decelerate when they interact with the target (grid) atoms as a result of which the emission of x-rays takes place.

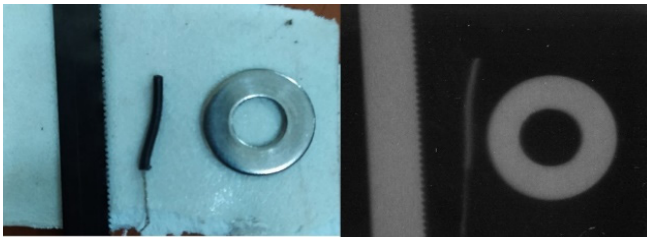


Figure A.2.14: X-ray radiography of some metallic samples during negative polarity of the grid.

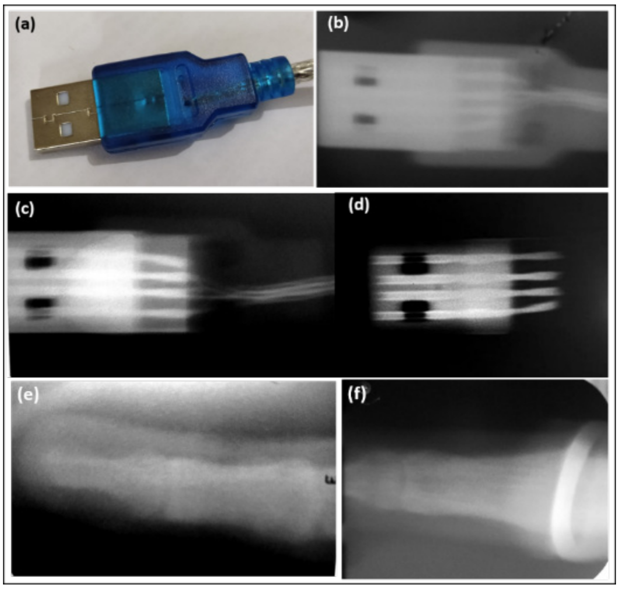


Figure A.2.15: (a) A USB plug used as a sample. Radiography images at (b) 25, (c) 35, and (d) 45 kV voltages. (e) image of the human little finger, and (f) the finger wearing a metallic ring.

After the successful detection of x-rays from the IECF device, the emitted x-ray has been utilized to perform radiography. Contact radiography is mainly performed in which the samples are kept in close contact with the photographic film. In the first case, the conventional negative polarity of the grid is employed, and the sample along with the film is attached to the glass window of the device. The radiography images exhibit good quality and intensity even if the x-ray source is comparatively broad. Figure A.2.14 shows the radiography images of some metallic specimen when operated at -70 kV for about 3 minutes. Figure A.2.15 (a-d) shows the radiography of a USB plug when the polarity of the grid is reversed (positively biased). The present study shows that the IECF device is not only a neutron source but also an effective x-ray generator that may be utilized as a highly efficient neutron/x-ray scanner in security facilities in the near future.

A.2.10 Inverse Mirror Plasma Experiment Device (IMPED)

Inverse Mirror Experimental Plasma Device (IMPED) figure A.2.16) (L = 3200mm, dia = 160mm) is dedicated to fundamental plasma experiments, investigating turbulence, flows, instabilities, and wave-interactions in collisional and collision-less magnetized plasmas. Contemplating the restricted steady operation window (8-12hrs) for the machine due to frequent breaking of tungsten filaments in the source, a centralized scheme for the operation and control of the device has been designed to allow multiple stakeholders to operate the machine from a single interface. Open source-based python routine has been implemented for system control, monitoring, and operation of various subsystems using a single terminal and initial integrated tests are successfully achieved. The new process automation software with server nodes operating at RS232, RS485, Modbus, and UART protocols will be unified with a single client using Ethernet protocol. A portable, robust, miniaturized, high vacuum compatible plasma probing system for precise automated spatial positioning is implemented during the year. The performance is validated for a linear scan of 0-80mm (maximum permissible travel length of 250mm) with ± 0.2 mm accuracy under the base vacuum of 10^{-6} mbar and magnetic field of 120 mT without any vacuum break. Extension of 12 such diagnostic systems with additional facility for angular rotation is incorporated, which shall accommodate all the intrusive diagnostics demands for IMPED diagnostics. A new Data Acquisition system capable of simultaneous high sampling (14MS/s) and long-time continuous acquisition is being implemented for wave interaction experiments to render relatively high temporal resolution for reconstructing the plasma dynamics. Multi-channel current - voltage (IV) and fluctuation measurement conditioning circuits are under test, which shall be soon integrated as a part of the system diagnostics. A diagnostic analysis package for semi-automated data analysis is in progress. A new buffer chamber with an improved pumping port for better vacuum conditioning and a revised source chamber is under fabrication

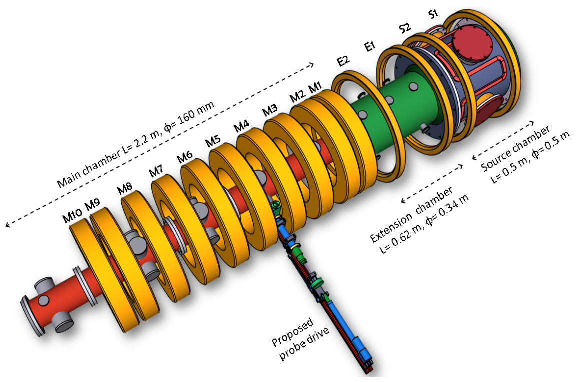


Figure A.2.16: Schematic of IMPED shown with magnet coil assembly and probe drive system.

A.2.11 System for Microwave Plasma Experiments (SYMPLE)

Attainment of microwave electric field parallel to the plasma density gradient: One of the critical requirements of the experimental investigations on microwave interaction with plasma taken up in SYMPLE (SYstem for Microwave PLasma Experiments) is with respect to having microwave electric field component parallel to the axial density gradient of the SYMPLE plasma.

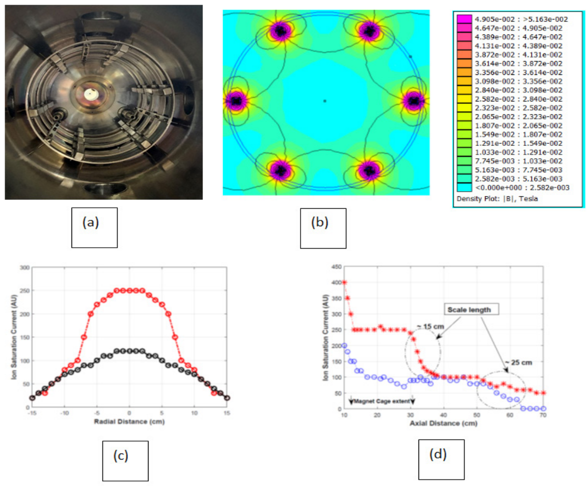


Figure A.2.17: Photograph of the magnetic cusp geometry in the actual experimental system (a), 2D simulated magnetic field profile (b) comparison of the radial plasma density profile (c) and axial density profile (d) with (red) and without (blue) employing the cusped magnetic field in the chamber.

This has been achieved with the help of a coupling scheme incorporating a specially designed and developed TE10– TM10 mode converter. This unit has been tested by coupling about 100W microwave power to the plasma chamber. Conversion of TE10 mode at the input port to TM10 prior at the output of the Mode converter has been experimentally verified in free space. Experiments were further carried out after coupling the power to the chamber to ensure attainment of wave electric field along the cylindrical axis of the chamber. The

SYMPLE system has microwave – plasma coupling system and we have measured axial density profile of plasma, designed the mode converter for electric field direction at the output port parallel to the plasma density gradient direction and the radial profile of the axial wave electric field has been measured within the plasma chamber and observed Ez peaking at the radial centre.

Plasma confinement using cusped magnetic field geometry: As requirement of having unmagnetized plasma for wave-plasma interaction studies prevents use of electromagnets for confinement, a permanent magnet based scheme is adopted, which enables the confining-field to be locally restricted to the inner chamber-periphery, retaining desired radial extent of central plasma column unmagnetized. As wave-absorption has critical dependence on scale-length of plasma density gradient, hence there is a requirement on controlling this factor, which is also achieved by this confinement scheme. Figure A.2.17 shows photograph of the cusp geometry (a), magnetic field profile (b) and a comparison of the radial plasma density profile (c) and axial density profile (d) with and without employing the cusped magnetic field in the chamber.

A.3 Tokamak Experiments

Both Aditya-U and SST-1 tokamaks made significant progress in terms of plasma operation and physics studies. The effect of divertor coils on plasma shaping was studied in Aditya-U. Consistent discharges with plasma current of about 170 kA and duration 370 ms were obtained using the parallel configuration of vertical magnetic field (BV) coils. A multipoint Thomson scattering diagnostics system was commissioned on SST-1 for the measurement of plasma density and temperature. Electron Cyclotron Resonance Heating (ECRH) experiments with two-pulses (breakdown and heating) were successfully carried out on SST-1 and Aditya tokamaks.

A.3.1 Aditya-Upgrade Tokamak

Both the top and bottom divertor coils have been operated simultaneously by driving 15 – 20 kA-turn current in these coils. Furthermore, the Auxiliary Divertor coils are also added to these main divertor coils. The effect of these shaping coils on plasmas has been studied. The current in both the top and bottom divertor coils is driven by separate capacitor-bank based power supplies. It has been observed that as the divertor is powered on, the soft-X-ray intensity increases and the Hα emission intensity decreases suggesting an improvement in the discharge characteristics. Along with increase in the soft-X-ray emission, the magnitude and period of the saw-tooth activity also increases during the charging of the divertor coils. These studies are being continued in the Aditya-U.

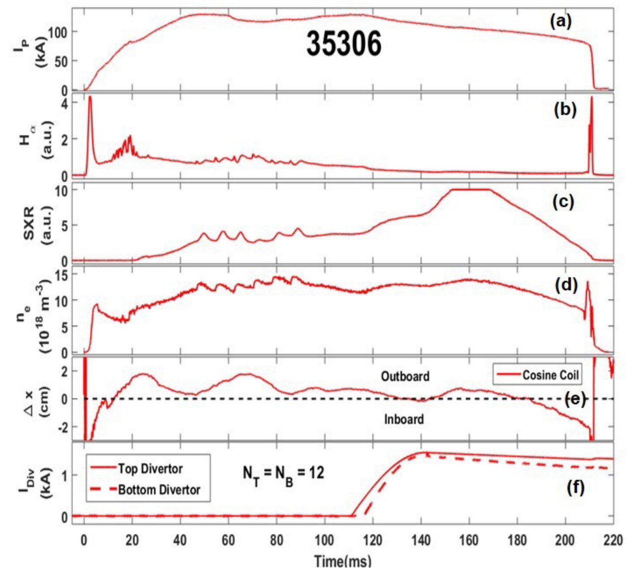


Figure A.3.1: Time evolution of Aditya-U discharge (#35306) represents upper & lower diverter current charging with parameters (a) Plasma current (IP) (kA) (b) H-alpha line emission (a.u.) (c) Soft X-rays (a.u.) (d) chord averaged electron density (ne) (m-3) (e) Horizontal plasma position (delta-X) (cm) (f) top & bottom diverter coils current (kA).

Aditya-U tokamak has two pairs of vertical field coils (namely BV1 & BV2) placed outside the top and bottom of the vacuum vessel equidistant from the horizontal mid-plane in the high and low toroidal magnetic field side, providing the required vertical magnetic field (equilibrium field). The required

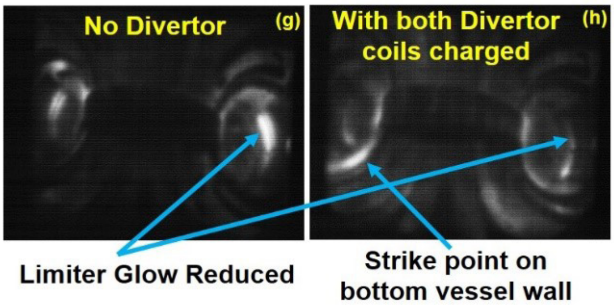


Figure A.3.1: (g) plasma image limiter phase and (h) plasma image diverter phase.

BV in Aditya-U for plasma current (IP) of ~ 250 kA is of the order of ~ 1000 Gauss and is supplied by the available VF power supply which is a 12 pulse converter based system having 2250 V/ 12.5 kA. The major straight vertical field is provided by a set of BV2 coils and the curvature in the vertical field lines are provided by set of BV1 coils. The direction of the vertical field is such that to reduce the net field in the inboard side and enhance it on the outboard side. Usually, these all four BV coils are connected in series to provide vertical field and hence offer a large value of inductance (L) as well as resistance (R). Because of this large L and R, the response time for the coil is slow. This cannot support the higher IP ramp-rate due to high L/R time constant of the coils. This causes problems in the initial phase, when plasma current rise is very fast, as well as in the flat-top phase while trying plasma current feedback on BV current with the help of these BV coils. Hence to support the high ramp rate of the plasma current, the only possibility of getting faster response from these BV coils was to reduce overall inductance and resistance of the coil assembly. To achieve this requirement, the top and bottom sets of BV coils were connected in parallel configuration in such a way that the overall symmetry of the machine was not disturbed. The block diagram of series and parallel configuration of BV coils is shown in figure A.3.2a and A.3.2b respectively.

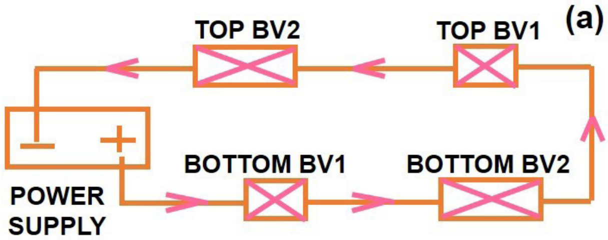


Figure A.3.2a: Schematic diagram for BV coils Series configuration.

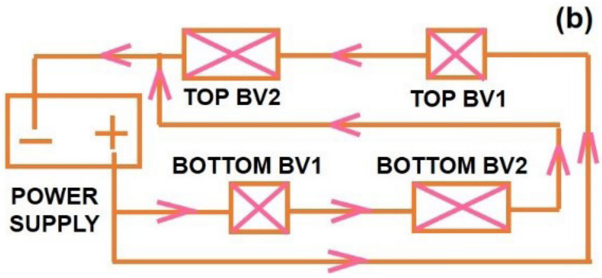


Figure A.3.2b: Schematic diagram for BV coils Parallel configuration.

The time evolution of the Aditya/Aditya-U plasma parameters shown in figure A.3.3 represents the effect of various shapes of BV current in accordance with the plasma performance. The highest ramp-rate of IP and BV current is observed in figure A.3.4 (black curve) with a parallel configuration of BV coils.

For the first time, with parallel configuration of BV coils, consistent discharges with IP ~ 170 kA, duration (t) ~ 370 ms, and flattop duration > 200 ms were obtained as shown in figure A.3.4.

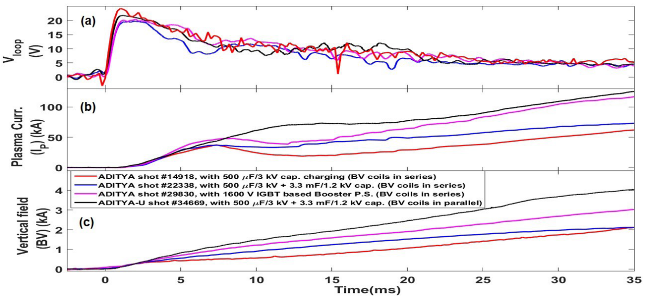


Figure A.3.3: Time evolution of Aditya /Aditya-U discharges parameters (a) loop voltage (V) (b) plasma current (kA) and (c) BV current (kA) shows the effect of various shapes of BV current in accordance with plasma performance.

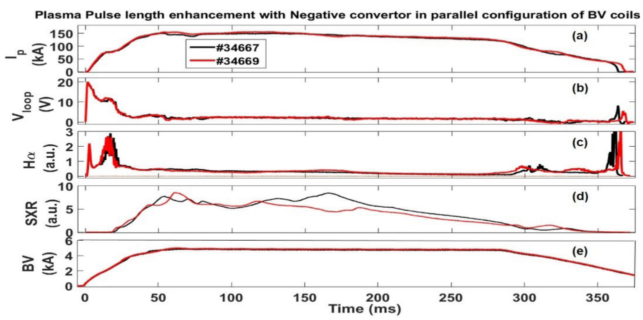


Figure A.3.4: Plasma pulse length enhancement with negative converter in BV parallel mode operation.

<u>*Gas-Puff Induced Cold Pulse Propagation in Aditya-U Tokamak:*</u> Short bursts (~1 ms) of gas, injecting ~10^{17}–10^{18} molecules of hydrogen and/or deuterium, lead to the observation of cold pulse propagation phenomenon in hydrogen plasmas of the Aditya-U tokamak. After every injection, a sharp increase in the chord-averaged density is observed followed by an increase in the core electron temperature. Simultaneously, the electron density and temperature decrease at the edge. The effect of gas pulse on the plasma parameters is shown in figure A.3.5. All these observations are characteristics of cold pulse propagation due to the pulsed gas application. The increase in the core temperature is observed to depend on the values of both the chord-averaged plasma density at the instant of gas-injection and the amount of gas injected below a threshold value.

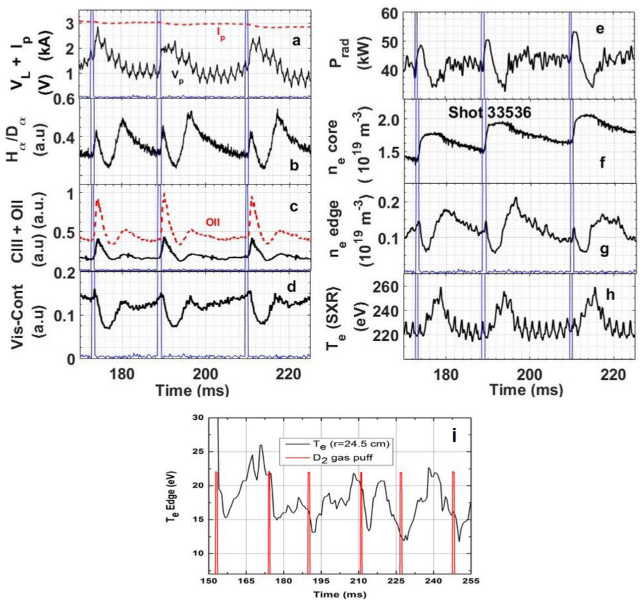


Figure A.3.5: The temporal evolution of Aditya-U discharge (#33536) parameters; (a) loop voltage, plasma current, (b) Hα/Dα line emission (c) CIII, OII line intensity (d) Visible continuum (e) Radiated Power (f) chord averaged electron density (ne), (g) edge density (h) SXR central electron temperature (i) edge temperature represents the effect of multiple gas puff pulses.

Increasing the amount of gas-puff leads to higher increments in the core-density and the core-temperature. Interestingly, the rates of rise of density and temperature remain the same. The gas-puff also leads to a fast decrease in the radially outward electric field together with a rapid increase in the loop-voltage suggesting a reduction in the ion-orbit loss and an increase in Ware-pinch. This may explain the sharp density rise, which remains mostly independent of the toroidal magnetic field and plasma current in the experiment. Application of a subsequent gas-puff before the effect of the previous gas-pulse dies down, lead to an increase in the overall electron density and consequently the energy confinement time.

Controlling the Rotation of Drift Tearing Modes by Biased Electrode in Aditya-U Tokamak: The influence of background plasma poloidal rotation on the rotation frequency of the m/n= 2/1 drift tearing mode (DTM) has been studied in Aditya-U tokamak.

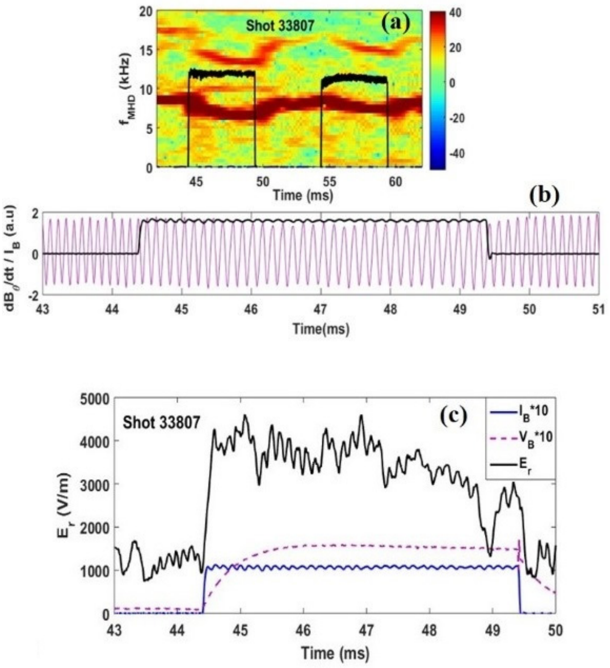


Figure A.3.6: (a) Spectrogram of MHD activity during positive bias (b) Change in the MHD activity dB(th)/dt (magenta) with bias current (black) and (c) Induced radial electric field (black) with bias voltage (magenta) and current (blue).

The poloidal rotation velocity of the background plasma in the ion diamagnetic direction is increased or decreased by inducing an outward or inward radial electric field, respectively, through a biased-electrode placed in the edge region of the plasma. The rotation frequency of the pre-existing drift tearing mode, rotating in the electron diamagnetic direction, concomitantly decreased or increased with the application of bias depending on its polarity. The positive-bias increases the background plasma rotation in the ion-diamagnetic direction from its pre-bias value, hence decreasing the DTM rotation frequency, whereas the negative bias reduces the plasma rotation velocity in the ion-diamagnetic direction, hence increasing the mode rotation as shown in figure A.3.6.

In addition to that, a short gas puff introduced during the positive and negative bias pulse further reduces the mode frequency as shown in figure A.3.7, however, with different amplitudes in different bias-polarities.

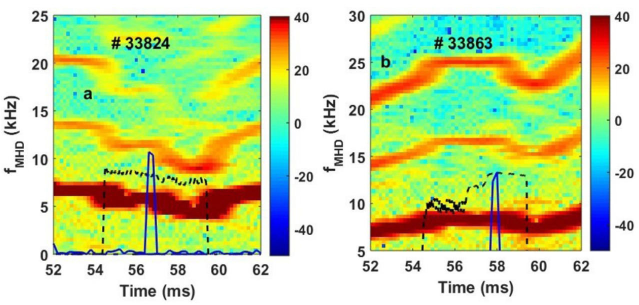


Figure A.3.7: Gas-puff pulse (blue) introduced during (a) positive bias voltage pulse (black) and (b) negative bias current (black) indicating a decrease in rotation frequency of the DTM due to gas puff in both cases.

These observations suggest that the background plasma rotation contributes significantly towards the rotation of DTMs, and the rotation frequency of the magnetohydrodynamic modes can be modified by varying the poloidal rotation of the background plasma and/or the diamagnetic drift frequency.

Lithium Wall Conditioning Techniques in Aditya-U Tokamak for Impurity and Fuel Control: In fusion devices, various techniques are employed for coating the plasma facing components (PFCs) including the vessel wall with low-Z material like lithium, boron, and silicon in order to enhance the plasma parameters and control. In Aditya-Upgrade tokamak, different techniques of lithium wall conditioning are developed and implemented to obtain uniform and sustainable coating of Li on PFCs and the vessel wall. In one of the techniques, a heated (fixed temperature of ~120 ^{o}C) Li-rod is placed inside the hydrogen glow discharge cleaning (H-GDC) plasma and the Li sputtered by hydrogen (H) ions and atoms coats the wall and periphery. In the second technique, the Li is vapourized using a high-temperature Li-evaporator and released into the H-GDC plasma for uniform coating of Li on the PFCs and vessel. Significantly enhanced plasma parameters are obtained after Li coating by both techniques, with the evaporated Li performing better than the Li rod case. With the Li coating obtained with evaporated Li at 600 ^{o}C (550 mg Li) with H-GDC, the Li wall conditioning has been observed to be sustaining for a larger number of plasma discharges in comparison to non-H-GDC assisted Li deposition. As the melting temperature of lithium hydride (LiH) is much higher (688.7 ^{o}C) than that of lithium (180.5 ^{o}C), this enhance the longer Li-coating lifetime relatively due to the formation of Li–H molecules on the vessel wall and PFCs as shown in figure A.3.8.

In Aditya-U, the carbon impurity and hydrogen recycling, due to relatively high surface area of graphite PFCs as well as their proximity to the plasma, limits the plasma performance and effective control. Hence, H-GDC, H-GDC with Li-rod sputtering or Li evaporation, helium-GDC, argon–hydrogen mixtures-GDC in particular sequence are carried out to obtain better plasma discharges.

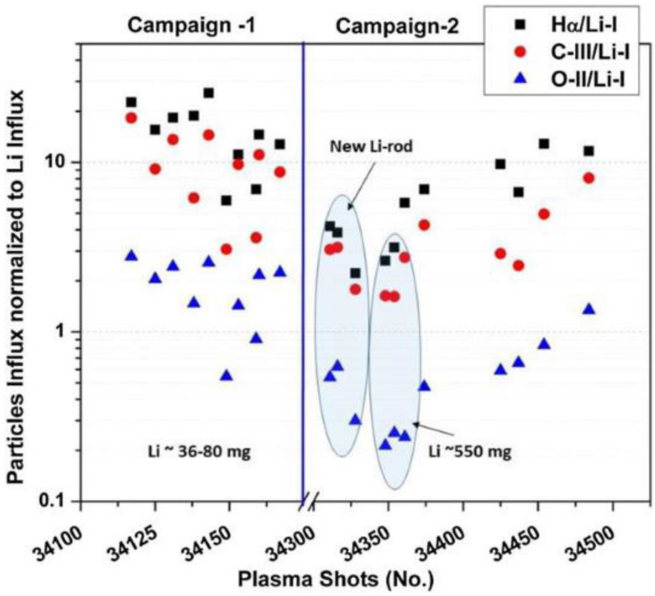


Figure A.3.8: Two campaigns: control of impurity particles and hydrogen recycling from PFCs and vessel wall by different Li wall conditioning techniques.

Observations of Visible Argon Line Emissions and its Spatial Profile from Aditya-U Tokamak Plasma: The spectroscopic studies of medium and high Z impurities have been the subject of interest in fusion research due to their role in mitigating plasma disruption and reducing heat load on the plasma facing components. Line emissions from these impurities provide the rotation velocity and ion temperature measurements along with the understanding of the overall impurity behaviour in plasma. In the Aditya-U tokamak, the spatially resolved Ar II line emissions have been observed using a high resolution multi-track spectroscopic diagnostic consisting of a 1m Czerny–Turner spectrometer coupled with a charge coupled device (CCD) detector using seven lines of sight viewing plasma tangentially along the toroidal direction.

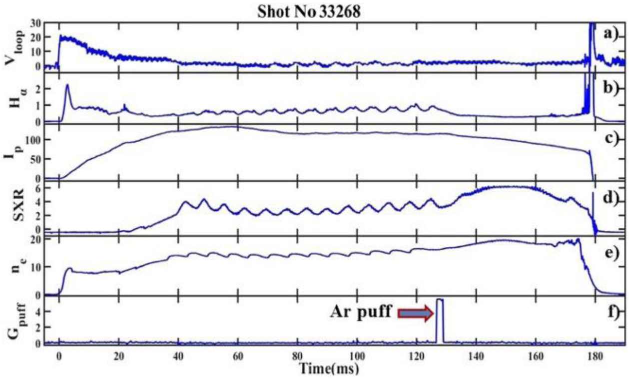


Figure A.3.9 (a-f): Typical Ohmic discharges of the Aditya-U tokamak for shot No. 33268. (a) Loop voltage (V), (b) Hα signal (a.u.), (c) plasma current (kA), (d) soft x-ray emission (a.u.), (e) electron density (×$10^{18}/m^3$), (f) argon gas puff at 126.6 ms.

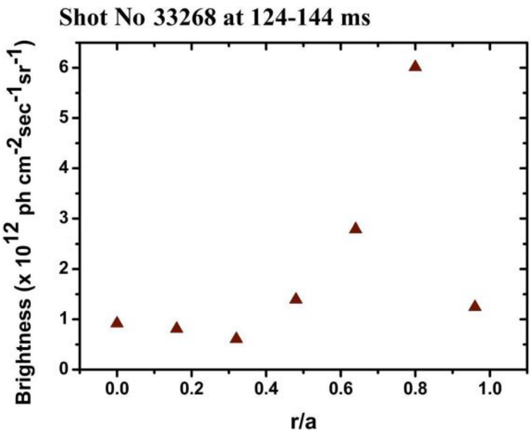


Figure A.3.9g: Typical Ohmic discharges of the Aditya-U tokamak for shot No. 33268. Spatial profile of Ar II line emissions at 458.96 nm.

The spatially resolved Ar II lines at 458.96 nm have been observed as shown in figure A.3.9. The singly ionized Ar emission peaks at the radial location of ρ = 0.8 of the plasma having a minor radius of 25 cm. Moreover, a 0.5 m UV–visible spectrometer coupled with a CCD detector and having a line of sight passing through the plasma mid-plane from the radial port was used to record visible Ar survey spectra within the 670–810 nm wavelength range, and all these lines will be further analysed.

<u>*Characterisation of Induced Vessel Current during Mirnov Probe Calibration Experiment in Aditya-U Tokamak*:</u> The stabilization of plasma column confined inside the vacuum vessel is supported by superposition of different vertical and horizontal magnetic field. These time varying magnetic field induces current in the vacuum vessel along with other neighbouring conducting structures. Magnetic probe results are greatly affected by induced vessel current in any nuclear-fusion experimental device. A central conductor is installed inside the Aditya-U sectionalized segment of vacuum vessel for the calibration of Mirnov probes. The poloidal field distribution around the inner periphery of the vacuum vessel surface is investigated experimentally by using Mirnov probe garland. An analysis is described for the magnetic field at different sinusoidal frequencies and conductors at different radial and vertical locations. Mismatching in the measured magnetic field and applied current in the central conductor, measured at different frequencies hints at the presence of induced vessel current. Dissimilarity in the simulated and measured magnetic signal is computed to characterise the induced vessel current for different Mirnov probes. This technique may be useful to characterise the induced vessel current during Aditya-U plasma discharges.

<u>*Optimization of the Metallic Vessel-Wall Effect on the Magnetic Diagnostics Calibration in Aditya-U Tokamak:*</u> Aditya-U has been recently upgraded to

limiter-divertor configuration from limiter configuration. Commissioning of various magnetic diagnostics along with the data acquisition system is done to measure the plasma parameters. Measurement of various plasma parameters will be used to control the real-time plasma position, shape and post-discharge fluctuation measurement and equilibrium reconstruction. Magnetic probe measurement is the appropriate diagnostic technique as they are easy to install and calibration can be done in the absence of the plasma. A different set of magnetic probes are installed inside and outside the vacuum vessel of Aditya-U to pick up the magnetic signals of the plasma. In-Situ calibration of the magnetic probe is performed in Aditya-U to mitigate the effects generated due to geometrical imperfection of the probes and deviation in the probe mounting, which are the main source of error. During the calibration experiment in Aditya-U, the effect of induced vessel current due to the time-varying magnetic field of the central conductor has been observed and examined in detail for different experimental cases.

Investigation of Recycling and Impurities Influxes in Aditya-U Tokamak Plasmas: Fuel particle and impurity influxes have been investigated for Aditya-U tokamak plasma operated with toroidal belt limiter using PMT based spectroscopic diagnostic system installed on machine. The influxes of hydrogen and impurity ions are estimated using various lines of sight (LoS) terminating on the graphite limiter and stainless steel wall to understand their contributions in recycled particle and impurities into the main plasma. It is found that the influxes of neutral hydrogen and oxygen are around 4 times higher in case of LoS terminating on the limiter than the wall while carbon influxes from the both Los's are comparable as shown in figure A.3.10.

The comparable integrated particle influxes from both Los's indicate the important role of the wall in the recycling and presence of the impurities in the plasma.

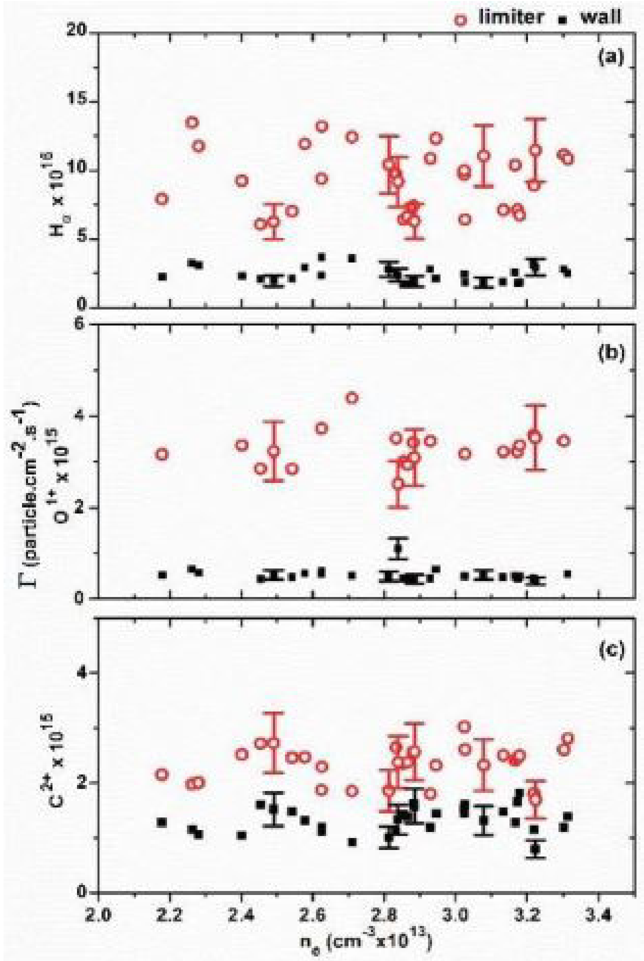


Figure A.3.10: Particle influxes of (a) neutral hydrogen, (b) oxygen impurity ion and (c) carbon impurity ion. Red circle and black square represent the influxes measured along the LoS terminating on limiter and bottom wall, respectively.

The particle confinement time (τp) and recycling coefficient (R) are also estimated to quantify those from the estimated particle influxes. The τp values varies from 8ms-25ms, when plasma electron density is in the range of 2.0 - 3.2 × $10^{19}m^{-3}$. Analysis of recycling coefficient, R suggests that the Plasma Facing Components (PFC) act as the particle sink at the beginning of the plasma operational campaign. The R values tend to become more than one as the campaign progresses suggesting that the PFC acting as the particle source.

<u>*Plasma Column Position Measurements using Magnetic Diagnostics in Aditya-U Tokamak:*</u> Due to several forces acting on the plasma column in a tokamak, the plasma column tends to move horizontally and/or vertically leading to many adverse events including termination of plasma. Precise measurement of plasma column position throughout the discharge with good temporal resolution in the real time is hence necessary in order to restrict the column movement using the stabilizing equilibrium magnetic fields. The plasma column position is measured by several magnetic diagnostics such as magnetic pick-up probe, Mirnov coil, Sine-Cosine coil along with flux loops in Aditya Upgrade tokamak (Aditya-U). In spite of the simplicity of the measurement principle of these probes as well as of their construction, obtaining the position of the plasma column is not very straightforward. The diversity of all these magnetic diagnostics in terms of their structures, installation location, mounting scenario etc. leads to improper position estimations as these probes are affected differently by the unwanted magnetic pick-ups. These unwanted pick-ups, especially those arising from vessel eddies, are successfully removed by introducing a scaling method for all the above mentioned position probes in Aditya-U based on the in situ calibration of these probes. The correction factors are deduced by estimating the known positions of a central current carrying conductor correctly using the probe measurements during the in situ calibration. These correction factors are used for estimating the plasma column position in the tokamak experiment along with proper nullification of magnetic fields arising from other magnets during tokamak operation. The plasma column position estimation from different magnetic probes are compared with each other and also with those estimated from diagnostics other than the magnetics.

<u>*Numerical study on the effect of plasma density on Runaway Electron suppression in the Aditya-U tokamak:*</u> Runaway Electrons (REs) generated during plasma disruptions in fusion grade tokamaks have the potential to severely damage the plasma-facing components.

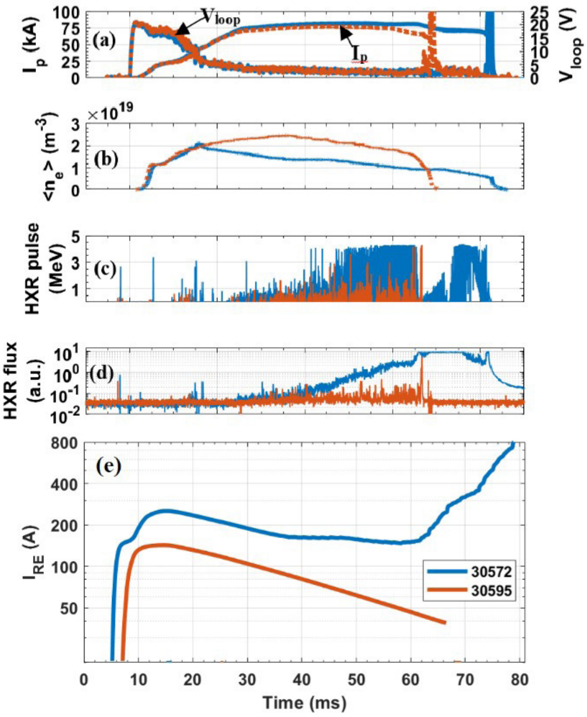


Figure A.3.11: Time evolution of plasma parameters for discharges #30572 (blue) and #30595 (orange): (a) Plasma current and loop voltage, (b) line-averaged electron density, (c) HXR pulse, (d) HXR flux, (e) simulated Runaway Electron current taking into account experimental parameters as an input.

Designing optimal plasma discharge scenarios for RE suppression in future experiments requires interpretative modelling of current experiments. Multiple experiments have been carried out on Aditya-U tokamak to design optimal plasma discharge scenarios for RE avoidance and suppression. In this context, recently, numerical simulations of RE parameters have been performed for the discharge scenarios where RE avoidance or suppression methods were applied in Aditya-U tokamak for study and better understanding. Figure A.3.11 depicts the first pair of representative plasma discharges, where plasma density was increased by gas puffs during the flap-top phase which is shown to suppress RE generation and henceresults in relatively small amount of RE current.

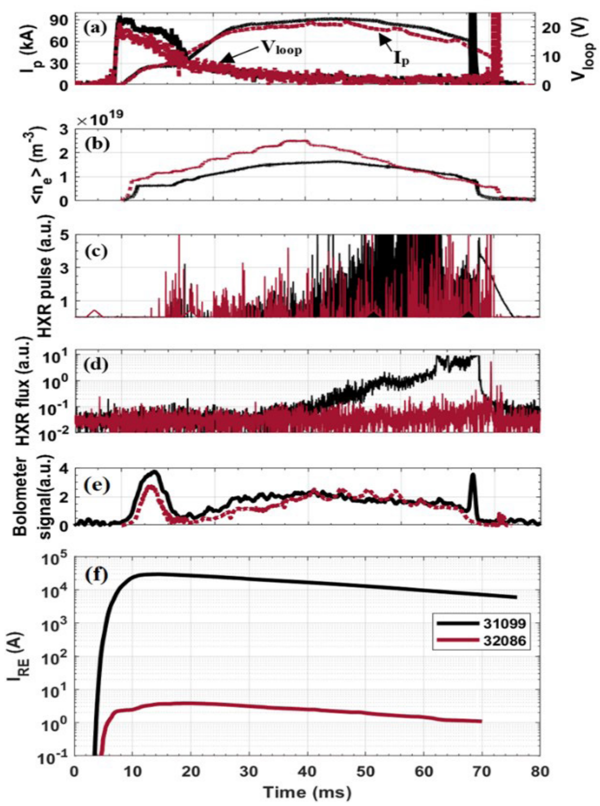


Figure A.3.12: Time evolution of plasma parameters for discharges #31099 (black) and #32086 (pink): (a) Plasma current and loop voltage, (b) Line averaged electron density, (c) HXR pulse, (d) HXR flux, (e) Radiated power from bolometer, (f) Simulated Runaway Electron current taking into account experimental parameters as an input.

Figure A.3.12 shows the second pair of the representative discharges where the effect of a lower ratio of peak electric field during breakdown to the pre-fill pressure is studied on RE generation. These simulations have been performed using the PREDICT code developed to study the dynamics of runaway electrons and validated on other tokamaks. The results are consistent with the experimental Hard X-Ray diagnostic observations that detect the presence of REs in plasma discharges.

<u>ECRH Two pulse experiments in Aditya-U:</u> The 42GHz-500kW ECRH system has shown many interesting results in Aditya-U. Till now single ECRH pulse is used to carry out either plasma start-up or heating in both the tokamaks. Looking at the experimental demand of two ECRH pulses (one for breakdown and second for heating), the power supply system of 42GHz Gyrotron is upgraded and a new advance anode power supply is commissioned with the system. The rise and fall time of this new power supply is ~1ms, which allows to operate the Gyrotron for more than one pulse.

The two-pulse ECRH experiments, the EC-assisted breakdown and heating experiments are carried out simultaneously in Aditya-U tokamak. Two ECRH pulses were launched in Aditya-U plasmas, first pulse of ECRH was launched before the loop voltage and another pulse was launched after a gap of 30 ms for plasma heating. The power in first pulse was 100 kW while in second pulse 150 kW power was launched. In Aditya-U tokamak, the operating toroidal magnetic field is 1.35T, so ECR layer lies inboard side the plasma.

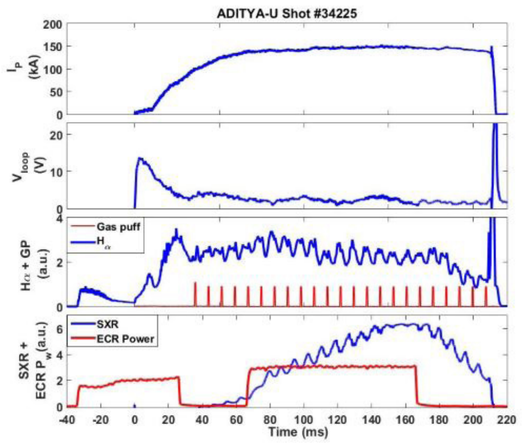


Figure A.3.13: ECRH two pulse in Aditya-U, I_p, V_{loop}, EC and SXR.

The loop voltage is around 13V and successful discharge of more than 200ms was achieved with plasma current close to 150kA. In Aditya-U, the effect of plasma heating during second ECRH pulse is observed as soft X-ray (SXR) exactly follows the ECH power (figure A.3.13). The soft x-ray (SXR) radiation is generated mainly by bremsstrahlung, which depends on both electron density ne and temperature T_e, ($P_{brem} \sim Z_{eff}\, n_e^2 T_e^{0.5}$).So the increase in flux at the detector due to ECRH power could be either due to increase in density or due to increase in electron temperature. Considering the Aditya-U plasma is fully ionized, the increase in soft X-ray could be due to increase in electron temperature. This need to be further confirmed with supporting diagnostics and it is planned in next plasma campaigns.

First results of MOCS (Magneto Optic Current Sensor) deployed for Aditya-U Toroidal Field coil current measurements: Reliable and accurate measurement of time-varying current in a large dynamic range (in current and frequency) is very much required in a wide range of applications such as in the power sector, industries and R&D sector.

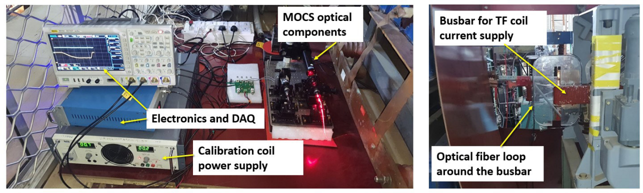


Figure A.3.14: MOCS experimental setup deployed for Aditya-U TF current measurements.

Several techniques are developed for the current measurements such as Shunt, Current Transform er, Rogowski Coil, Hall Sensor and Magneto Optic Current Sensor (MOCS). From these different techniques, the MOCS has emerged as a promising measurement technique as it has several advantages over the conventional techniques, namely the ability for DC and AC measurements up to GHz frequency range, being an optical measurement technique it can provide reliable measurement in the presence of electromagnetic noise environment, it identifies forward and reverses currents, and it can provide remote measurements with electrical isolation.

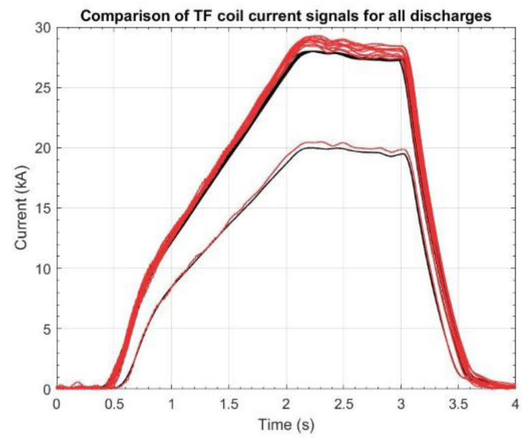


Figure A.3.15: TF current pulse and comparison between MOCS and CT measurements.

The MOCS technique is based on the measurement of the Faraday rotation (theta) of input polarized light in the optical fiber sensing element that is proportional to the applied magnetic field (B) over a length (L), it follows the relation: $\theta=V_\lambda B L$, where, V_λ is the Verdet constant. Recently, the MOCS measurement system has successfully been implemented for Toroidal Field (TF) current measurement in Aditya-U. Several pulses of TF current passing through the busbar have been recorded and it has been found that the MOCS system can estimate the current within ±5% deviation from the conventional CT measurements (figure A.3.15). As a next step, the installation of the MOCS system on the Aditya-U tokamak vacuum vessel is envisaged for plasma current measurements.

SoC-Based Automated Diagnostic Instrument for FMCW Reflectometry Applications: The existing setup of the Reflectrometry diagnostics is rigid and bulky utilizing precious tokamak lab space, lacks remote configurability option, and requires manual intervention to change control parameters. Hence, we propose a system-on-chip (SoC)-based automated reflectometry diagnostic instrument (ARDI) is proposed to implement all the four major electronic components into a single instrument. The analog driver is designed to generate a non-linear sweep voltage of 0–20 V in order to drive the ultra-wideband voltage controlled oscillator (VCO). The data acquisition system (DAQ) is deployed to acquire the in-phase (I) and quadrature (Q) components of a signal at 245 mega samples per second (MSPS) with 14-bit resolution. The trigger unit operating in pattern mode at 100 MHz is responsible to trigger all the units synchronously. The data processing unit, normalizes the signal using the proposed hardware accelerator clocked at 200 MHz. The proposed normalization technique is analyzed and compared with envelope-based normalization technique. This study conveys that the proposed technique utilizes lesser hardware resources with the availability of both I and Q components, making it computationally simpler and faster. The designed ARDI can be configured and monitored remotely by developing a graphical user interface (GUI).

Lab view-FPGA-Based Real-Time Data Acquisition System for Aditya-U Heterodyne Interferometry: Microwave interferometry has been used extensively for plasma diagnostics in tokamak for real-time electron density measurements. Real-time density measurement is an indispensable part of advanced tokamaks, as it can be used as feedback to control the plasma operation. A phase extraction method has been developed in a heterodyne interferometer for real-time density estimation using a field-programmable gate array (FPGA). FPGA provides parallel processing, minimum control delay, more efficient processing architecture, and jitter-free synchronization between different control layers. Digital CORDIC algorithm is used for the estimation of the phase between two arms of the interferometer. A LabVIEW program is developed for the FPGA target and host controller to acquire the data and estimate electron density in real time, which can be used for feedback purpose by regulating the amount of gas injection using piezoelectric valve that requires a high voltage (~100 V) for about 1 ms. The delay in generating the feedback signal is proportional to the sampling speed (100 kHz) of the analog signal. The developed interferometer and data acquisition (DAQ) system installed on Aditya-U tokamak can measure the electron density in the range of 1×10^{18} - 10^{20} m^{-3}. The algorithm used for the estimation of phase difference is validated using a conventional arctan method. The developed reconfigurable FPGA-based DAQ system uses low power, has a reconfigurable hardware structure for fast real-time signal processing, and can be easily upgraded.

Design and Characterization of Radiometer System for Electron Cyclotron Measurements at Aditya-Upgrade Tokamak: Instrumentation and characterization techniques have been developed for a 16-channel radiometer system to obtain localized electron cyclotron emission (ECE) measurements at Aditya-Upgrade tokamak. Inverse dependence of the EC radiation on the toroidal magnetic field constrains the hardware for measurements at a fixed radial location. This results in having costly and complex sweep systems or use of multiple receiver units dedicated to a specific toroidal magnetic field. A simple, cost effective solution to this issue could be using a fixed frequency wideband intermediate frequency (IF) receiver. This multiple channel hardware unit can do localized measurements at fixed as well as different magnetic fields thereby improving the measurement range. Designed system provides a spatial resolution of 1.2 cm and a temporal resolution of 10 µs. Noise figure of the system varies from 15–22 dB while the sensitivity is 0.1×10^6 V/W.

A Diagnostic for Measuring Radial Profile of Visible Continuum Radiation from Aditya-U Tokamak Plasmas: On Aditya-U tokamak, a spectroscopic diagnostic has been developed to measure the radial profile of visible continuum radiation for determining the plasma effective charge, Z_{eff}, to study the impurity transport and MHD driven instabilities. It consists of the collimating lenses, optical fibers, a multi-channel wavelength selection system, and photo multiplier tubes. The optical system allowing continuum radiation measurements around 536 nm (the wavelength selection system) consists of set of lenses, optical fibers and an interference filter with diameter of 5 cm and bandwidth of 3 nm. The spatial profile of radiation with a spatial resolution of ~3 cm has been recorded from eight lines of sight viewing the plasma using an UHV compatible rectangular view port placed on the bottom port of the Aditya U tokamak. The centrally peaked spatial profile of visible continuum radiation has been recorded from the Aditya-U tokamak plasmas. The chord averaged Z_{eff} values estimated from the brightness measured along the central chord fall within 2.5 to 4.1 for the electron densities of 1.0 - 2.2 × 10^{19} m^{-3}.

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

Development of a Novel Spiral Antenna System for Low Loop Voltage Current Start-Up at the Steady State Superconducting Tokamak (SST-1): Superconducting tokamaks require low loop voltage current start-up for the safety purpose of their poloidal field coils. The loop voltage inside the vacuum vessel of Steady State Superconducting Tokamak (SST-1) is low in nature since its central solenoid is located outside the cryostat. The low loop voltage current start-up of the SST-1 is routinely performed by using the electron cyclotron resonance (ECR) method at the toroidal magnetic field B_t = 1.5 T (first harmonic) and 0.75 T (second harmonic). Recently, an alternative RF-based plasma current start-up system has been planned for operating the machine, especially for a higher toroidal magnetic field regime 1.5T < B_t < 3T. The system was already developed based on an antenna system, made of a series of combinations of two flat spiral antennas, to assist plasma current start-up at a lower inductive electric field. It has already been tested and installed in the SST-1 chamber. The system testing was performed without a background magnetic field within the frequency regime of 35 MHz–60 MHz at present. The test results show that it can produce an electron density of ne ~ 10^{16} m^{-3} measured by the Langmuir probe at the expense of 500 W RF power. The spectroscopy results indicate its capability of producing plasma density greater than 10^{13} m^{-3} and an electron temperature of T_e = 2–6 eV. In addition, the results also show the presence of a turbulent electric field of the order of 10^6 V m^{-1} at the antenna center and a finite anomalous temperature of neutral particles. Calculations show that the obtained density is sufficient for SST-1 low loop voltage plasma breakdown. The antenna system is also capable of producing plasma at higher frequencies.

Thermo-Hydraulic Study of MgB_2 Superconducting Feeder for SST-1 Tokamak: Better cryo-stability is mandatory for any superconducting (SC) feeders system of fusion devices as the large amount of the magnet-stored energy can be safely dumped via feeder path only. Magnesium diboride (MgB_2) as a feeder may provide an innovative solution in lieu of low temperature superconductor. It has a critical SC transition temperature (TC) of 39 K, ductile nature, and ease of availability at a relatively lower cost. SST-1 Tokamak utilizes NbTi/Cu based cable-in-conduit conductors for its SC feeders rated at 10 kA and designed to be cooled using forced-flow helium at 4.5 K, 0.4 MPa. In order to assess the suitability of MgB_2 as a feeder, a thermo-hydraulic study of 10 kA rated SC feeders for SST-1 is done. The results show that MgB_2 SC feeders can provide benefits of higher temperature margin at a lower mass flow rate with reduced pressure drop and the cryo-plant capacity savings in comparison to existing NbTi-based feeders.

Insulation of Current Leads for Superconducting PF-3 Coils of SST-1: Conventional copper current leads (CLs) for superconducting magnets of SST-1 are fabricated to operate in dc condition for toroidal field coils and fast current ramp up to 10 kA for poloidal field (PF) coils at low temperature under vacuum. Two pairs of CLs are required to be installed with PF-3 coil terminals in current feeder system chamber (CFSC) for shaped plasma operation in SST-1.The PF coils of SST-1 are subjected to the induced voltages of around 1 kV due to ohmic coil discharge. In past few campaigns, high induced voltages on PF coils due to ohmic coil discharge have caused arcing inside the CFSC between high potential PF CLs and grounded thermal shield. This arcing resulted in severe damage to the PF current leads and helium hydraulic lines. To prevent this, Paschen leak tight electrical insulation for cylindrical CLs with variations in diameter and geometry along its length are developed and implemented. The developmental procedures include the sample preparations and optimization of insulation processes. The scaled down version of CLs samples were prepared after the investiga tion of curing kinetics of insulation resin at 140 °C and 110 °C. The high voltage testing of these insulation samples was carried out up to 28 kV at room temperature (RT) before and after multiple thermal shocks. These insulation samples were also tested up to 5 kV dc and 80 K temperature in Paschen test setup. The insulation resistance and breakdown voltage of these samples was found to be more than 100 GΩ and 28 kV, respectively at RT.

Plasma Density and Temperature measurement using Thomson Scattering Diagnostics: A Multipoint Thomson scattering system with six Nd: YAG lasers (1.6 J energy, 8 ns pulse width) has been installed and calibrated on the SST-1 Tokamak. It measures temperature and density from 8 spatial channels. Indigenously designed and developed filter polychromators are used for the spectral dispersion and detection of the Thomson scattered spectrum. The system operates with a spatial resolution of 10 mm and temporal resolution of 5.3/33 ms depending upon the plasma parameters. The Thomson scattering system has been calibrated in situ using Raman scattering by filling nitrogen gas inside the SST-1 vacuum vessel. Figure A.3.16 shows the Raman calibration for seven filter polychromators (FP-1 to

7) corresponding to different spatial locations of the Vertical Thomson scattering system of SST-1. From the absolute calibration data, the minimum detectable density is estimated to be ~4 x 10^{12} cm^{-3}.

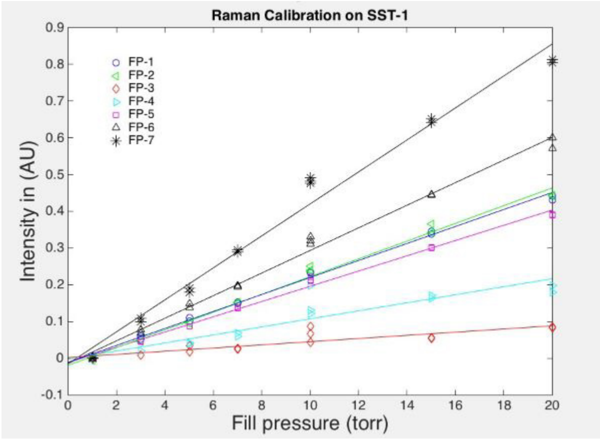


Figure A.3.16: Absolute calibration of SST-1 Thomson scattering system using Raman scattering. FP-1 to FP-7 represent seven spatial channels.

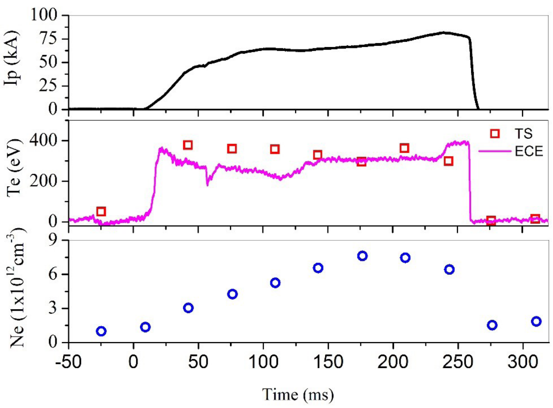


Figure A.3.17: The plasma temperature and density were estimated using the VTS diagnostics on SST-1 for plasma shot No 9721 at the center. The temperature estimated from VTS is compared with the spatially resolved temperature data of ECE diagnostics.

After successful installation and commissioning of the vertical Thomson scattering (VTS) system on SST-1, the VTS system was operated for the subsequent experimental campaign. Figure A.3.17 shows the temporal evolution of plasma density and temperature for shot no 9721 at SST-1 at the plasma center. The estimated plasma temperature is compared with the temperature measured by the ECE diagnostics and it is observed that the data from both the diagnostics are matching reasonably.

ECRH Two pulse experiments in SST-1: In SST-1, the 42GHz-500kW ECRH system is mandatory for plasma start-up. In the SST-1, two ECRH pulse experiments (breakdown and heating simultaneously) have been carried out successfully. As shown in figure A.3.18, the first pulse of 150kW power for 50ms duration was launched for start-up and after a gap of 25 ms another pulse of same power was triggered.

LHCD feedback control: During the non-inductive current drive phase, the plasma current is mainly driven by LHCD power whose coupling depends on various plasma parameter as well as edge plasma conditions.

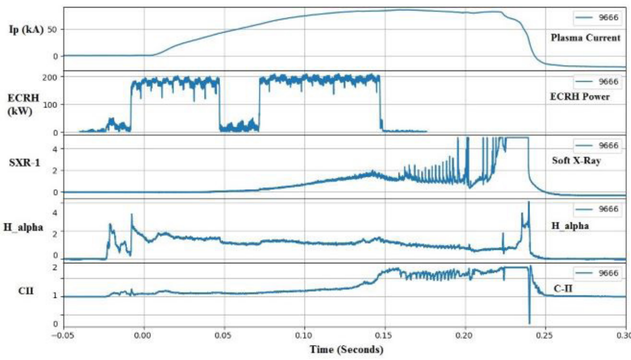


Figure: A.3.18: SST-1 plasma shot with two ECRH pulses.

To maintain the plasma current constant, a feedback system is desired which would increase/decrease the LH power online based on the error signal which is generated by comparing the measured plasma current with set plasma current value. The feedback process tries to minimize the error signal and thus maintains the plasma current constant at predefined set value. The automatic LHCD power control algorithm is implemented on the PCS (planned control system). Although the final architecture is based on transfer of data through a reflective memory module but initial testing was done employing an analog fiber-optic link. The loop time of the control algorithm is one millisecond.

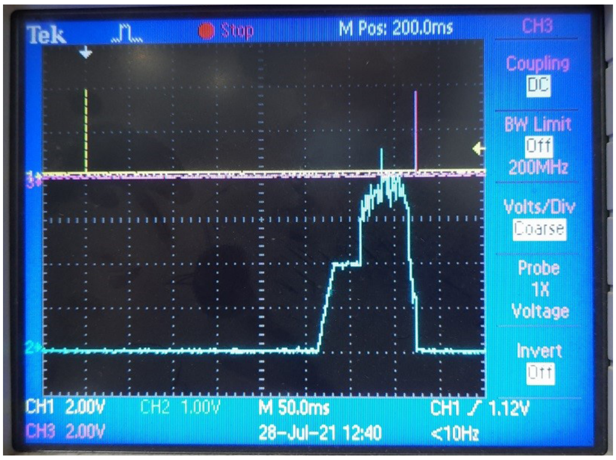


Figure A.3.19: Trigger Pulse and LHCD power.

The automatic LHCD power control algorithm is event based triggered i.e. either at a predefined time or based on the plasma current threshold set value. The above scheme is successfully tested during 27th SST-1 campaign in standalone mode where the control was established without plasma. Figure A.3.19 shows the typical results obtained during the experiment. As seen, the LH power (ch-2) starts around 250 ms after the trigger pulse (ch-1) is initiated. It ramps the power to a set level (~2V) and maintains it for ~25-30ms after which the feedback control is initiated. Thereafter the LH power is feedback controlled until the end pulse is received, which stops the LH power injection.

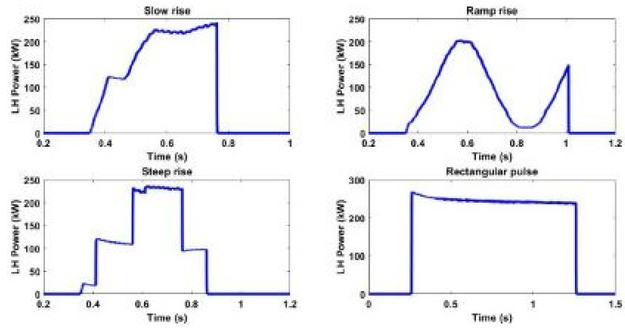


Figure: A.3.20: Various temporal profiles of LH power.

The above feature could only be demonstrated once launching of LH power in arbitrary temporal profile was successfully incorporated in LHCD control system. Several temporal profiles (like CW, steep/slow rise and ramp cases) were tested and demonstrated on dummy load before proceeding to actual plasma experiments and the results obtained are shown in figure A.3.20.

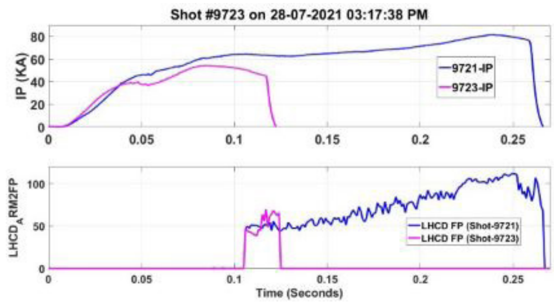


Figure A.3.21: LH pulse termination using LHCD power stop signal.

Another important control which is incorporated in the control system is to generate an end pulse from the timing control system which inhibits the LH power and prevents the deleterious effect of RF-power launched in machine in absence of plasma. The end pulse is initiated with reference to plasma current signal. A predefined threshold (set) value is assigned for the minimum plasma current limit such that when plasma current falls below this threshold limit, a LHCD-Power-Stop signal is initiated and thus inhibits the LH power. This feature was also successfully implemented and tested during this campaign and typical results obtained from the campaign are shown in figure A.3.21. It is obvious from the figure that LH power is terminated immediately after the current falls, although the set time for RF injection was for 1 second.

A.4 Fusion & Related Technologies

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

A.4.1 Magnet Technologies

Nb_3Sn superconducting solenoid development : Nb_3Sn strand of ~2000 kg and length 425 km has been imported. Around 125 km long Nb_3Sn strands are used to make cable of length 1100 m with an industry. A single 10 m Nb_3Sn CICC (figure A.4.1) of size 15 mm x 15 mm is fabricated in first trial and a solenoid coil with 4 turns & 250 mm diameter are wound and heat treated at the institute to make it a superconducting magnet which has been cold tested (figure A.4.2) & and charged up to 10 kA.

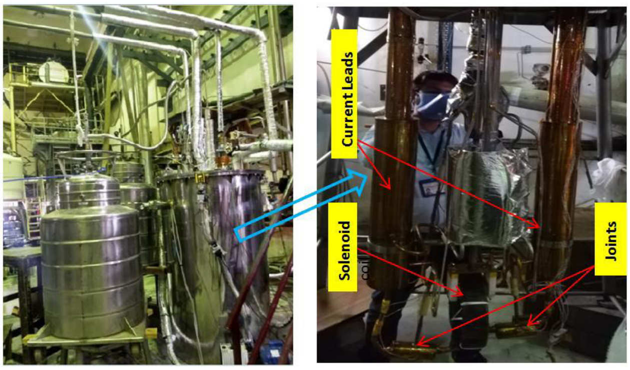


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Figure A.4.1: Nb_3Sn CICC test setup.

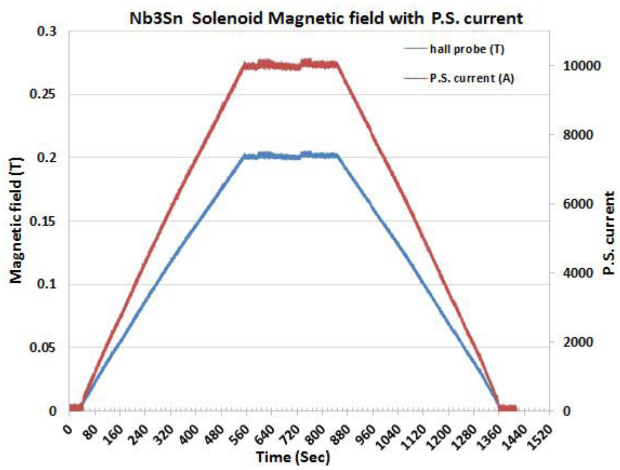


Figure A.4.2: Test results.

Development of HTS solenoid coil: a) High temperature superconductors (HTS) are promising candidates for the next generation high field compact magnets (figure A.4.3). Winding, inter-pancake and terminal joints are challenging technology for the fabrication of HTS tapes based high field magnets. Magnet System Division (MSD) has fabricated a HTS solenoid coil of Room Temperature (RT) bore

50 mm having 21 double pancakes, 20 inter-pancake joints, 576 nos. of turns and length 230 mm. This solenoid coil has been cooled to 64.5 K and charged up to 110 A current (figure A.4.4) per turn and generated steady magnetic field of 0.23 T at the center of RT bore.

Figure A.4.3: HTS coil before testing before insertion in test cryostat.

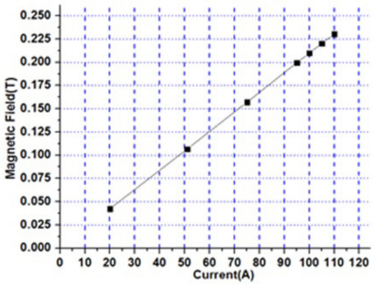


Figure A.4.4: Measured magnetic field at operating current.

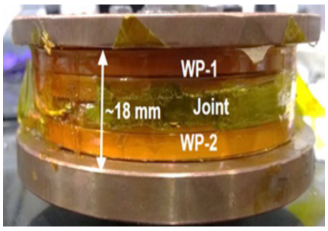


Figure A.4.5: REBCO Coil.

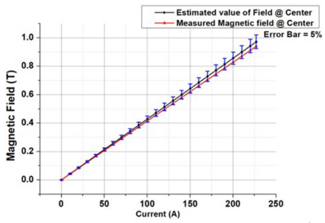


Figure A.4.6: Measured & estimated magnetic field vs operating current.

b) A HTS solenoid coil with insulated REBCO tape of cold bore diameter 50mm with two double pancakes, one inter-pancake joint, 268 nos. of turns and length 18mm, has been fabricated in-house. This solenoid coil was cooled to 10K using cryocooler and charged up to 226A current per turn and produced central magnetic field ~ 1T. Figure A.4.5 is showing the REBCO coil and A.4.6 is showing the performance test results for the REBCO coil setup.

Development of High-Temperature Superconducting (HTS) cable: HTS cables are potential future conductors for power cables, magnetic fusion, accelerator and medical research magnets. A HTS cable (figure A.4.7) of overall outer diameter ~43 mm has been designed, fabricated & tested at 77 K. Stacked HTS cable is fabricated using BSCCO-2223 & copper tapes of 4.8 mm wide and 0.2 mm thick and inserted in a vacuum insulated flexible cryostat with helium leak tight terminations for cryogen flow and the current communication. Its electrical testing was carried out in liquid nitrogen (LN_2) bath at 77K and with force flow LN_2 cooled condition up to 1kA current.

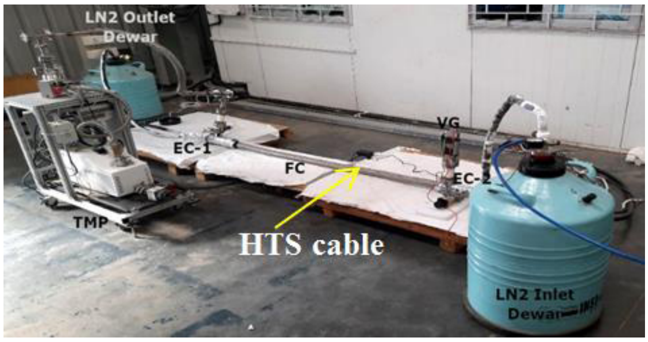


Figure A.4.7: HTS cable test set up.

Deuterium Ion irradiation study on HTS tape: DI-BSCCO superconducting tapes are irradiated with the 100 keV deuterium ions and the effect of ion irradiation on the critical current carrying capacity (Ic) of the High-Temperature Superconducting (HTS) is investigated. The damage formation simulations are carried out using the SRIM-TRIM code to study the spatial distribution and depth profile of the damage events in the HTS tape. The radiation dose of 2.90 MGy degrades the 44% critical current capacity of the tape. The results of the dpa and dose deposited by the deuterium ions are used to derive an empirical relation to predict the degradation of the critical current of the tape. This empirical relation successfully confirms the enhancement of Ic due to the heavy ion irradiation and degradation of Ic due to the light ions irradiation. This empirical relation can also be used in neutron and heavy ions irradiation and can be used to predict the lifetime of superconducting DI-BSCCO tape in fusion reactors and accelerator applications

Development of HTS current leads: A pair of prototype HTS current leads are fabricated and delivered to the institute by NFTDC. Installation and commissioning of these current leads carried out after realizing the low resistance copper to MgB_2 bottom joints in a dedicated test cryostat The performance testing of the prototype HTS current leads conducted satisfactorily up to 1800 A in the test setup (figure A.4.8).

Figure A.4.8: Integrated current leads with test setup.

A.4.2 High Temperature and Material Technologies

High Heat Flux Test Facility (HHFTF): HHFTF that was earlier operated in leased premises has now been disassembled, transported to institute and then again made operational. It uses a 200 kW/45kV electron beam as heat source for performing high heat-flux testing of plasma facing materials and water cooled plasma facing components. It can raster the e-beam at high speeds on the surface of components with a pre-defined beam pattern so as to generate steady-state as well as pulsed heat loads. HHFTF (figure A.4.9) includes a High-Pressure High-Temperature Water Circulation System for active cooling of the components during heat flux testing. Over the next 2 years, HHFTF will also be integrated with a high pressure high temperature Experimental Helium Cooling Loop (EHCL) that is now in the advanced stage of installation. This integration will allow heat flux testing of helium gas cooled plasma facing components such as First Wall of Test Blanket Module for ITER-like fusion device. New Target Handling System for HHFTF is under procurement for testing helium cooled components.

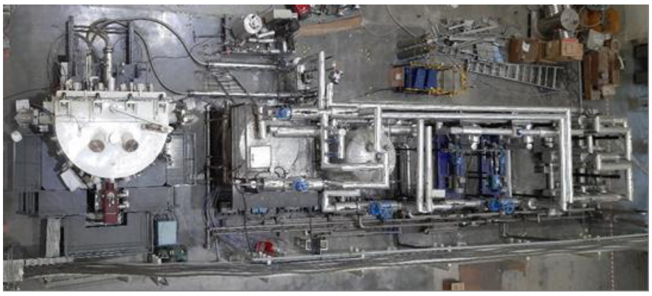


Figure A.4.9: A bird's eye view of the high heat flux test facility in operation.

Plasma Surface Interaction (PSI): Studies on the retarded recrystallization of tungsten in CIMPLE-PSI exposed under extreme surface temperature and He^+ fluence. In the ITER divertor, the surface temperature of the tungsten may increase beyond 1300˚C, which will lead to recrystallization of the metal, grain growth and deterioration of its surface properties. Previous experiments had demonstrated that prior exposure of the metal under helium ions may retard the process of grain growth, which was attributed to the drag force exerted by the helium bubbles/pinholes on the grain-boundaries of the metal. Experiments were carried out in the CIMPLE-PSI device (figure A.4.10) to study the re-crystallization behavior of tungsten, while exposed under very high He^+-fluence (3.6×10^{27} $m^{-2}s^{-1}$) and extreme target temperature (1593±5 ˚C).

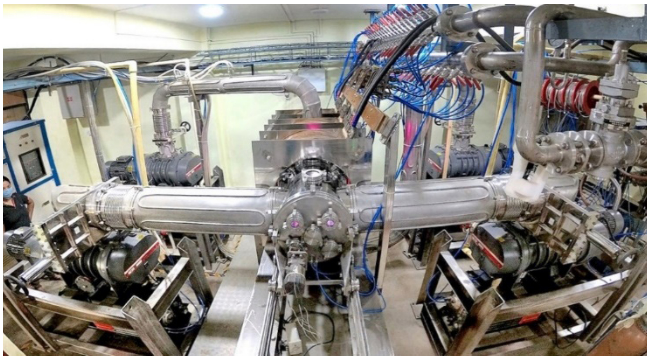


Figure A.4.10: CPP-IPR CIMPLE-PSI device.

CIMPLE-PSI is a tokamak divertor simulator device, developed for controlled plasma fusion research relevant plasma surface interaction (PSI) studies, which can reproduce both ion-flux (~10^{24} $m^{-2}s^{-1}$) and heat-flux (~5 MWm^{-2}) at ITER like limits. In contrast to previous experiments, targets during the present experiment were heated up entirely by plasma exposure, without any post annealing carried out in a vacuum furnace.

Exposed samples are characterized by optical microscopy (OM), field emission scanning electron microscopy (FESEM), electron backscattered diffraction (EBSD) and micro hardness tester (HV). It is observed that the grain boundaries in the high temperature exposed samples were densely populated with helium pinholes with very large sizes even beyond five hundred nanometres. Retarded grain growth was also detected in this sample, up to a depth of several tens of micrometre below the surface, although it was observed before that pinning effect from diffused helium may reduce with increasing size of the bubbles. Figure A.4.11 shows FESEM micrographs of the samples kept at high temperatures.

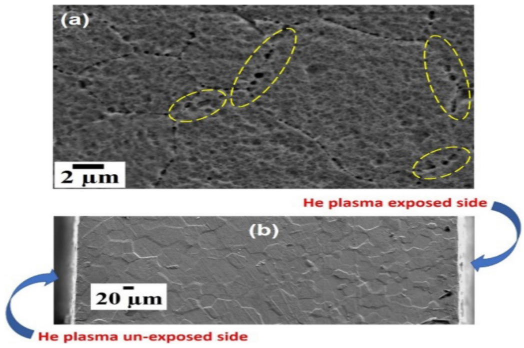


Figure A.4.11: (a) FESEM micrograph of plasma exposed sample at 1593±5 ˚C show large helium pinholes at grain boundaries (b) Cross-sectional FESEM of sample exposed at 1410±6 ˚C show grain size variation across the width of the target.

A.4.3 Fusion Blanket Technologies

<u>*Design and development of high-pressure, high-temperature (8.0 MPa, 300 - 400 ºC) helium cooling system:*</u> The Experimental Helium Cooling (EHCL) System (figure A.4.12) is being developed to perform testing of various fusion components such as tritium breeding blanket and helium-cooled diverter. As it is first of a kind facility, integrated operation of the close loop system, validation of operational and control logic, and performance validation of its different typical components such as high speed centrifugal circulator (figure A.4.13), Printed circuit type heat exchangers, Electrical heaters etc. are crucial. This loop will simulate Helium cooling system for fusion blanket (Test Blanket Module in ITER). Presently the system is in advance stage of Integration and testing. The system has been successfully tested for leak and pressure testing. Figure A.4.14 shows the installation

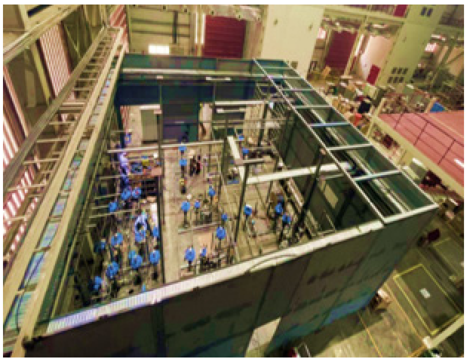


Figure A.4.12: Bird`s eye view of the EHCL system at site.

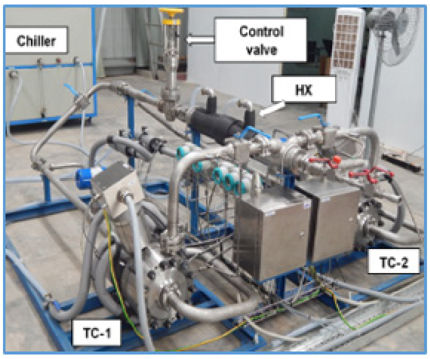


Figure A.4.13: Helium circulator test facility.

Figure A.4.14: Installation of EHCL components.

of EHCL components.

<u>*Development of Lead Lithium (Pb-Li) Loop at IPR for thermo-fluid MHD studies:*</u> *T*he Liquid Lead Lithium Magneto Hydro Dynamics (LLMHD) experimental facility is designed to perform various MHD R & D experiments associated with conducting liquid metal flow under strong transverse magnetic field. Major parameters of the loop are – Molten Pb-Li with 60 litre inventory, operating temperature of 300 °C, operating pressure of 3.0 bar and flow rate up to 8 kg/s.

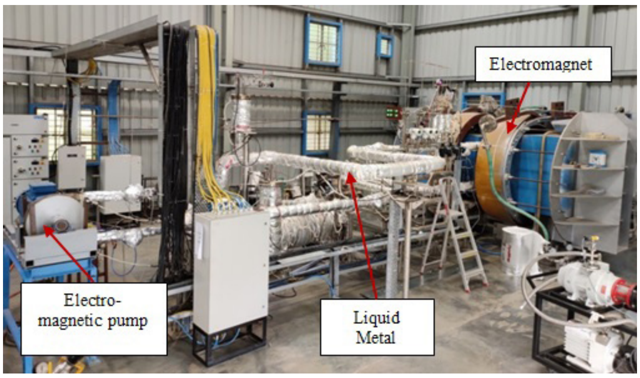


Figure A.4.15: LLMHD loop at the institute.

LLMHD Electromagnet consists of 2 nos. of water cooler Cooper Coils and C-shaped Low Carbon Steel Electromagnetic Core of weight ~ 60 metric ton. The electromagnet is designed to generate a magnetic field of 1.4 T in the polar volume of 1000mm (Poloidal) × 370mm (Toroidal) × 400mm (Radial). Each coil having internal radii of 782 mm has 12 turns of OFE Copper hollow conductor, 60 mm x 60 mm square cross section, with 32 mm dia. hole for cooling water. A 24 kA DC bus bar system with 24 nos. of 100 mm x 6 mm Copper Bars in parallel connects the Power Supply to the Electromagnet.

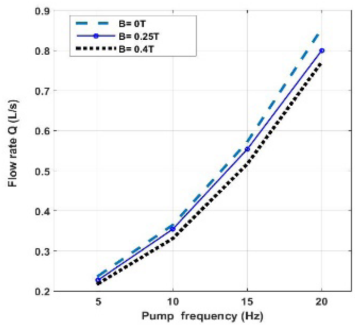


Figure A.4.16: Variation of flow rate with pump frequency at B=0T, 0.25T & 0.4T.

The assembly and installation of LLMHD loop has been completed (figure 4.1.15) and MHD experiments have been performed with a test mock up having circular flow geometry under transverse magnetic field (up to 0.5 T). Preliminary results indicate reduction in Pb-Li flow rate in presence of the magnetic field (figure 4.1.16). The sinusoidal distribution of the wall electric potential has also been observed, as expected.

Development of Magneto Hydro Dynamic (MHD) Flowmeter for high temperature conducting fluids: Institute has developed MHD type flowmeters for high temperature applications, which have high precision and can work with corrosive/non-corrosive electrically conducting fluids (figure A.4.17). It works on the Faraday's law of induction, wherein an emf is generated in a conducting fluid when it travels through a transverse magnetic field. The flowmeters are successfully tested at temperatures of 300°C - 350°C, 3 bar, flow rates of ~100 ltr/m. It utilizes a magnet arrangement producing a magnetic field of ~ 0.8 T and provides a high sensitivity of 0.33 mV.min/ltr and can be continuously used in high operational temperatures. In order to calibrate such flowmeters, sophisticated calibration facility and numerical techniques have been developed and verified.

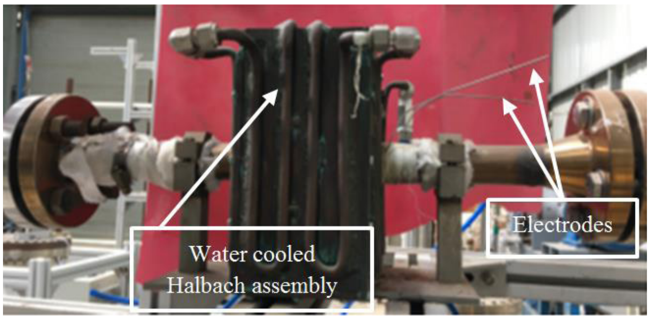


Figure A.4.17: MHD flow meter developed at the institute.

Indigenous Pb-16Li Production and its qualification: An in-house Lead Lithium Eutectic (Pb-16Li) production system has been developed at the institute for the production of Pb-16Li ingots. The system uses MHD stirring technique to mix the molten lead and molten lithium to produce Pb-16Li alloy. The capacity of the system is ~75kg per batch. The samples from the produced Pb-16Li ingots (figure A.4.18) have been characterized through Differential Scanning Calorimetry (DSC) analysis to determine the melting point of the sample. The result of the analysis confirms the formation of Pb-16Li eutectic. The elemental analysis to determine the composition of Li in the Pb-16Li sample is under progress. The produced Pb-16Li ingots will be used in the various liquid metal experiments at the institute.

Figure A.4.18: Produced Pb-16Li ingots.

Investigations on electrical insulating coatings for Lead-Lithium applications: Electrical-insulating coatings are of great importance for applications in liquid metal breeder/coolant based systems relevant to nuclear fusion power plants. Such coatings are being actively investigated for their criticality in addressing various functionalities including, reduction in MHD pressure drop, corrosion resistance to structural materials and development of specific diagnostics. Experimental studies are under progress towards application of $AlPO_4$ bonded high-purity alumina (Al_2O_3) coatings on SS-316L substrates and further rigorous validation in static PbLi environment (figure A.4.19). The optimized heat cure parameters require a low temperature heat treatment (< 450 °C) yielding average coating thicknesses in the range of ~ 100 µm – 500 µm. Coated samples are rigorously validated for their electrical-insulation integrity within static PbLi for continuous durations upto 1360 h at operational temperature between 300°C - 400°C. In-situ estimations of thermal derating factors and volumetric electrical-resistivity suggest good insulation characteristics (order of 10^9-10^{11} Ω-cm) without significant degradation after long term exposure to liquid PbLi. Detailed metallurgical analyses (SEM/EDX and XRD) are being conducted for coating thickness estimations, liquid metal ingress detection and microstructure examinations. The validated coating is now being utilized to fabricate complex liquid-metal flow channel configurations for applications in MHD pressure drop reductions.

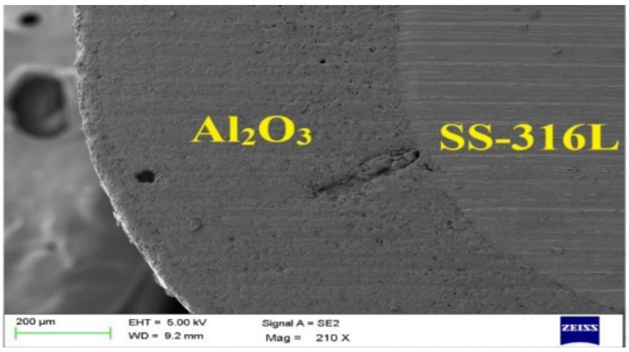


Figure A.4.19: SEM image of a compact alumina layer well-adhered to SS-316L substrate.

<u>*Development of a two-phase detection probe for Lead-Lithium applications:*</u> Existence of a two-phase flow in lithium-based liquid metal breeders for nuclear fusion blankets are a cause of concern due to critical issues including reduced tritium breeding ratio (TBR), generation of hot-spots and improper nuclear shielding. Additionally, a large density ratio between liquid metal and gas requires experimental database towards the development and validation of the numerical models. In this view, a liquid metal–gas two-phase detection diagnostics is imperative for PbLi environment. However, corrosive nature of PbLi at high operational temperature severely restricts commercially available diagnostics. In this view, an electrical-conductivity and temperature measurements based multivariable two-phase detection probe is developed using high-purity alumina coating as an electrical insulation and a functional material inhibiting corrosion of sensor. Probe validation is performed in PbLi–argon vertical column with bulk liquid metal temperature upto 400°C over a wide range of time-averaged void-fractions (0 to 0.95), covering flow-regimes from bubbly flow upto in-box loss of coolant accident (LOCA). The probe is assessed to provide high reliability & temporal resolution towards individual bubble detection. The probe is being utilized for estimations of time-averaged void-fraction, average bubble frequency & residence time and bulk two-phase temperature. Figure A.4.20 showing the probe schematic and test facility.

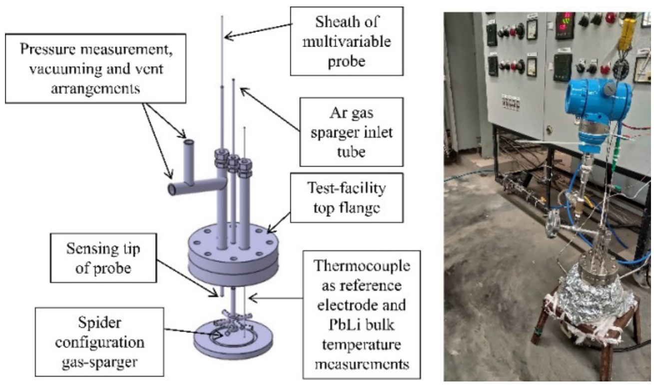


Figure A.4.20: PbLi-argon two-phase flow test facility for calibration and validation of developed probe.

<u>*Development of Lithium Ceramic (Li_2TiO_3) as tritium breeder material and characterizations:*</u>

Institute has developed qualified Lithium ceramic (Li_2TiO_3) pebbles as the tritium breeder material. Extensive characterizations are also being carried out to meet the desired properties. Indigenously developed high temperature effective thermal conductivity measurement of pebble bed is currently under progress using steady state axial heat transfer method & hot wire method.

Effective thermal conductivity of (Li_2TiO_3) pebble beds: The effective thermal conductivity of lithium metatitanate pebble beds has been measured as a function of the pebble bed temperature (up to 800 °C) and under helium gas pressure (0.105 MPa - 0.4 MPa) using the installed test facility based on the steady-state radial heat flow methods.

Experiments to measure the strain of a side wall mock-up plate: Experiments have been performed to measure the thermal strain data in the structural material using a high-temperature compatible strain gauge. The results have been validated with the two-dimensional digital image correlation (2D-DIC) techniques. Figure A.4.21 shows the experimental mock-up plate and the test facility.

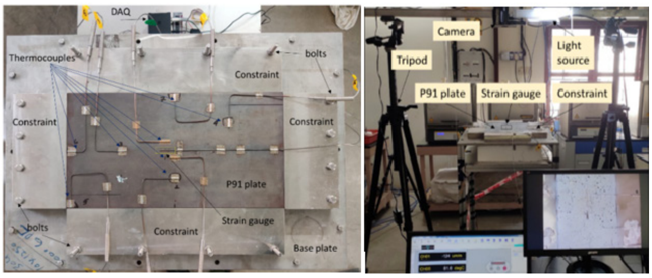


Figure A.4.21: Experimental test facility to measure strain of a side wall mock-up plate.

Installation and testing of the tendered thermo mechanical test facility: Installation and testing have been successfully carried out for the thermo-mechanical test facility (figure A.4.22) for the characterization of lithium ceramic pebble beds. The preliminary cyclic compression and thermal creep experiments on the lithium metatitanate and alumina pebble beds have been performed after the installation of the machine in the lab.

Figure A.4.22: Experimental facility for Pebble bed thermos-mechanical experiments.

A.4.4 Large Cryogenic Plant and Cryosystems

In-house Development of Liquid Nitrogen cooled sorption cryopump for SST-1 Tokamak: A Liquid nitrogen-cooled sorption cryopump has been developed for the pumping of the vacuum vessel of the SST-1 Tokamak. This pump was tested for its performance and then installed on the radial port of SST-1. The pump has been designed for operation during the baking of the SST-1 vacuum vessel at 150°C. The pumping speed for water vapour was observed to be approximately 26,000 litre/sec while maintaining a pressure of 10^{-6} mbar, for evacuating gas load of ~2.6×10^{-2} mbar-litre/sec. The pumping speed was maintained by 258 Watts of external radiation heat load. This is a contribution to Atmanirbhar Bharat. Figure A.4.23 shows the team who developed the cryopump placed at the center.

Indigenous Development of Helium Compressors: Helium compressor system of industry scale, required for the helium refrigerator/liquefier (HRL) plant has been successfully developed. This has been achieved by modification of an industry-scale air compressor. This is done for the first time in India. This is a part of the development project of HRL plant being carried out in the institute. In such plants, 2 major systems are involved: Cold box which contains the cold components and the compressor system which provides pure and pressurized (~14 bar) helium gas at about room temperature to the cold box for production of liquid helium at 4.5 K (-268.65^{0}C). The most difficult gas to liquefy is Helium, more than 90% of this helium gas returns back to suction of compressor system at little higher than atmospheric pressure (~1.05 bar) and about room temperature. Thus, in closed loop, helium is circulated.

Figure A.4.23: Developed cryopump with team members of Cryopump Division, SST-1 Vacuum and Cryogenics Division.

The compressor systems required for HRL plant are oil injected screw compressor type. This type of air compressors are also used where medium pressure and high air flow rates are required (figure A.4.24). For making helium compressor, here, such type of air compressor has been procured from Indian market and modified. Compared to air compressor, compressor of HRL plant involves significant critical design aspects, like: oil content in the delivery helium should be few tens of PPB (parts per billion), smooth and continuous operation of few days (few weeks in some cases), high helium leak tightness, closed-loop operation with controlled start-up and shut down. These have been achieved indigenously. Two main sub-systems required, which were developed and added to the open-loop air compressor for making the closed-loop helium compressor are PPB level oil separation system with its measurement and warm gas management system with automation of operation.

Parts per Billion (PPB) level oil separation with its measurement: The oil separation from the discharge helium gas is very important before operating the cold box, as, oil going to the low temperature parts can get solidified and can choke many helium components leading to severe damage to turbines also. Oil content should be < 100 PPB (parts per billion by volume). To achieve this, threecoalescers and an oil adsorber purifier bed have been indigenously designed, fabricated tested and installed. An oil impurity analyzer or gas chromatograph, called as THC (total hydrocarbon) analyzer have been used. This is also made indigenously. The installed indigenous oil separation sub-system provides oil at the outlet < 50 PPB while oil content at inlet is ~3 PPM (figure A.4.25).

Warm Gas Management: The room temperature helium gas is required to be fed to the compressor pipe lines from the gas helium process tank during start-up and reverse happens during shut-down. This needs to be done smoothly. For this certain pressure control valves, pressure transmitters, PLC and a control logic for automatic process are required. These have been successfully implemented and compressor system is operated in automatic mode. This has been developed indigenously for helium flow of 60 g/s and pressure 14 bar. It has three pressure control valves, different instruments (pressure, differential pressure, flow meter, etc) a helium process tank, PLC system with control logic for operation. Mostly, these have been developed indigenously and operated successfully and based on this automation, the whole cold box operation down to 4.5 K will become easier.

Automation of helium CORS: Institute has developed an automation system required for the operation of the indigenous helium compressor system in closed loop. During start of the compressor, helium gas need to be fed to the compressor system in a controlled manner so that required suction pressure of about 1 bar is maintained. During this time, 3 pressure control valves (PCV) need to be operated in controlled manner, to get the required pressure at suction and discharge line (figure A.4.26). If the pressure is sub-atmospheric, then, air as impurity can ingress to the helium gas and if the pressure is more than 1.1 bar, then load on the compressor increases. Manually controlling these 3 valves is very tedious job and there can be error. This automation system has made the compressor operation easy. The similar requirement comes while stopping the compressor system. With this developed automation system the pressure variation acheived is within ~50 mbar which is right for helium turbine operation and so for the cold box of the helium plant.

Successful Commissioning of helium turbines: Commissioning of high speed cryogenic helium turbines has been successfully performed at the institute. The three turbines have design speeds of 2.2, 1.6 and 1.1 lakhs RPM respectively and its

Table A.4.1: Some salient features of developed helium compressor.

Features	**Tested values**	**Features**	**Tested values**
Helium flow rate	~60 g/s	Oil content in the delivery gas	< 50 PPB
Delivery pressure	14.5 bar	Helium flow rate at suction	760 m^3 per hour
Suction pressure	1.07 bar	Helium leak tightness	0.04 m^3 per day
Electrical power consumption	177 kW	Cooling provision	By only ambient air, no water-cooling

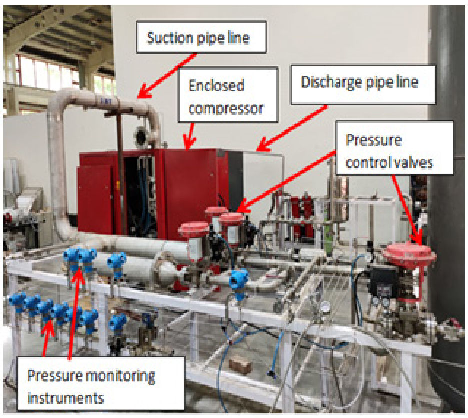


Figure A.4.24: Developed helium compressor.

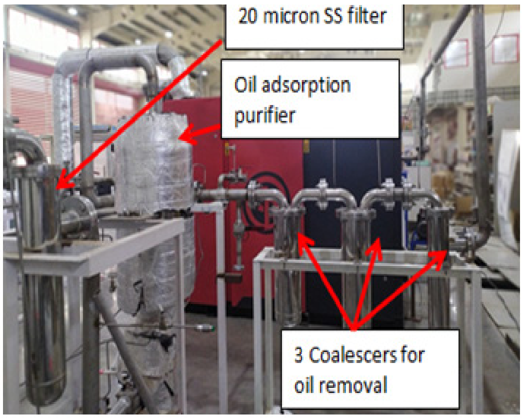


Figure A.4.25: Picture of developed Secondary oil removal system.

Figure A.4.26: Indigenously developed pressure control valve for helium service.

nominal inlet helium temperatures are 33, 15 and 7 K respectively. These turbines were imported for the helium refrigerator plant which is being indigenously developed at the institute.

Development of Indigenous Helium Refrigerator-cum-liquefier Plant: Institute is developing an indigenous liquid helium refrigerator plant. This plant has many critical components developed completely indigenously, except helium turbines and cryogenic valves. The helium compressor and oil removal system required for helium plant operation should be of quite good quality and this has been developed using an open-loop air compressor. The assembly of this helium plant was completed in June 2021.

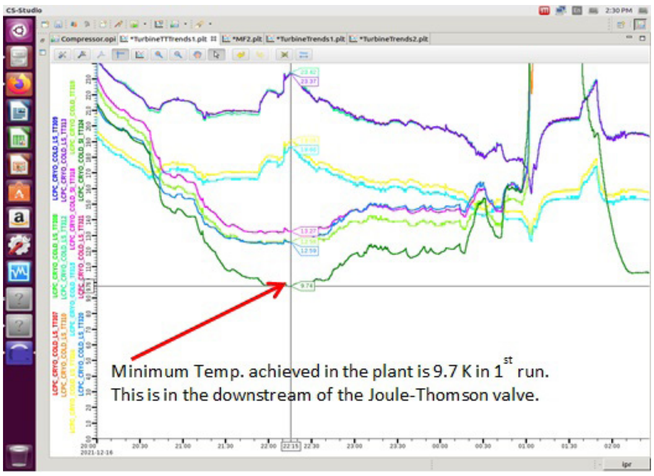


Figure A.4.27: Minimum Temperature of the plant achieved 1st run.

Different systems and sub-systems were operated step by step before going to do the complete helium plant operation. After these steps, complete plant was operated in Dec 2021 and the performance of the plant was tested with target performance of 200 W refrigeration at liquid helium temperature ~4.5 K the refrigeration power of ~500 W at ~15 K or 1000 W at ~50 K but not simultaneously. The cooling power more than 600 W at ~18 K was achieved in the 1st operation of the indigenous helium plant at 4.5 K with liquid helium generation in the liquid helium chamber inside the cold box successfully. Further enhancements are in progress. Figure A.4.27 shows the typical performance of the plant.

Development of medium and high pressure helium circulator: Considering the requirement of high pressure leak tight helium circulator for different applications, an attempt has been made to develop it. Recently it has been developed and successfully tested with operating pressure up to 35 bar and helium leak rate from circulator body < 5 x 10^{-5} mbar. ltr/s.

A.4.5 Remote Handling & Robotics Technologies

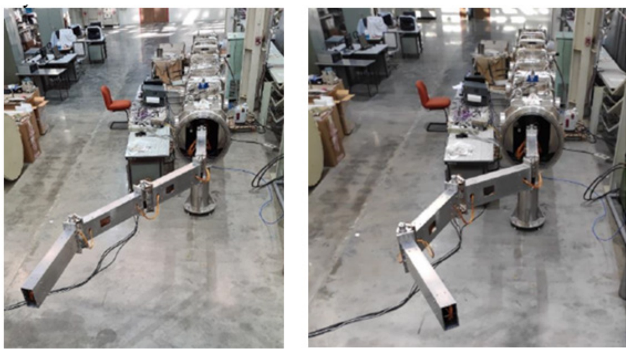


Figure A.4.28: IVIS system.

Development of In-vessel Inspection System (IVIS) for remote inspection of Tokamak components: Plasma facing components (PFCs) in a tokamak are subjected to high heat & particle fluxes, which damages them over time. Hence periodic inspection is essential for health monitoring of PFCs in-between plasma experiments, and this must be done without breaking the ultra-high vacuum. An In-Vessel Inspection System (IVIS) (figure A.4.28) has been developed to perform remote in-service inspection inside a toroidal vacuum vessel. The IVIS is compatible with 10^{-7} mbar vacuum and 100°C temperature. It consists of a six-DOF articulated arm with reach up to 4 m, mounted on a linear guide and a vacuum storage chamber (VSC). IVIS is controlled remotely using virtual reality based monitoring and control. During initial testing, position Setup of 14-MeV Neutron Generator Measured Dose Rate repeatability of ±2mm has been achieved. IVIS can also be adapted for inspection & maintenance in any large system having a challenging environment like vacuum, temperature, narrow spaces etc.

Interactive Virtual Reality CAVE facility: A three sided fully immersive Cave Automatic Virtual Environment (CAVE) VR facility has been successfully established at the institute as shown in figure A.4.29 and A.4.30.

Figure A.4.29: VR facility at IPR.

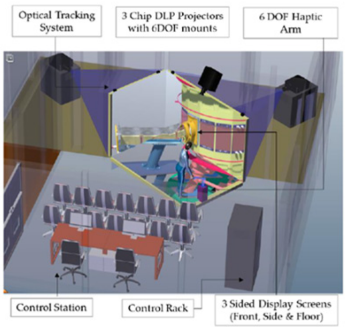


Figure A.4.30: Layout of virtual reality.

The remote handling and robotic operations inside challenging environments such as tokamaks require accurate perception of the dynamic working environment. The aim of this facility is to give the operators the same unrestricted knowledge of the task scene as would be available if they were physically located inside the remote environment. Using this facility, users can instantly view and interact with virtual 3D models of any machines/systems and feel as if they are fully immersed in the actual environment. With haptic arm, the users can feel the collisions and forces while carrying out virtual assembly task or while performing master slave robotic operations. The facility is extremely useful in developing 3D virtual walkthroughs of systems/machines, design reviews, accurate virtual prototyping thereby eliminating the need for physical prototypes, system interface & integration studies, real-time monitoring and control of remote handling/robotic operations and customized operator training by developing simulated scenarios using CAD & simulation software, etc.

A.4.6 Negative Ion Neutral Beam Technologies

Experiments for Negative Ion Sources:

RF Operated Beam source in India for Negative ion (ROBIN): The negative hydrogen ion source named ROBIN have been operated in volume and surface mode under controlled Cesiated conditions and assisted by Langmuir probe and optical emission spectroscopy diagnostics at appropriate locations. Residual Gas Analyser (RGA) monitored control over the impurities by baking and continuous pumping of the source have reduced the partial pressure of water vapour and residual gases. Additionally, Cryo-pumping further improved upon vacuum conditions. An extremely slow raise of the reservoir temperature of the Cs oven to increase the Cs density as per experimental observations were implemented. This have resulted in achieving H- ion current densities > 30 mA/cm^2 with electron to negative ion ratios < 1 and with Cs consumption ~12 mg/hr. Figure A.4.31a shows the source performance in terms of negative ion current density and electron to ion ratio for the full experimental campaign and figure A.4.31b shows the beam transmission which is between 60-80% (typically). The experiments have established the ITER relevant H^- ion source operation parameters and are significantly important and provide the much needed operational data base and experience for operation of 8 driver diagnostic neutral beam source on the India test facility (INTF). A systematic parametric dependence of the source performance in terms of the filling pressures (0.6 Pascal – 0.35 Pascal), RF power (30-80 kW), effect of the bias voltage on the accelerated H^- ion current densities electron to ion ratios, and transmitted beam has been performed. The results obtained have been analysed to determine the plasma and negative ion densities and electron temperatures. Analysis is underway but the primary signatures show top bottom asymmetries in plasma and negative ion densities and the electron temperatures.

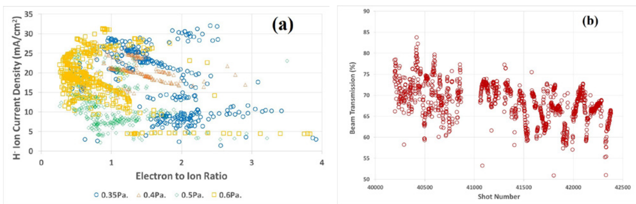


Figure A.4.31: (a)ROBIN source performance in terms of negative ion current density and electron to ion ratio for the full experimental campaign and (b) Transmitted beam for the full experimental campaign.

A new configuration of using additional electrodes in front of the extraction zone to control the electron to ion ratio especially, at lower operational pressures has been added to the current experimental set up for the upcoming experimental campaign. Provisions for biasing the electrodes either to the same voltage as that of the plasma grid or independently have been made. The observations shall provide an additional insight into source operations to ensure the desired beams with better control on electrons especially at the lower operational pressures.

TWo driven Ion source for Negative ion (TWIN SOURCE): The TWIN source test bed is an experimental test bed with 2 drivers RF based negative ion source which has been fabricated indegeneously. The present set up allows plasma operations with RF power from a single RF generator coupled to two RF drivers through a matching circuit. This configuration similar to the one anticipated for operations of the 8 driver RF beam source on the INTF.

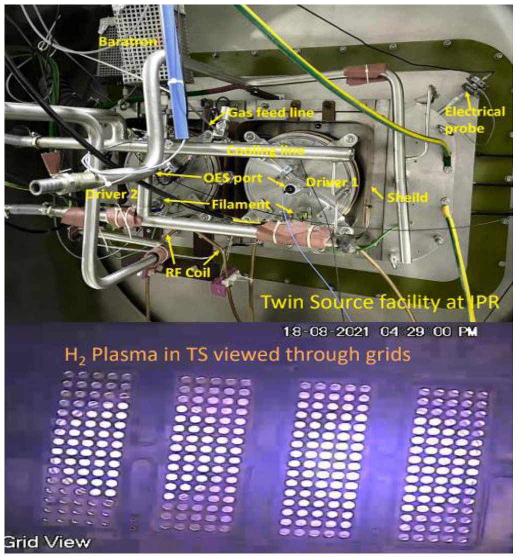


Figure A.4.32: Photograph of actual experimental setup of Twin Source (top) and camera view of Hydrogen plasma in twin source viewed through the dummy grids.

Twin source has been operated in single driver as well as TWIN driver configurations by coupling RF power from an indigenously built solid state 40 kW, 1MHz Solid State RF generator. The source was operated in the range of 0.4 -1 Pa source pressure for pulse lengths of 1-4 sec and RF power ranging from 5-40KW. The diagnostics used during the operations are OES, Langmuir probe measurements & water calorimetry. The coupling of RF power is established by changing of RF frequency and then further optimized using the parameters of the matching circuit. Plasma densities of the order of 10^{17} m^{-3} have been obtained through coupling of 40 kW RF power to the source. Figure A.4.32 shows a picture of TWIN source and plasma operation with two drivers.

Upgradation of cooling water system for Twin source experiments: Cooling water system for Twin source experiments has been upgraded for grid cooling requirements, valves and instrumentations (like pressure safety valves, RTDs , conductivity meter, p H meter, glove valves etc). Upgraded system successfully tested for a total flow rate of 650 lpm @ 5 bar pressure. Prior to this flow test, full system has also been tested for hydrostatic testing up to 15 bar. Figure A.4.33 shows the TWIN source upgraded cooling water system.

Figure A.4.33: Cooling water system of TS.

Manufacturing of Grid holder boxes: Grid holder boxes for next phases for Twin source beam extraction experiments are successfully manufactured and received at institute site shown in figure A.4.34. These have been high precision machined components having tolerances close to 100 microns.

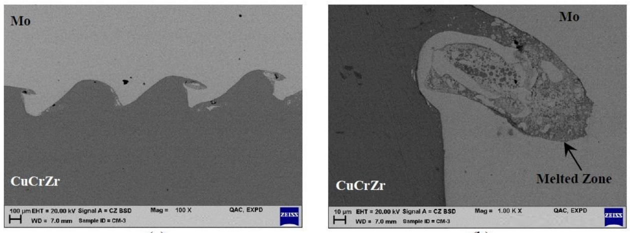
Figure A.4.34: Grid holder boxes.

Manufacturing activities on Twin source extraction system: Manufacturing activities on Twin source beam extraction system (grids) progressed at manufacturer's site. One set of extraction grids successfully manufactured and tested for pressure testing, leak testing and IR thermography. The achieved leak rate is less than $5x10^{-9}$ mbar-lit/sec in local mode (vacuum) and close to $7x10^{-9}$ mbar-lit/sec in global mode (pressurized mode) at room temperature and elevated temperature of $100^{0}C$. Static pressure testing done with dry nitrogen at 12.5 bar for 10 minutes.

Manufacturing of Ceramic post insulators: Ceramic Post insulators with metallic parts (for Twin Source) are successfully manufactured and received at the institute. The machined ceramic cylinders have dimensional tolerances close to 50 microns. These post insulators are parts of Twin source extraction system and would be integrated with grids. Ceramic post insulators also tested for high voltage testing for 120kV in air mode.

Development of Explosion cladding technology for providing Mo over the CuCrZr / CuOF: Plasma Driver Plate (PDP) for Neutral Beam RF based Ion sources requires the Molybdenum layer to the level of ~ > 1mm to protect the base material surface from plasma and back streaming ion sputtering.

Conventionally for the present Ion sources, this Mo layer is achieved by Physical Vapour Deposition (PVD) process, by which the thickness normally achieved is ~3-5 microns because of technological limitations. However, the Ion sources for ITER like machine requires much higher thickness of Mo, upto 1mm. The same has been explored through explosive welding technique. Explosive welding is a solid state welding process where welding is accomplished by accelerating one of the components at extremely high velocity to impact on another component through the use of chemical explosives. During this development, important objectives were to (1) Optimization of explosive quantity required to accelerate the flyer plate to the specified flyer velocity and create the required impact energy necessary for bonding of the two surfaces (2) For this specific combination, to study the effect of welding parameters which includes stand-off distance, surface roughness and explosive mass. Different types of joint qualifications tests were conducted to verify the integrity of the explosively welded joint. These qualification tests include both the metallurgical evaluation such as visual examination, optical microscopy, SEM imaging along with EDX, XRD as well as mechanical tests such as, qualitative chisel test, bend test, hardness test, Ram tensile test, tensile strength and tensile shear strength determination etc. Figure A.4.35 shows the SEM image of Cu/Mo weld interface region.

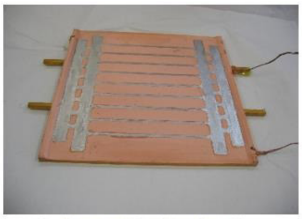


(a) (b)

Figure A.4.35: SEM BSE image; Cu/Mo weld interface at (a) 100X (b) 1.00KX.

<u>Indigenous Development of Electrodeposition Technology for accelerator grids (in collaboration with RRCAT):</u> Accelerator grids for neutral beam system for nuclear fusion application need active

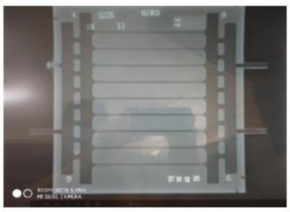
Plate with cooling channels filled with 'WAX'



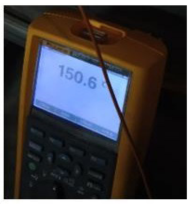
Surface activation by Silver Paint- ready for electrodeposition

Electro-deposition in process

Electro-deposited plate- He leak tightness in the range of 10^{-9}mbarl/s



Radiographic Scan of the Electrodeposited plate, presenting the embedded cooling channels



Hot Helium Leak Test (Temp ~140 deg C, Pressure 30 bar, achieved leak rate in the range of 10^{-9}mbarl/s)

Figure A.4.36: Electrodeposition technology for accelerator grids and its different tests.

water cooling for absorbing the incident heat loads during beam operation. Copper Electrodeposition (CuED) is the process used to manufacture such grids with embedded narrow cooling channels, which typically shall withstand the water pressure of 25 bars at the operational temp upto 150^{0}C. Indigenous technology has been developed in collaboration with RRCAT, for such electrodeposition over the area of ~ 300mm x 300 mm. The quality of the deposition, bond characteristics, and the integrity has been established through high pressure test and the Hot Helium leak test. Figure A.4.36 shows the CuED technology steps and its vacuum integrity test.

Indigenous Development of Vacuum Barrier: A substitute of imported vacuum barrier for RF systems is successfully developed indigenously in collaboration with Nonferrous Materials Technology Development Centre (NFTDC) under a BRNS project.

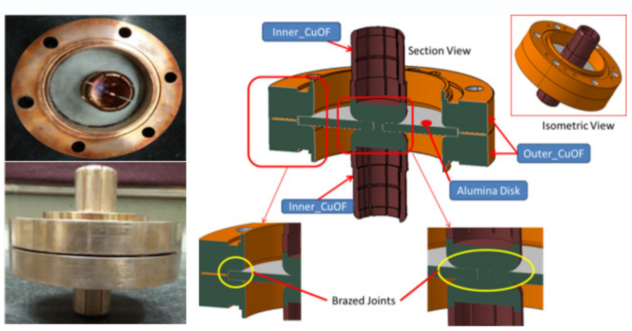


Figure A.4.37: Configuration of Indigenously developed Vacuum Barrier and a real developed product (left).

The Vacuum barrier is used to deliver RF power from RF generators to the systems operated in vacuum environment. It also provide high voltage isolation between inner to outer conductor of RF coaxial conductor. Brazed configuration of RF vacuum barrier with Alumina as an isolator is not commercially available locally as they are made to specific design for functional needs. This leads to import of high priced vacuum barriers from foreign manufactures. The cost of indigenous vacuum barrier will be half than the cost of vacuum barriers being imported and it can be further reduced if manufactured in bulk. During this development, the main challenge was to carry out simultaneous brazing at two different locations for joining inner and outer conductor (Copper) with Alumina. This was successfully addressed with the help of fixture design, joint configuration development, brazing cycle optimization etc. The indigenously developed vacuum barrier were qualified through the demonstration of Helium leak tightness of the order of 10^{-9} mbar-ltr/s. In its present form, this development can be directly applied for vacuum to atmosphere interfaces for fusion and accelerator experiments. Additionally, this development provides confidence in achieving the similar brazed assemblies of ceramic to metal in other applications like accelerators. Figure A.4.37 shows a real developed vacuum barrier and its configuration.

Characterizing electro-deposited copper layer on copper substrates for high temperature operation in fusion machines: Several components used in fusion machines use electro-deposition as the process to cover the milled cooling channels on the base plates. One such components are the grid segments of the extractor and accelerator system of the neutral beam systems. The degree of complication is added with the need for such components to operate under high temperature conditions. Till now no database or code exists globally towards the characterization of such electro-deposited layers at room temperature and also at elevated operational temperatures. A procedure has been established by ITER-India, where, customized configuration have been prepared for the study of bond strength of the electrodeposited layer to its base material. 20 different samples from different electrodeposition baths and operating under different conditions have been tested for the bond strengths and room temperature and elevated temperatures, for obtain a statistical data set. It is observed that for the samples under study the bond strength varied between 122 MPa to 162 MPa, against a 120 MPa bond strength for the base material at room temperature. Further the bond strength reduced to 60 MPa - 80 MPa at elevated temperature of 150^{o}C. It is established that lower bond strength at elevated temperatures would lead to failure of the bond between the electrodeposited layer and the base material thereby preventing its use at elevated temperatures, 150^{o}C, and elevated pressures of ~25 bar.

A.4.7 Neutronics Studies

The lab-scale D-T neutron generator has been developed using a 2.45 GHz Electron Cyclotron Resonance Ion Source (ECRIS) and water-cooled rotating tritium target to produce ~10^{12} n/s (figure A.4.38). It will serve the purpose of performing fusion neutronics studies. In this device, Neutrons are going to be generated from the nuclear reaction 3H(D, n) 4He by bombarding solid tritium (TiT) target with accelerated deuterium ion (D^+) up to 300 keV via electrostatic accelerator. However, the realization of this device depends on the availability of an accelerator capable of delivering 20 mA D^+ ion beams at energies up to 300 keV easily, reliably, stably, and affordably. It also depends upon the performance of the water-cooled rotating target. The main subsystems of the D-T neutron generator are ECRIS, High voltage deck, Low Energy Beam Transport (LEBT) system, Acceleration column, Medium Energy Beam Transport (MEBT) system, 300kV HVPS, Tritium handling & recovery system, and Rotating tritium target. The LEBT transports the extracted deuterium ion beam from ECRIS to the acceleration system.

Figure A.4.38: Setup of 14-MeV Neutron Generator.

The MEBT transports the accelerated deuterium beam and bombards the Tritiated target, which produces the 14-MeV neutron. The deuterium ion beam has been characterized with measurement of beam current, beam diameter, and beam emittance. The achieved D^+ beam current, beam diameter, and beam emittance are 19.94 mA, ~20 mm, and 0.27 π·mm·mrad, respectively. The neutron generator has been tested for continuous operation with an average neutron yield of 7×10^{11} n/s, which will go to 5×10^{12} n/s at full strength, the most powerful such source in India.

A.4.8 Power Supply Systems

Power Supplies for Particle Accelerator Based Application (500 kV/100 mA DC): The 500 kV/100 mA DC Power Supply is designed and developed (figure A.4.39)using Symmetrical Voltage Multiplier Topology. This topology/configuration is best suited for Low Power (< 100 kW), High Energy (>50 keV) Particle (ion/electron) Accelerator Application. The power supply is integrated and commissioned for 500 kV and tested upto 320 kV/80 mA Load as on date. It is designed and developed considering scalability/upgrade upto 1000 kV/100 mA rating. It is conceptualised and designed in-house and developed with the support of Indian MSME's.

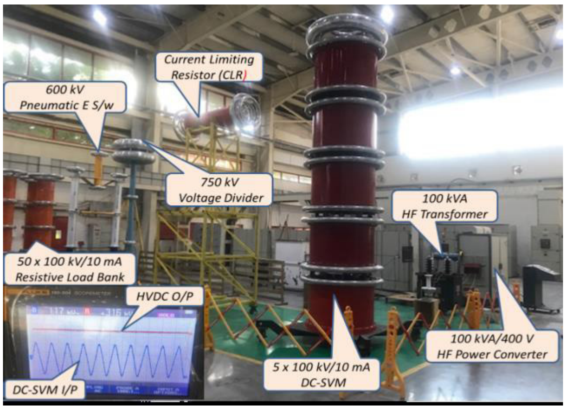


Figure A.4.39: View of 500kV 100mA DC power supply.

Power Supplies for Negative Neutral Beam Injector (N-NBI) (500 kV/2 A DC): The 500 kV/2 A DC Power Supply is being designed and developed (figure A.4.40) in two phases. Phase-I shall demonstrate the functioning of power supply upto 300 kV/2A and in Phase-II the power supply will be scaled/upgraded upto 500 kV/ 2A rating. The topology/configuration decided as shown above figure is best topology for Particle Accelerator Application demanding High Power (> 1 MW), High Energy (> 100 keV), Low Stored Energy (< few tens of Joules), and fast transient response. In particular the power supply is aimed to be used for Negative Ion Neutral Beam Injector (N-NBI) for future Fusion grade Tokamak machines. The two of the three major sub-system i.e. AC/DC Converter (Controlled Rectifier), and T-NPC based DC/AC Converter (Inverters) are Integrated, Tested & Commissioned at Rated Load Condition (> 95 %). The third sub-system i.e. High Voltage Transformer Rectifier is under manufacturing. The power supply is being indigenously (100 % Make In India (MII) compliant) developed with the support of Indian MSME's.

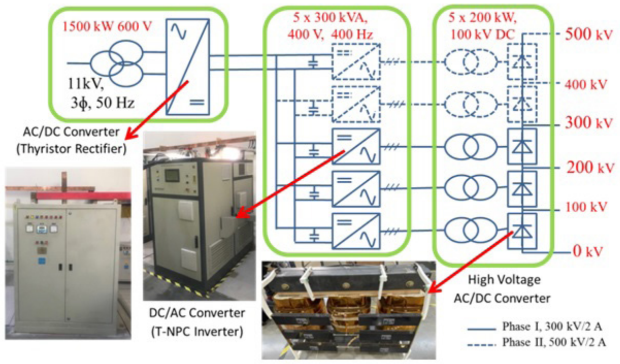


Figure A.4.40: 500kV 2A Power supply for N-NNB.

Fast Response Bipolar Power Supply (FRBPS) Project: Fast response bipolar power supplies are being developed for Divertor coil of Aditya-U Tokamak and PF6 coil in SST-1 Tokamak. The parameters of the Divertor coil are 60 micro henry and 2 milliohm, and PF6 coil parameters are 100 micro henry & 1 milliohm. The power supply is 5 kA bipolar, 500 VDC with fast response minimum 1 MA/s to max V/L A/s. The power supply will be capable of responding to Arbitrary reference (random signal W, trapezoidal, triangular or sinusoidal). The advantages of in house development are ease in troubleshooting & upgradation. Control will be fully digital with high end remote communication which was previously analog. It will be a highly reliable system with less number of modules and configurable ratings. Presently single module is tested and components for all 10 modules have been procured.

A.5 Theoretical, Modelling & Computational Plasma Physics

IPR has continued its excellency in theoretical, modelling and computational research with a lot of the results published in reputed journals. The important works are categorized and summarized below

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

In 2021, ANTYA HPC achieved an uptime of more than 99% (~99.45%), an increase of ~3% as compared to 2020. There was a planned downtime of 2 days only in June 2021 for the hardware maintenance and software upgradation activities. Throughout the pandemic, it has provided large amounts of remote computational resources to ensure the development of research remains of utmost importance during turbulent times. With the resumption of users to office, the use of resources has expanded and we have witnessed more than 90% utilization almost consistently in quarter 1 (Q1) of 2022. The same has been reflected in the number of internal library publications which were more than 100 during 2021-2022. Table A.5.1 gives a summary of the computational resources (CPU and GPU) of ANTYA available during the period April 2021 to March 2022.

Institute's ANTYA having a maximum performance of 1 PetaFlop (PF) maintained its position to rank in the top 15 in the Top Supercomputers-India list (TopSC.in) released in Jan 2022 by C-DAC, a pan-Indian equivalent of the Top500 HPC list *(https://topsc.cdacb.in/topsc.php/filterdetails?slug=January2022).*

Table A.5.1: Computational Resources (April 2021 to March 2022) Summary of 1 PetaFlop ANTYA HPC Facility.

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

<u>Procurement Started for a New GPU Cluster:</u> The Institute recognizes the paradigm shift in the programming models being developed using GPUs in the in-house developed codes and also in open-source scientific and commercial engineering applications. To cater to the needs of Scientists and Researchers in the Institute and this growth in GPU HPC applications, a dedicated GPU-based HPC fa-

cility is being planned. This new GPU cluster will be having a total of 16 latest GPU cards which can provide a capacity of upto 112 multi GPU instances. Considering the emergence of Artificial Intelligence (AI) and Deep Learning (DL) in scientific research, the new system being planned will offer an AI compute capability of 10 PetaFlops. This will greatly support and enhance the inhouse efforts being put to develop AI applications in the field of medical research, predictive simulations for tokamak operation and control, etc.

ANTYA Usage Demographics: At the end of March 2022, the active users on ANTYA were 260 spanning the scientific and engineering community of the Institute apart from supporting the academic project collaborations with other Institutes/Universities. In 2021 alone, 60 new HPC Users have been added and their applications have been ported successfully on ANTYA. More than 47000 HPC jobs have been successfully completed on ANTYA using 1.7 million CPU cores and 8.5 thousand GPU cards by the users cumulatively from April 2021 to March 2022. Figure A.5.1 shows ANTYA utilization charts.

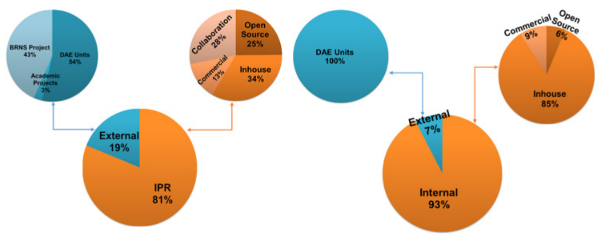


Figure A.5.1: Utilization charts showing the utilization of (Left) CPU and (Right) GPU compute resources of ANTYA cluster by HPC users.

Several new codes and tools have been added to the list of applications given in Table A.5.2 covering the range of scientific disciplines. For the Intel compilers, from 2021 onwards, an open source oneAPI toolkit has been installed for all the Intel libraries and compiles. Also for the GPU codes, open source HPC SDK suit has replaced PGI compilers. We have also introduced the usage of package managers like spack and conda for installation in ANTYA.

Table A.5.2: List of major codes/applications being used on ANTYA

Major Codes
Open Source **LAMMPS, PLUTO, CP2K, Bout++, RASPA, NAMD, Xoopic, VMD, Visit, Scilab, Salome, Paraview, moose**
In-House Developed **GMHD3D** (CPU and GPU versions, 3D), **EPPIC** (Expanding Plasma PIC, CPU and GPU version), **PEC2PIC,** (2-D Parallelized Electrostatic Cartesian PIC), **MPMD 2-D and 3-D** (Upgraded Multi-GPU version), **3D - MD Code**
Collaboration **GTS (**Gyrokinetic Tokamak Simulation), **Osiris4.0** (3-D, relativistic, object-oriented PIC code), **ORB5 (**Gyrokinetic Tokamak Simulation)
Commercial **ANSYS, COMSOL, CST, MATLAB, IDL, NAG, STARCCM+**

Utilization of Computational Resources: With more than 3.8 million cores available for usage in ANTYA from April 2021 to March 2022, there was a significant increase in the average and peak usage as compared to the previous period. The quarterly peak utilization charts are shown in figure A.5.2.

HPC Community Outreach: The HPC Newsletter "GAṆANAM" has been received very well by the HPC community of the institute and HPC team continues to publish it every month without any interruption. Considering the outreach potential of the newsletter, HPC Team has increased the number of pages from 2 to 3 with the additional 3rd page being used to further disseminate HPC-related technical information to IPRites. Every issue of the 3-page newsletter contains a new research article of the work done using the HPC resources apart from an HPC article focussing on increasing the proficiency of Users towards the available HPC tools, ANTYA software updates, an interesting HPC picture of the month, other recent HPC-

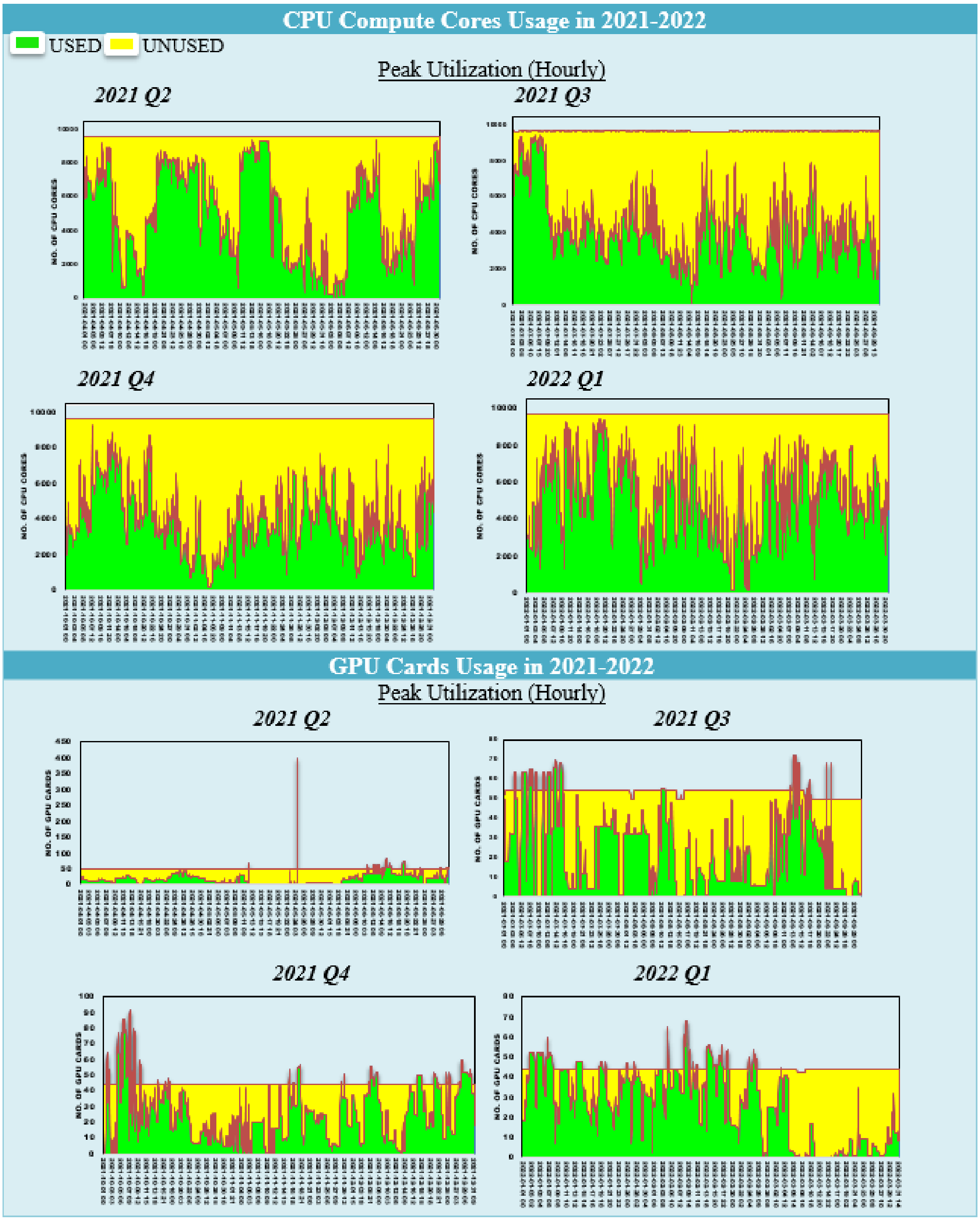


Figure A.5.2: Quarterly utilization charts showing the peak utilization of CPU and GPU compute resources of ANTYA cluster.

related work published in the institute's library, and Tip of the Month.

All 12 monthly issues published between April 2021 and March 2022 are available at *https://www.ipr.res.in/ANTYA/*.

Parallel Computing Workshop: HPC Team along with support from Locuz Inc. experts organized a 3-day Parallel Computing Workshop in the institute. This 3-day workshop was held during 13th, 15th and 16th April 2021 virtually during the lockdown using the our VC facility, JITSI. The workshop brought together more than 35 participants with their applications from various divisions of the institute having expertise with different domains/programming languages.

GPU Application Hackathon 2021 (GAH-2021): One team from the institute comprising of three HPC Users participated with the objective to test the in-house developed GMHD3D code on the latest GPU in the National PARAM Supercomputing Facility at C-DAC and improving the scaling on multinode multiGPU cards. The code achieved > 2.5x speed up over P100 architecture when run on a single A100 GPU card.

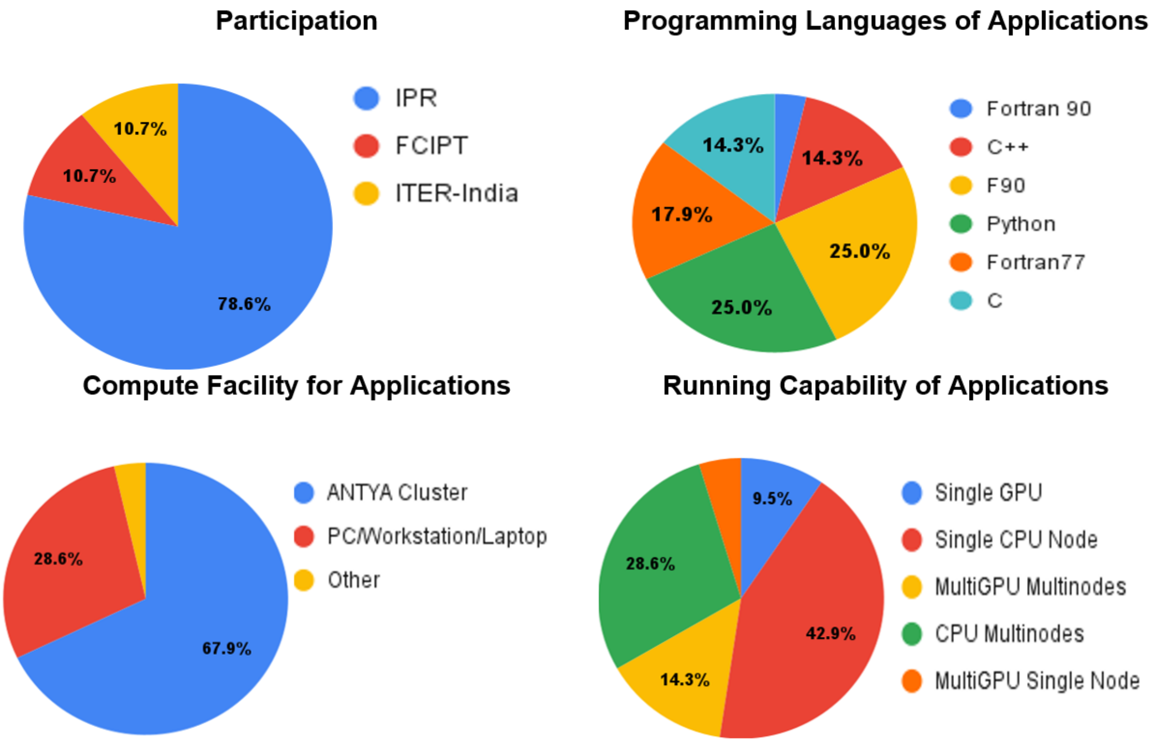


Figure A.5.3: Participation statistics of the HPC Users for the GPU Bootcamp highlighting the number of HPC applications capable of running on GPU cards employing serial, openMP and MPI algorithms.

GPU Programming Bootcamp: With the ongoing effort to efficiently utilize the GPUs and make our In-house developed applications/codes ready for the emerging computational architectures, HPC Team along with the help from Nvidia Team conducted this 2-Half day GPU Bootcamp virtually on 20-21 October 2021. No GPU programming knowledge was required for the participants. All the participants were given access to institute's 1 PetaFlop HPC Cluster, ANTYA for carrying out the hands-on lab sessions. This Bootcamp brought together more than 25 participants for two half-days from various divisions in of the institute having expertise with different domains/programming languages. Figure A.5.3 shows the participation charts of HPC users for GPU programing Bootcamp.

Scientific Highlights: With several publications this year, the below work represents the breadth of scientific research work carried out by institute's HPC Users using the ANTYA HPC facility.

Recent results of simulations performed on ANTYA

Rocket Propulsion with Detonations: A Numerical Simulation Study: The CFD solver has been used for development of detonation-based rocket engines to harness the higher thermodynamical efficiency of detonations.

Numerical simulations of deflagration to detonation transitions (DDTs) using 3D CFD solver: IPR has developed an open-source and low cost 3D CFD solver for DDT applications using OpenFoam. A screen shot is shown in figure A.5.4.

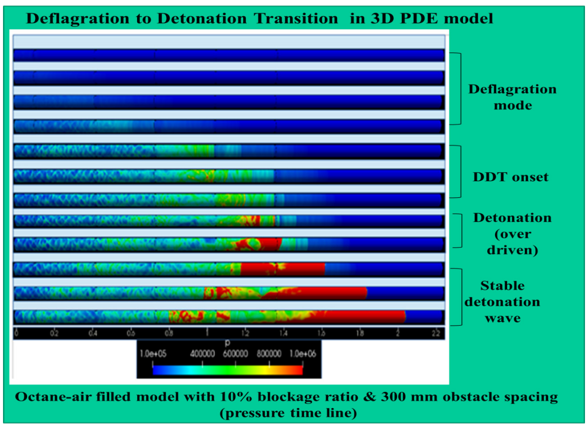


Figure A.5.4: 3D simulations of pulse detonation tube filled with octane-air mixture (pressure timeline)

The solver has a wide range of capabilities and models to simulate DDT phenomena in both structured and unstructured grids. This CFD tool can be deployed in any HPC or PC environment with parallel processing features. Several versions of this solver is installed at institute's state of art ANTYA HPC to carry out case studies and complex problems involving DDTs of various fuel-air mixtures. The physics involved in this solver has wide range of simulation applications like pulse detonation engines (PDE), accidental hydrogen releases in nuclear installations, mining explosions, DDT studies of rocket propellants , fuel sprays , fire safety (flame/shock interactions with obstacles) etc.

Reduction of plasma turbulence and radial transport using impurity seeding in tokamak: The obtained results are useful for the interpretation and/or predictive purposes in most experimental situations of nutral seeding in the edge and SOL regions. Radiation cooling pattern after nitrogen impurity seeding is shown in figure A.5.6.

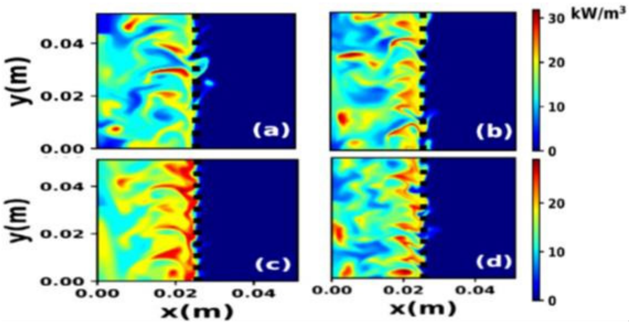


Figure A.5.6: Radiation cooling front from nitrogen ions obtained from 2D simulation for non-coronal equilibrium state.

Figure A.5.6 (a), (b), (c), and (d) are taken at 0.55 ms, 0.60 ms, 0.65 ms, and 0.70 ms, after the gas puff, respectively. The magnitude of the color bar is in kW/m^3. The vertical dotted line indicates the edge-to-SOL transition region.

Coherent Structures Formation in an Overdense Plasma: In laser plasma interactions, laser reflects back from critical density. In this study, we simulated how current vortices can travel into denser regions of plasma where powerful laser can not. When spatially overlapping currents break into filaments due to various instabilities there's a generation of magnetic field in the perpendicular plane. The result from PIC simulation, the evolution of Bz as current profiles were in X-Y plane is presented in figure A.5.7. In this study we have used a p-polarized laser pulse of 1 µm wavelength and intensity 10^{21} W/cm^2 and it is made to interact with an overdense inhomogeneous plasma. These snapshots shows the generation of Bz inside the plasma (t=50), filamentation of current sheets (t=100), organization of magnetic fields into a coherent structure (t=200, 600), propagation into denser plasma (t=900), turning its trajectory and separating into monopole coherent structures (t=1500-4000).

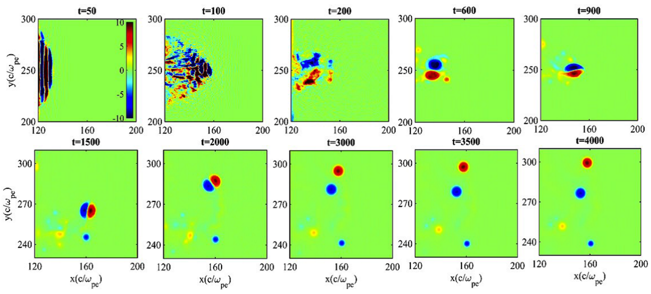


Figure A.5.7: Spatio-temporal evolution of Bz in X-Y plane.

Turbulence Study in a 3D Complex Plasma using MPMD-3D: This study can address the effect of changing Reynolds number on the turbulent spot dynamics, without altering the flow scale or its amplitude using our in-house developed MPMD-3D code which scales reasonably well on both CPU and GPU compute resources (figure A.5.8).

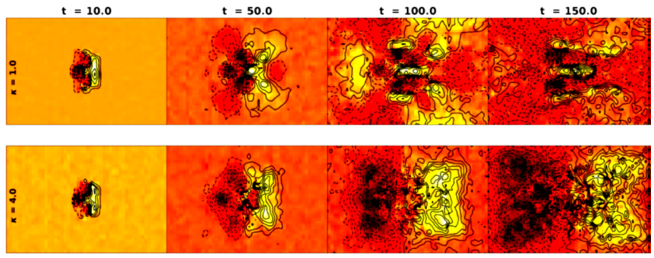


Figure A.5.8: Vx fluid velocity fields at K = 1.0, 4.0 at Y = 0 plane. The horizontal direction is X and the vertical direction is Z.

The blue and red regions are non-zero and white regions are zero Vx fluid velocity regions (figure. A.5.9). The non-zero regions are turbulent while the zero regions are laminar. As there is no base flow along ˆz direction, the velocity fluctua-tions shown in this figure are mainly due to the turbulence induced in the system.

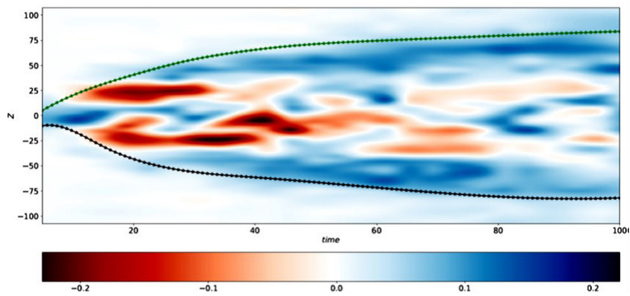


Figure A.5.9: It shows the co-existence of laminar-turbulent regions in Z-t plane.

Numerical Validation of Magnetoplasmons in a Rotating Dusty Plasma Experiment: The developed pseudo-spectral code will enable to investigate linear and nonlinear effects in a strongly coupled rotating dusty plasma which may be applicable in a strongly coupled magnetized plasma (figure A.5.10). The rectangular simulation zone located in the frame co-rotating with the dust is drawn at time t (solid line) and at quarter of the rotation period after time t (dotted line) in the laboratory frame. (Right) Simulation and Experimental longitudinal dispersion relations of a weakly and strongly coupled rotating dusty plasma, respectively, with different rotational frequency.

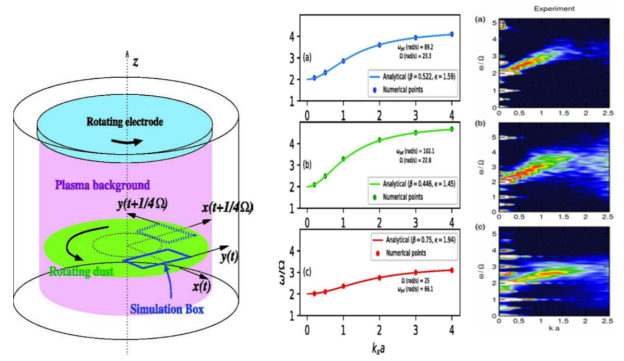


Figure A.5.10: (Left) Schematic of the setup of dusty plasma rotating with frequency induced by a rotating electrode.

<u>*Characterizing the Microscopic Density Fluctuations of Yukawa Fluids in Terms of Various Transport Coefficients:*</u> A unified approach to obtain sound speed, thermal diffusivity and adiabatic constant from microscopic density fluctuations that can be applied to experiments as well as simulations was studied.

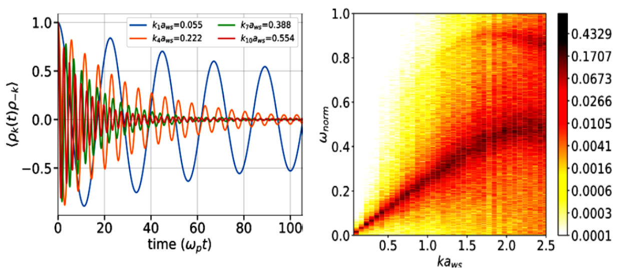


Figure A.5.11: (Left) A Density Autocorrelation Function (DAF) plot generated using MD simulation (Solid lines) and non-linear least square fitted curve in black broken lines for T = 80 and K = 1.0. (Right) FFT of longitudinal current fluctuation showing the acoustic mode dispersion.

The parameters estimated were within <15% deviations with published results from different models (figure A.5.11).

<u>*Impact of Plasma Flows on Tokamak In-stabilities:*</u> In tokamak operations, flow is an unavoidable aspect of operations. By understanding the nature of flows using CUTIE code, a tokamak performance, confinement and control impurities (figure A.5.12) can be improved.

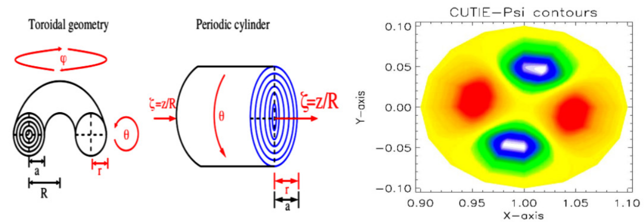


Figure A.5.12: (Left): A schematic representation of the geometry of a tokamak. Here, R = Major Radius, a = Minor Radius and r = radial position. (Right) Contour plot of the (2, 1) tearing mode as obtained from the CUTIE code.

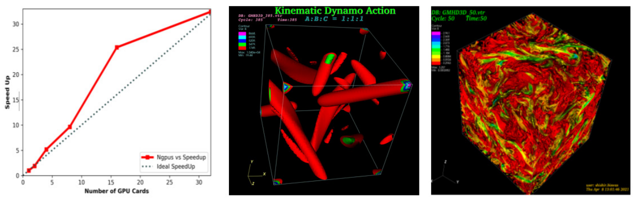


Figure A.5.13: (Left): Speedup across 32 P100 GPU cards in ANTYA. (Middle): Kinematic dynamo action. (Right): Self-consistent dynamo action.

<u>*Multi-GPU Acceleration of Three Dimensional Pseudo-Spectral Magnetohydrodynamic Code for Large Scale Plasma Simulation:*</u> To simulate the

large scale MHD systems, upgraded a three dimensional compressible single GPU MHD solver (G-MHD3D) to multi-node, multi-card GPU architecture using OpenACC & MPI and achieved super linear speed up across 32 P100 GPU cards as shown in figure A.5.13.

A.5.2 Non-Linear Plasma Theory & Simulation

Sticky Islands in Stochastic Webs and Anomalous Chaotic Cross-Field Particle Transport by Electron Drift Instability: The electron drift instability, present in many plasma devices, is an important agent in cross-field particle transport. In the presence of a resulting low frequency electrostatic wave, the motion of a charged particle becomes chaotic and generates a stochastic web in phase space. A scaling exponent to characterise transport in phase space is defined, to show that the transport is anomalous, of super-diffusive type. Given the values of the model parameters, the trajectories stick to different kinds of islands in phase space, and their different sticking time power-law statistics generate successive regimes of the super-diffusive transport.

Nonlinear Simulation Study of the Effect of Toroidal Rotation on RMP Control of ELMs: The numerical simulation studies on the combined influence of a resonant magnetic perturbation (RMP) and a sheared toroidal flow on the characteristics of edge localized modes (ELMs) is performed. The study finds that the presence of a sheared flow enhances the stabilising effect of the RMP in a synergistic manner. For a fixed RMP power a comparative study is made of the nature of ELM dynamics for different flow configurations. A counter-current off-axis flow is found to be the most effective in mitigating ELMs by changing their nature from a spiky type-I kind of ELMS to a grassy variety. There is also a concomitant improvement in the overall plasma beta and energy confinement time.

A.5.3 Tokamak & Fusion Reactor Studies

Finite Electron Temperature Gradient Effects on Blob Formation in the Scrape-Off Layer of a Tokamak Plasma: Nonlinear coherent dense plasma structures—'*blobs*'— form in the turbulent edge plasma of a tokamak play an important role in the anomalous nature of the plasma transport in that region. A plasma blob is normally formed when another kind of coherent structure—a radially elongated streamer structure—breaks due to differential stretching in the radial and poloidal directions. A study on the nature of such a blob formation in the scrape-off layer region by taking into account electron temperature effects is performed. It is found that the shear related to the poloidal gradient of the poloidal electric field plays a major role. A blob is predicted to form when this shear exceeds the interchange mode growth rate within the radially elongated region. The theoretical estimate of this extended criterion for blob formation is validated from three dimensional numerical simulation results using the BOUT++ framework and could be useful in the interpretation of blob formation in the presence of finite electron temperature gradient that is applicable in the High confinement and Low confinement mode discharges.

Deep Sequence to Sequence Learning-Based Prediction of Major Disruptions in Aditya Tokamak: Major disruptions in tokamak plasmas need to be identified well before their occurrence and appropriately mitigated. Otherwise, it may dump the heat and electromagnetic load to the vessel and its surrounding plasma-facing components. A predictor system based on precursor diagnostics may help in forecasting the disruptive events in tokamak plasma and raise the alert beforehand to take necessary actions to prevent the major damages inside the vacuum vessel. The prediction model describes a predictor system built with a few selected diagnostic signals from the Aditya tokamak and trained on a time-sequence long short-term memory network to predict the occurrence of disruption to 7–20 ms in advance with an accuracy of 89% on the testing set of 36 disruptive and 6 non-disruptive shots. This real-time network can infer to one time-step results under 170 μs on an Intel Xeon processor running python, suggesting minimal computation cost and best suited for the real-time plasma control applications.

Generalization of the Stability Condition for the Semi–Implicit Formulation of the Radial Impurity Transport Equation in Tokamak Plasma in terms of the Magnetic Flux Surface Coordinate: The radial impurity transport equation for tokamak plasmas is a set of non-linear, parabolic, partial differential equations, solving which generates the radial distributions of all impurity charge states (Z) within the plasma. The present study illustrates the application of a semi-implicit method over the ρ -based impurity transport equation, generated by applying a transformation of the coordinate for the poloidal cross-section of the torus-shaped plasma confinement system, from its geometric radius (r) to the magnetic flux surface coordinate system (ρ). The study further discusses the von Neumann stability analysis of the numerical scheme applied to this transformed (ρ-based) impurity transport equation. The von Neumann stability analysis of the semi-implicit formulation of the radial impurity transport equation has been reported earlier. The stability condition derived in this study is, therefore, a generalization to the earlier reported stability condition now applicable to all ρ (r) including the specific case ρ = r considered in the earlier study. The effects of the impurity transport coefficient (D and v) profiles and the plasma and impurity parameter profiles on the derived ρ -based stability condition are analysed in this study. The impurity element considered is oxygen ($1 \leq Z \leq 8$) and the geometry and plasma parameters of the Aditya tokamak are applied to the cases studied for consistency.

Studies on Impurity Seeding and Transport in Edge and SOL of Tokamak Plasma: Numerical simulation studies on impurity seeding using nitrogen, neon, and argon gases has been performed. These impurity gases are ionized by the electron impact ionization. These ions can be at multiply ionized states, recombine again with the plasma electrons, and radiate energy. The radiation losses are estimated using a non-coronal equilibrium model. A set of 2D model equations to describe their self-consistent evolution are derived using interchange plasma turbulence in the edge and SOL regions and solved using BOUT++. It is found that impurity ions (with single or double-positive charges) move in the inward direction with a velocity ~ 0.02 Cs so that these fluxes are negative. These fluxes are analyzed for different strengths of an effective gravity that help to understand the impurity ion dynamics. Increased gravity shows an accumulation of certain charged species in the edge region. The radiation loss is seen to have a fluctuation in time with frequency 5–20 kHz that closely follows the behavior of the interchange plasma turbulence. The simulation results on the radiated power and its frequency spectrum compare favourably with observations on the Aditya-U tokamak. The negative fluxes of the impurity ions, their dynamics in the edge region, and the fluctuating nature of the radiation loss are the most important results of this work.

Power Conversion from Spherical Tokamak Test Reactor with Helium-Cooled and Water-Cooled Blanket: Possible configurations for Power Conversion System (PCS) for a futuristic, small, pulsed Spherical Tokamak (ST) fusion reactor are studied. For the typical blanket coolant choices namely, helium and water, an intermediate heat-exchanger (IHX) cum buffer energy storage system (ESS) with Molten Salt (MS) is introduced to examine Rankine and Brayton cycle's effectiveness. Preliminary thermal sizing of the involved heat-exchangers and parameters of the optimized cycle are analyzed. S-CO_2 Brayton cycle seems to be a promising candidate for efficient power conversion for a pulsed plasma reactor with efficiency of 42.75%. Rankine cycle yields efficiency of 35–42% depending on water/helium as the choice of the blanket coolant.

A.5.4 Fundamental Plasma Studies

Dynamic Mode Decomposition of Inertial Particle Caustics in Taylor–Green Flow: Inertial particles advected by a background flow can show complex structures. By considering inertial particles in a 2D Taylor–Green (TG) flow and characterize particle dynamics as a function of the particle's Stokes number using dynamic mode decomposition (DMD) method from particle image velocimetry (PIV) like-data. It has been observed that the formation of caustic structures and analyze them using DMD to (a) determine the Stokes number of the particles, and (b) estimate the particle Stokes number composition. This analysis in this idealized flow will provide useful insight to analyze inertial particles in more complex or turbulent flows. It is proposed that the DMD technique can be used to perform similar analysis on an experimental system.

Possible Einstein's Cluster Models in Embedding Class one Space-time: For the first time, Einstein's cluster model in embedding class one spacetime is presented. The study show that for any neutral configurations there is only one Einstein cluster solution in embedding class one. In fact, one can find two solutions where the first solution is an unphysical one as it has zero density profile as well as violates the Pandey–Sharma condition (i.e. not a class one solution). However, the second solution can describe matter distribution representing Einstein's cluster which is in static and equilibrium as it satisfies the static stability criterion and TOV-equation. The second solution not only satisfies the above conditions, but also satisfies the energy conditions. The equation of state parameter ωt is less than unity signifying that it can represent physical matters.

Effect of Collisions on the Plasma Sheath in the Presence of an Inhomogeneous Magnetic Field: A low-pressure magnetized plasma is studied to find the dependency of sheath properties on ion-neutral collisions in presence of an inhomogeneous magnetic field. A self-consistent one-dimensional two-fluid hydrodynamic model is considered, and the system of equations is solved numerically. The study reveals that the width of the plasma sheath expands and space charge increases with collisions. The ion-neutral collisions and the inhomogeneous magnetic field restrict the ions to move towards the surface. The movement of the ions towards the wall can be controlled by choosing a suitable configuration of the magnetic field and ion-neutral collision frequency. A comparison between two different magnetic field configurations has been presented alongside to differentiate the commonly found scenarios in the field. The outcome of the study is supposed to help in understanding the complex dynamics of ions in plasma confinement and plasma processing of materials. Furthermore, the present work seeks to create a framework for two-fluid modeling of magnetized plasmas with any arbitrary magnetic field profiles. The analysis provided here is supposed to act as a basis for any future work in the respective field.

Effect of In-Plane Shear Flow on the Magnetic Island Coalescence Instability: Using a 2D Viscoresistive Reduced MagnetoHydroDynamic model, the magnetic island coalescence problem is studied in the presence of inplane, parallel shear flows. A wide range of values of shear flow amplitudes and shear scale lengths have been considered to understand the effect of sub-Alfvenic and super-Alfvenic flows on the coalescence instability and its nonlinear fate. It is observed that for flow shear length scales greater than the magnetic island size, the maximum reconnection rate decreases monotonically from sub-Alfvenic to super-Alfvenic flow speeds. For scale lengths smaller than the island size, the reconnection rate decreases up to a critical value υ_0c, beyond which the shear flow is found to destabilize the islands. The value of critical reconnection rate decreases with a decrease in the value of shear flow length scale. Interestingly, for our range of parameters, we find suppression of the Kelvin–Helmholtz instability in super-Alfvenic flows even when the shear scale length is smaller than the island width. Observation of velocity streamlines shows that the plasma circulation inside the islands has a stabilizing influence in strong shear flow cases. Plasma circulation is also found to be responsible for the decrease in upstream velocity, causing less pileup of magnetic flux on both sides of the reconnection sheet.

Electromagnetic Wave Transparency of X Mode in Strongly Magnetized Plasma: An electromagnetic (EM) pulse falling on a plasma medium from vacuum can either reflect, get absorbed or propagate inside the plasma depending on whether it is overdense or underdense. In a magnetized plasma, however, there are usually several pass and stop bands for the EM wave depending on the orientation of the magnetic field with respect to the propagation direction. The EM wave while propagating in a plasma can also excite electrostatic disturbances in the plasma. In this work Particle-In-Cell simulations have been carried out to illustrate the complete transparency of the EM wave propagation inside a strongly magnetized plasma. The external magnetic field is chosen to be perpendicular to both the wave propagation direction and the electric field of the EM wave, which is the X mode configuration. Despite the presence of charged electron and ion species the plasma medium behaves like a vacuum. The observation is understood with the help of particle drifts. It is shown that though the two particle species move under the influence of EM fields their motion does not lead to any charge or current source to alter the dispersion relation of the EM wave propagating in the medium. Furthermore, it is also shown that the stop band for EM wave in this regime shrinks to a zero width as both the resonance and cut-of points approach each other. Thus, transparency to the EM radiation in such a strongly magnetized case appears to be a norm.

Bispectral Analysis of Nonlinear Mixing in a Periodically Driven Korteweg–de Vries System: The nonlinear response of a periodically driven Korteweg–de Vries model system is studied using a variety of nonlinear drivers and compared to previous results obtained for a purely time-dependent sinusoidal driver by Mir et al. It is found that a nonlinear driver in the form of a cnoidal-square wave or a traveling wave driver produces a spectral response that is closer to experimental observations of Nosenko et al.than that predicted by the simple sinusoidal driver. Using a bispectral analysis, we also firmly establish that the nature of the nonlinear oscillations, is established considering the interaction between the periodic source and the inherent collective mode of the system. It is predominantly governed by a three-wave mixing process. Furthermore, by studying the variation in mixing patterns, from a broad to a sparse frequency spectrum, as a function of the driver frequency and its functional form, we propose a means of tailoring the nature of such patterns. The results could find useful applications in the experimental interpretation and manipulation of nonlinear wave mixing patterns in weakly nonlinear and dispersive plasma systems or similar phenomena in neutral fluids.

A.5.5 Laser-Plasma Interaction

Resonance Absorption in Laser-Driven Deuterium Cluster: In a laser-irradiated atomic cluster linear resonance absorption occurs when Mie-plasma frequency (ω_M) matches the laser frequency (ω); and laser absorption is unconditionally presumed to be maximum here for the collisionless interaction. To judge it, a study on interaction of short laser pulses of various intensity, polarization, and pulse duration with a deuterium cluster using molecular dynamics simulation is performed. For a given laser energy and pulse duration, the study shows that absorption peak is red-shifted from the expected Mie-resonance condition $\omega=\omega_M$, irrespective of linear polarization (LP) and circular polarization (CP) of laser. Increasing the intensity, red-shift of absorption peak increases; and above an intensity, it disappears (sometimes followed by a growth in absorption) when outer ionization saturates at 100% which also holds true for fixed pulse energy and increasing pulse duration. Laser absorption and red-shift of the absorption peak for LP and CP are found to be almost equal.

Ponderomotive Force Driven Mechanism for Electrostatic Wave Excitation and Energy Absorption of Electromagnetic Waves in Over-dense Magnetized Plasma: The excitation of electrostatic waves in plasma by laser electromagnetic (EM) pulse is important as it provides a scheme by which the power from the laser EM field can be transferred into the plasma medium. A fundamentally new ponderomotive pressure-driven mechanism of excitation of electrostatic waves in an overdense magnetized plasma by a finite laser pulse is developed. Particle-in-cell simulations using the EPOCH-4.17.10 framework have been utilized for the study of a finite laser pulse interacting with a magnetized overdense plasma medium. The external magnetic field is chosen to be aligned parallel to the laser propagation direction. In this geometry, the EM wave propagation inside the plasma is identified as whistler or R and L waves. The group velocity of these waves being different, a clear spatial separation of the R and L pulses are visible. In addition, excitation of electrostatic perturbation associated with the EM pulses propagating inside the plasma is also observed. These electrostatic perturbations are important as they couple laser energy to the plasma medium. The excitation of electrostatic oscillations are understood here by a fundamentally new mechanism of charge separation created by the difference between the ponderomotive force (of the EM pulse) felt by the two plasma species, viz., the electrons and the ions in a magnetized plasma.

Self-Organization of Pure Electron Plasma in a Partially Toroidal Magnetic-Electrostatic Trap: A 3D Particle-In-Cell Simulation: The dynamics of a pure electron plasma magnetically confined in a partial toroidal trap is investigated using 3D3V PIC simulation. In particular, a toroid having a rectangular meridian, a tight aspect ratio of 1:6, and a $3\pi/2$ toroidal domain is considered. Externally applied negative end-plug potentials electrostatically seal off the toroidal ends of the device for the confined electron cloud. A homogeneous square toroidal segment of pure electron plasma is loaded in the middle of the trap. Strong non-uniform sheared poloidal flow reshapes the square cross section into an elliptical profile with symmetric closed contours of density peaking in the center. On the toroidal midplane, the plasma gets shaped into a crescent by the opposing dispersing and confining forces of the self-electric field and the end-plug fields, respectively. Density inside the crescent falls symmetrically from the middle to the two tapered ends. The self-reorganization of the loaded square toroidal segment into an "elliptic-crescent" is completed within a time scale of ~0:1 μs. The cloud then starts to engage in poloidal orbits of the fundamental (toroidal) diocotron mode. The poloidal orbit's time period is ~2 μs. The first orbit is turbulent and incurs significant electron losses (~30%) to a particular segment of the poloidal boundary. Subsequent orbits are dynamically stable with a compression expansion cycle of the cloud as it moves in and out of strong magnetic fields on the poloidal plane. The poloidal compression–expansion cycle is collisionless coupled with the toroidal cloud shaping through the self-electric fields and manifests as an elongation–contraction cycle of the crescent on the toroidal midplane. A radical improvement of the device's confinement is observed when its volume is isotropically compressed keeping other parameters the same. The numerical design of the partial toroidal trap has several novel aspects such as the use of specialized numerical "pseudo-dielectric" layers for producing functional end-plug fields in the numerical device setup.

A.5.6 Dusty and Complex Plasmas

Spot Formation in Three-Dimensional Yukawa Liquid: Dynamics of a three-dimensional (3D) plane Couette flow (PCF), which subjected to a 3D finite amplitude particle velocity perturbation, is addressed using 3D "classical first principles" molecular dynamics simulation with screened Coulomb potential or a Yukawa potential as the inter-particle interaction. For small cross-sectional aspect ratios ~20, starting from Re ~1211-717, a laminar 3D PCF initial condition is shown to become unstable to localized 3D finite amplitude perturbation for various increasing amplitude strengths, clearly demonstrating the formation of a turbulent spot. This spot is found to spread in time into the otherwise laminar regions, a signature of subcriticality or co-existence of laminar and turbulent regions in PCF in a 3D Yukawa liquid. It is shown unambiguously that the range of interaction of Yukawa potential determines the nature of spot formation and its dynamics. At long range, a qualitative similarity of our results to those found in turbulent spots of PCF in conventional hydrodynamics is discussed. The present findings may have ramifications for a wide range of physical systems that exhibit subcritical transition to turbulence.

Dust-Ion-Acoustic Solitary Wave Structure in Magnetized Plasma with Nonthermally Distributed Electrons and Positrons: The dust–ion–acoustic (DIA) solitary wave (SW) propagation in a magnetized dusty plasma consisting of mobile positive and heavy negative ions, nonthermal electrons and positrons is presented. By using reductive perturbation technique, three dimensional Zakharov–Kuznetsov (Z–K) equation is derived and the solution is obtained by using the tan-hyperbolic method. Here, the dust grain charging process by plasma constituents is represented by the equation following orbital motion limited (OML) theory. The characteristics features of solitary wave amplitudes arising due to different plasma parameters such as ions mass ratio, nonthermal parameters of electrons and positrons, temperature ratio of electrons and positrons, ions density ratio, and dust density ratio are analyzed. In this analysis, the influence of nonthermal electrons on solitary wave amplitude variation is observed as more significant than that of nonthermal positrons. The findings of this work can be helpful in understanding of the Earth's ionosphere, mesosphere, solar photosphere.

<u>*Collective Excitations of Rotating Dusty Plasma under Quasi-Localized Charge Approximation of Strongly Coupled Systems:*</u> Collective excitations of rotating dusty plasma are analyzed under the quasi-localized charge approximation (QLCA) framework for strongly coupled systems by explicitly accounting for dust rotation in the analysis. Considering the firm analogy of magnetoplasmons with "rotoplasmons" established by the recent rotating dusty plasma experiments, the relaxation introduced by rotation in their strong coupling and two-dimensional (often introduced by gravitational sedimentation) characteristics is emphasized in their dispersion. A finite rotation version of both strong and weak coupling dispersions is derived and analyzed, showing the correspondence between a "faster rotating but weakly coupled" branch and its strongly coupled counterpart, relevant to both magnetized and unmagnetized dust experiments, in gravity or microgravity conditions. This work presents the first correspondence between their measurements in rotating plasmas and the QLCA produced dispersions in a rotating frame, with an independent numerical validation.

<u>*Kelvin-Helmholtz Instability in Strongly Coupled Dusty Plasma with Rotational Shear Flows and Tracer Transport:*</u> Kelvin-Helmholtz (KH) instability plays a significant role in transport and mixing properties of any medium. This study numerically explore this instability for a two-dimensional strongly coupled dusty plasma with rotational shear flows. The study has been performed using generalized hydrodynamic fluid model which treats it as viscoelastic fluid. Few specific cases of rotating vorticity with abrupt radial profiles of rotation are considered. In particular: single-circulation, and multi-circulation vorticity shell profiles have been chosen. The KH vortices at each circular interface between two relative rotating flows along with a pair of ingoing and outgoing wavefronts of transverse shear waves are observed. These studies show that due to the interplay between KH vortices and shear waves in the strongly coupled medium, the mixing and transport behaviour are much better than inviscid hydrodynamic fluids. In interests of substantiating the mixing and transport behaviour, the generalized hydrodynamic fluid model is extended to include the Lagrangian tracer particles. The numerical dispersion of these tracer particles in a flow provides an estimate of the diffusion in such a medium.

<u>*Numerical Optimization for Fluid Flow in Turbo-expander Wheel of Helium Liquefaction Plant:*</u> A radial turbine is one of the vital components of a helium liquefaction plant and its design becomes critical due to its compact size and high-speed configuration. In this study, numerical optimization has been performed for the three-dimensional steady flow of helium gas in the radial inflow turbine of a helium liquefaction plant at a nominal condition. The computational fluid dynamics simulation algorithm is adopted in this study to reach the final results and Ansys CFX is used for the simulation. From the analysis, it has been observed that the number of rotor blades was overestimated in the mean line design. Performance parameters like total-to-static efficiency and velocity ratio were also found to be optimum numerically under a preliminary design condition. Finally, power of 1.7kW was achieved at total-to-static efficiency of 71.4%. The deviation in analytical and numerical results is within ±10% for performance as well as geometric parameters.

A.5.7 Fusion Technology Related Simulation

<u>*Parametric Investigation for Modulation Instability of Ion Wave in Negative Ion Plasma Sources:*</u> The nonlinear Schrodinger equation describing the

modulational instability of ion waves in the presence of negative ions and multispecies positive ions is derived from fluid equations for such plasma system. The average mass of positive ions is found to have a key role in the modulationally unstable ion wave in electronegative plasma. The numerical study of modulational instability of ion waves in such plasma reveals a universal parabolic relationship between the critical density ratio of negative to positive ions and average ionic mass ratio. This relation can be utilized to study the modulational instability experimentally in any realistic negative ion plasma source on a large scale.

A.5.8 Material Studies

Statistical Analysis for Cost Effective Process Parameters and Localized Strain Hardening Behavior of Al-7050 Foam: Cost effective process parameters of fabricating Al-7050 foam were obtained by reducing amount of blowing agent and processing time in advancement of low cost, low density and high mechanical properties for structural applications. Quasi-static compressive properties and localized plateau deformation behavior were studied. Maximum strength to density ratio up to 40.38 MPa/(gm/cm^3) with utilizing 0.2 wt% TiH_2 was achieved. Localized brittleness of plateau cell walls were observed by localized strain hardening behavior in plateau deformation.

Electrical Transport Properties of Liquid Pb-Li Alloys: It is generally observed that electrical transport properties of simple liquid metal based alloys can be explained well in terms of Faber-Ziman theory, 2kF scattering model and finite mean free path approach. However, these approaches give poor description for materials, which show departure from nearly free electron (NFE) model. Taking Pb-Li as a test case of a system showing departure from NFE (which also exhibit compound formation tendency and disparate mass system), a new technique is proposed to compute electrical transport properties using model potential formalism coupled with t-matrix formulation. The valence number of Pb & Li are considered as a parameters in determining phase shifts. Further, rather than calculating phase shift in terms of Muffin-Tin potential, a model potential formalism is used. Present results suggest that compared to other three theoretical approaches mentioned above, present coupling scheme reproduce qualitative features of electrical transport properties of liquid Pb-Li alloys, which can be used further to study electrical transport properties of similar systems.

A Molecular Dynamics Study of Displacement Cascades and Radiation Induced Amorphization in Li_2TiO_3: Molecular dynamics simulations are conducted on β-Li_2TiO_3 to evaluate several radiation damage related properties. Firstly, including the polarization of the O atom through a core–shell potential while modeling cascades was found to predict a qualitatively acceptable level of primary damage. The primary damage was dominated by Li Frenkel pairs followed by O and Ti Frenkel pairs. Except for LiTi and TiLi antisites had negligible contribution. Computational samples were amorphized by explicitly moving atoms and relaxing the structure. The dose to amorphization was around 0.5dpa (displacement per atom), but required displacement of Ti and O atoms to cause the peaks of pair correlation functions to disappear, indicating a collapse of the crystalline structure. Displacing Li atoms alone did not cause any noticeable change to the structure even for high doses. Propensity of tritium trapping was studied by examining the number of Li in (Oi) in O (Li) voronoi cells. Nearly 41% of Li (48% of Oi) were found to be in the voronoi cells containing an O (Li) atoms, indicating that primary damage can increase tritium inventory within the material by formation of hydroxyl groups.

A.5.9 Artificial Intelligence and Machine Learning

Deployment of DeepCXR software in a national programme: Institute is developing an Artificial intelligence (AI) software in collaboration with ICMR, Delhi for automated detection of footprints of pulmonary tuberculosis/other chest ailments in Chest X-Ray Images. The developed Deep Learning based software "DeepCXR" is in use for national TB eradication programme coordinated by ICMR Delhi. Earlier training of the DeepCXR was done on a limited data set, so the entire range of variables could not be covered. Under an MOU signed with ICMR Delhi head quarter and NIRT Chennai in 2020, training of the tool has been initiated on data from culture-confirmed X-rays from earlier surveys. Annotated X-rays images are being shared with 1000 normal and 3700 abnormal & annotated images have already been received from ICMR and more are being progressively delivered. Figure A.5.14 shows a typical output of the preprocessing software.

To provide a general AI software that would work for all four zones of India a central website has been developed at ICMR Delhi https://tb.ai.icmr.org.in/ai4tb/ in collaboration with the institute. More than 20 institutes and medical colleges from all over India are involved and ICMR Delhi is the central coordinator. The role of the participants is to provide necessary Chest X-ray images with classification and annotation of confirmed TB and related cases. To facilitate conversion between various formatted data from different system/sites a pre-processing software is developed and delivered to the participating institutions. An example of pre-processing software output is shown in figure below. Institute has organised multiple training session with ICMR empaneled radiologists and participant institutes for TB-AI program. At present the 1st prototype of the required AI tool has been developed which can differentiate normal/abnormal. The AI software has been developed with chest x-ray images received from ICMR NIRT, Chennai and ICMR, Delhi for training/testing of the AI model. The trained model achieves accuracy parameters of more than 95 % on the dataset from the same source and 78 – 80 % on dataset from other sources. Further development to detect various types of TB and other chest diseases in underway. Once the training of the AI software is completed, DeepCXR will be placed in survey vans aimed at the automated high-speed detection of pulmonary TB and other lung ailments from chest X-rays.

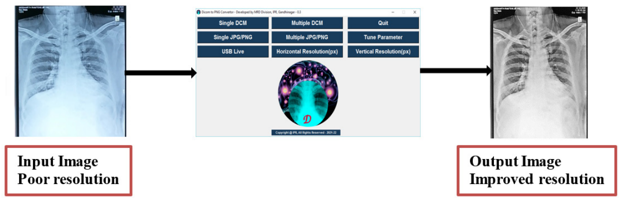


Figure A.5.14: Developed pre-processing software as part of AI tool for detection of TB & other lung diseases from Chest X-rays.

Low-cost chest X-ray digitizer: X-Rays are the oldest and foremost highly used diagnostic still being used by doctors. Dearth of experts/radiologists in rural places prohibits the fast screening/generation of reports. Professional scanners exists but are limited to mass adoption in Public Health Centers due to high price. The X-Rays generated via analog device can be digitized using the institute developed X-Ray scanner for tele-consultation and faster diagnosis. A few typical outputs of the digitizer is shown in figure A.5.15.

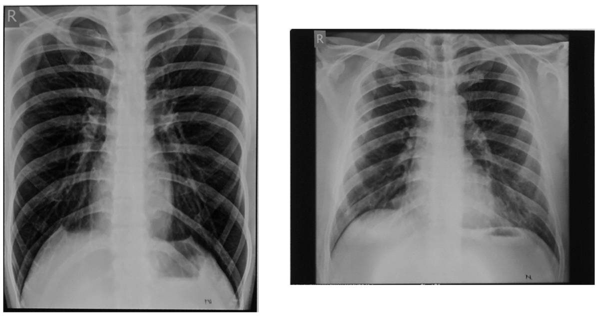


Figure A.5.15: A few digitized X-Rays films by the digitizer.

The low cost digitizer machine digitizes the analog X-Rays and converts it into digital format in its highest possible image quality and resolution. The CXR digitizer comes with a customized USB camera with plug and play features. The technology integrates a customized motherboard with the inbuilt software features to receive/capture/save/display X-Rays image. The digitizer box has been validated by local radiologists, wherein it is found that all the digitized X-Rays using the digitizer box are reportable.

AI tool for human detection from CCTV in complex environments: Video surveillance is used for remote video monitoring with purpose to protect the perimeter of the property or the perimeter of buildings and monitor day to day operation. Video surveillance system require human interaction to continuously monitor and trigger alarms whenever security violation is detected. By integrating with Artificial intelligence and computer vision technology it can lead to an automated video surveillance system. With Deep learning technology of AI, the software can analyse images directly from live video feeds to recognize objects of interest. Thus assist the end-user by making data more searchable and refined, get more insight so that they can make informed decisions to fill gaps in the security system. Artificial Intelligence Software been developed by the institute and is currently deployed in with human detection as capability. It is a smart and complete solution which can aid in the effectiveness of monitoring. The software is able to run from any pc within the LAN by mounting a server directory with login credentials. The specificity, sensitivity, accuracy of the trained AI model is more than 95 % on 40,000 images.

AI software is useful for industries, factories and places where human detection is required. It is useful for automated security situations, e.g. for imaging in a factory, campus in/out-door, automated drone imaging as required. It functions and achieves the objective under various environment like outdoor, indoor, night with sufficient light, daylight, in a camouflage like environment. Figure A.5.16 shows different CCTV snapshots with automatic identification of a human in the frame.

Figure A.5.16: Works in high contrast lighting environment & remote outdoor.

CHAPTER B

INTERNATIONAL COLLABORATIONS

B. International Collaborations

Apart from in-house activities, the institute is also actively participating and contributing to the following major international experimental collaborations like ITER and laser interferometry gravitational wave observatory setup as equal partner in designing, fabricating, testing and supplying various systems and subsystems.

B.1 Activities of ITER - India

ITER India continues its steady progress forward towards ensuring timely and quality adherent supplies to ITER related to the nine procurement packages. While 100 % deliveries of the four important ITER first plasma packages, viz cryostat, inwall shields, cooling water systems and Cryolines systems have been completed, technology development and performance demonstration of the complex first of kind systems related to ICRH, ECRH, DNB and the diagnostics continues to be a front runner in the various laboratories of ITER India.

In parallel construction activities at ITER are in full swing. Till date ~80 % of work has been completed. This includes the installation and acceptance of the several of the components supplied by India to ITER and includes, the components of the cryostat,

Figure B.1.1: Aerial view of the ITER site.

the cooling water system, the various sections of the multi feed cryo cold and warm lines. The in-vessel shields supplied by ITER India to EUDA and KODA continue to be installed in the vacuum vessel sectors. Figure B.1.1 shows the bird's eye view of the ITER site in March 2022.

The following sections provide a brief and pictorial summary of the progress related to component supply, installation and testing of the various packages supplied to ITER by ITER India and the status of the test beds dedicated to establishing the performance of the components related to IC, EC, DNB, PS and diagnostics in the various laboratories of ITER India in the institute.

Cryostat: The various segments of the 29 m tall and 29 m wide stainless steel cryostat manufactured and shipped to ITER from the works of M/S L&T, Hazira have been assembled and welded together in the ITER India cryostat laboratory at the ITER site over the past years and have included the base section and the lower and top cylinders. This year was marked by the arrival of all the segments of the top lid at the ITER site and their subsequent opening and mock assembly at the cryostat workshop. It is to be noted that the top lid is the thickest and second heaviest (more than 700 tonnes) of the four cryostat sections and structurally complex. The welding activities commenced on 7th June, following a traditional coconut ceremony in the Cryostat Workshop that was broadcast live to India. This is a special welding technique where two welders work parallely on opposite sides of the component's skin. The campaign is being performed under the joint expertise of workforce from MAN energy solutions as the sub-contractor to M/s Larsen and Toubro and engineers from ITER IO and ITER India. The challenging job considering the thick skin, large circular opening at the centre and complex arrangement of ribs underneath will be constantly monitored to keep the distortions due to the welding process under control to achieve the desired dimensions, fitment and tolerances.

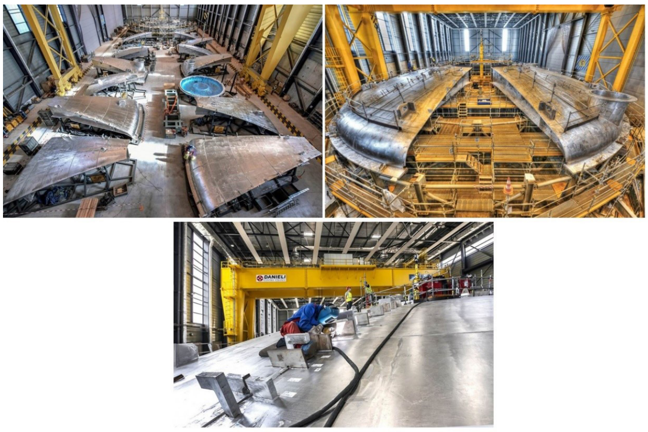


Figure B.1.2 : Clockwise from top ; Top segments of the cryostat top lid lined up in the cryostat workshop at ITER site, assembled to check for proper fitment and the commencement of the welding activities of the top lid segments on the 7th of June 2021.

Parallely the welding of the base section and the lower cylinder of the cryostat has been completed in the Tokamak pit, figure B.1.3.

Further there has been significant progress in the manufacturing of the ITER Torus Cryo-Pump Housing (TCPH) assembly, figure B.1.4. It is a penetration located on the Cryostat cylinder with main functions to accommodate and support the Torus Cryo-Pump (TCP), connect it to the Vacuum Vessel and provide tritium confinement. The ITER Torus Cryo- Pump Housing (TCPH), forms a primary vacuum boundary and is manufactured from SS304/304L material. TCPH consist of inner cylinder to support cryopump and tritium confinement whereas the outer rectangular box structure provides re-generation volume for TCP. They are interconnected through vertical ribs for providing stiffness and transferring load of cryopump to the Cryostat.

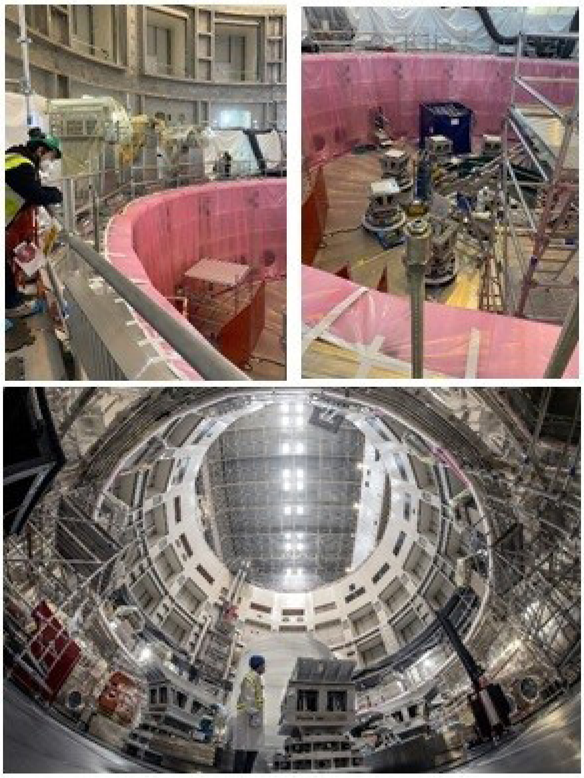


Figure B.1.3: Welding the base section to the lower cylinder in the tokamak pit.

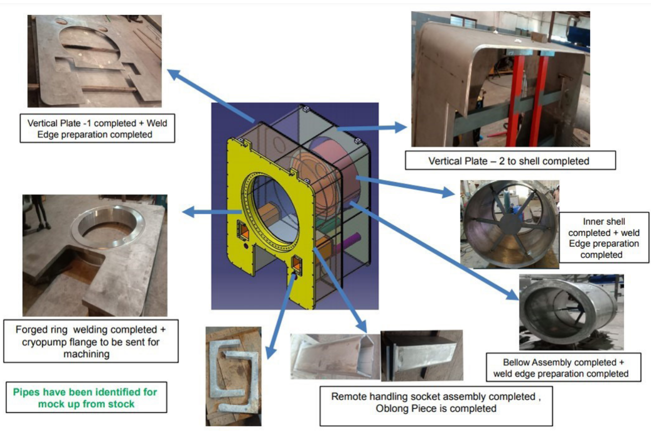


Figure B.1.4 : TCPH mock up assembly.

<u>*In wall shields:*</u> The inwall shields supplied by INDA to EUDA and KODA continue to be installed in the vacuum vessel segments. Figure B.1.5 shows some snapshots of such assemblies.

Figure B.1.5: In sequence : IWS lowered for assembly in VV sector, IWS assemble around flexible support housing between outer and inner shells of VV, inspection after assembly to ascertain needed clearance, VV segment view after assembly of IWS and ready for welding the outer shell.

<u>*Cryoline and cryodistribution system:*</u> ITER employs a magnetic “cage” to contain the hot plasma. This cage makes use of superconducting magnets, which must be cooled to minus 269 ^{0}C, just 4 degrees above absolute zero. The biggest cryoplant in the world at ITER interfaces with these Cryolines to distribute the liquid helium & nitrogen produced by this plant to maintain the desired operating temperatures.

Approximately 4 km of Cryolines, operating at temperatures ranging from minus 269 to minus 193 ^{0}C, and about 6 km of return lines for warm gases, have been manufactured by M/s INOXCVA (www.inoxcva.com) in India and then dispatched to the ITER Worksite in France. The last consignment of these lines was flagged-off on 29th July’21 at M/s INOXCVA's factory in Kalol Village near Vadodara in Gujarat, Figure B.1.6.

Figure B.1.6: Last consignment of the Cryolines manufactured at M/S INOX CVA Vadodara flagged off from the factory on 29th July 2021.

These Cryolines are made to stringent Nuclear standards. These are 'first of a kind systems' in terms of large size (diameter upto 1 m), and include multiple process pipes with very low heat loss and complex layout. ITER-India and M/s INOXCVA established the design through meticulous prototyping and qualification before starting production. ITER-India, DAE and M/s INOXCVA are proud that India has demonstrated its ability to develop a hi-tech, first-of-a-kind product in Cryogenics, at par with the best in the world, a good illustration of Atmanirbhar Bharat.

The ceremony was remotely attended by Sh. K.N. Vyas, Secretary, DAE, Late Dr. Bernard Bigot, Ex-Director General of ITER Organization, Director of the institute, and many others. Dr. Bigot applauded the engineering & manufacturing capabilities of INOXCVA and the quality and promptness of project related deliveries. Addressing the audience Sh. Vyas said, "I am happy to see M/S INOXCVA as one such industry which has made its presence felt globally in a short span of 5 years in cryogenic lines at 4K temperature level, and I congratulate them for this"(figure B.1.7).

Figure B.1.7 : Figure 9 : Shri K N Vyas, Chairman DAE and Late Dr Bernard Bigot Ex - Director General ITER France addressing the audience remotely.

Figure B.1.8 : Last consignment of the Group X Cryolines leaving the premises of M/S Air liquid advanced technologies.

In addition to the above the last consignment of Group-X cryolines lines was flagged off on 03-March-2022. Figure B.1.8, from the storage zone of M/s Air Liquid Advanced Technologies (ALAT) with in-person presence of ITER Organization, M/s ALAT and ITER site representative of ITER-India. With this last consignment, the supply part of All the ITER cryolines and warmline have been successfully completed under the procurement arrangement between ITER-India and ITER Organization.

Parallely installation works of the cryo and warm lines continued at various location at the ITER site. INOX installation works in B50s (Bulding 51, 52 and Area-53) have been completed and a small ceremony at ITER site organized to celebrate the end of installation of Group-Y cryolines and Group-W lines in B50s on 10th August 2021. All the group Y Cryolines in B50's have attained the required vacuum level of < 5 x 10^{-3} mbar at room temperature.

Figure B.1.9: Network of warm and Cryolines supplied by India installed in B50's at ITER site.

Site acceptance tests have been carried out successfully and final acceptance from IO has been received. Figure B.1.9 shows an overview of the various warm and croyline network at various locations in ITER.

Figure B.1.10: ACB assembly under progress.

Steady progress also continues towards ensuring the manufacturing completion of the auxiliary cold boxes (ACB) with the one for ACB-5 in the advance stage. The top plate with valve sleeves, middle and bottom vacuum shell, integration of the casings of the cold rotating machines, the phase separator assembly with heat exchanges and internal piping have been fabricated. Figure B.1.10 shows an overview of the work in progress for the ACB's.

Diagnostic neutral beam system: Diagnostic neutral beam system includes the 8 driver RF driven negative ion source to produce 100 keV 60 A H- beams, neutraliser to convert negative ion beams to a mixture with ion and neutral components and electrostatic residual ion deflector to separate the ionic and the neutral beam components and a calorimeter to diagnose the properties of the accelerated neutral beam.

Figure B.1.11: Trial assembly of the accelerator grid.

Steady progress continues related to the manufacturing of the components and in preparing the INTF test bed for beam operations. Majority of the parts of the DNB beam source have been completed and include L shaped segments of the plasma box, segments of the angled electrodeposited accelerator grids, bias plate segments, electron dumps, post insulators, grid holder frames and flanges. As far as the beam line components are concerned, the manufacturing of the various parts of the neutralizer has been completed. The issue related to the water transition welding to the electrostatic residual ion panels has been resolved by developing alternative manufacturing technology of mechanical fixing of the water cooling stubs to the panels followed by copper deposition for leak tightness. Trial assemblies of the various components of the source have been initiated to ensure proper fitment and alignment of the manufactured components as shown in Figure B.1.11. The various panels and support structures of the neutralizer are in their final stage of assembly, Figure B.1.12. The Factory acceptance tests of the neutralizer and the electrostatic residual ion dump assembled components are expected in Q2-Q3 of this year.

Figure B.1.12 : Neutraliser under assembly.

Progress on INTF includes completion of the acceptance tests on the indigenously fabricated multi feedthrough dished head assembly of the high voltage bushing (figure B.1.13), INTF cooling water system (figure B.1.14) and gas feed system. Installation of the radiation shields of the 10 cryopump modules has been completed (figure B.1.15) and preparations are underway to test the performance of a full scale cryopump.

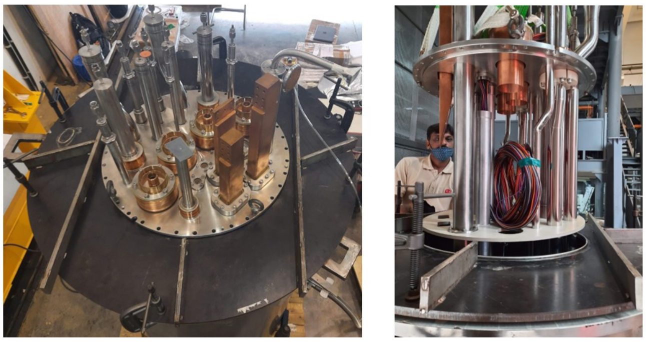


Figure B.1.13 : Multi feed thru dished head assembly for high voltage bushing.

Figure B.1.14: Water cooling system network for the INTF.

In addition to the above an ITER task agreement for the supply of the HNB3 vacuum vessel for ITER has been signed with ITER organization. The tender activities related to the vacuum vessels for the DNB and the HNB3 have been initiated.

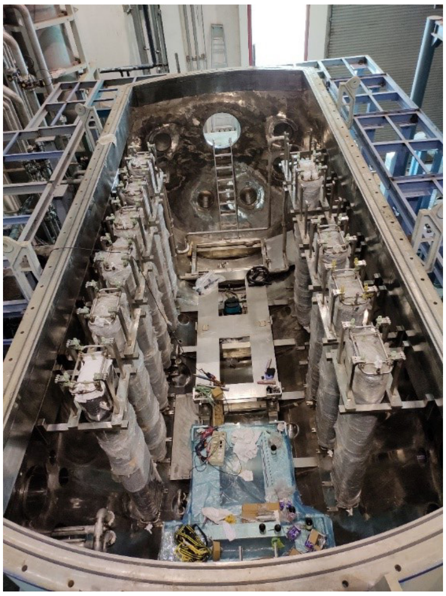


Figure B.1.15 : 10 cryopump 80K radiation shields installed in INTF vacuum vessel.

Time	Frequency (MHz)	HPA3					HPA2					SSPA
		Pout fwd (kW)	Pout ref (W)	Va (kV)	Ia (A)	Gain (dB)	Pout fwd (kW)	Pout ref (W)	Va (kV)	Ia (A)	Gain (dB)	Pout fwd (kW)
Run Test												
0s	60.00	1504	1717.0	21	118.40	15.14	46.00	490	13	8.70	14.67	1.57
720s	60.00	1509	1850.0	21	118.30	15.16	46.00	467	13	8.70	14.67	1.57
1200s	60.00	1509	1899.0	21	118.30	15.16	46.00	460	13	8.70	14.67	1.57
2040s	60.00	1508	1923.0	21	118.20	15.16	46.00	452	13	8.70	14.67	1.57
Bandwidth Check												
	59.00	1393	600.0	21	126.20	14.41	50.48	750	13	8.60	15.04	1.58
	59.25	1611	875.0	21	120.00	14.73	54.20	578	13	8.62	15.35	1.58
	59.50	1643	1479.0	21	124.50	14.85	53.80	548	13	8.74	15.32	1.58
	59.75	1557	1430.0	21	124.50	14.93	50.00	534	13	8.75	15.00	1.58
	60.00	1505	1340.0	21	118.90	15.07	46.80	543	13	8.75	14.72	1.58
	60.25	1454	1770.0	21	115.10	15.20	43.86	439	13	8.70	14.43	1.58
	60.50	1442	1900.0	21	114.00	15.24	43.14	380	13	8.68	14.36	1.58
	60.75	1492	2150.0	21	116.60	15.20	45.10	310	13	8.65	14.56	1.58
	61.00	1640	2800.0	21	126.40	15.10	50.70	243	13	8.62	15.06	1.58

Figure B.1.16: Dicrode system operation at 60MHz to achieve 1 dB BW for pulse lengths of 2000s.

<u>*Ion cyclotron resonance frequency heating sources:*</u> After the successful demonstration of the 1.5 MW RF amplifier chain in the recent years, efforts continue towards doing the needful to demonstrate 3 MW RF power per source. This is done by combining RF outputs from two amplifier chains through an indigenously developed combiner circuit. Diacrode based RF power source (RFS) was operated for more than 2000s continuously at 60 MHz with tuning and setting the system to achieve required 1dB BW (figure B.1.16).

Another important inhouse In-house development relates to 10kW Solid State Power Amplifier (SSPA). two Nos. of power amplifier modules, input splitter & lumped combiner have been fabricated & tested successfully. Bulk production of remaining modules, splitters, combiners & control cards has also been completed. Figure B.1.17 shows the power response and bandwidth at various frequencies of the test modules.

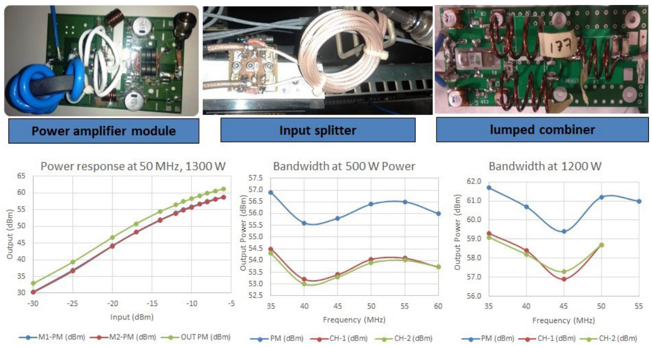


Figure B.1.17: Tests on the indigenously developed power amplifier module, input splitter and lumped combiner related to the 10 kW solid state power amplifier.

Voltage stand-off test equivalent to 2.5MW RF power level was conducted on in-house developed 3dB Hybrid combiner (figure B.1.18). Two diagonal ports (1 & 4) shorted, port 3 used as an input port (1.5MW) and port 2 as an output port (DL) are matched at 60MHz. Due to high Q response of the configuration, high voltages to the tune of 15 - 17 kV were detected near strap edge which the combiner could withstand. However arcing was observed at 22 kV which is the equivalent voltage of >3.5 MW RF power level.

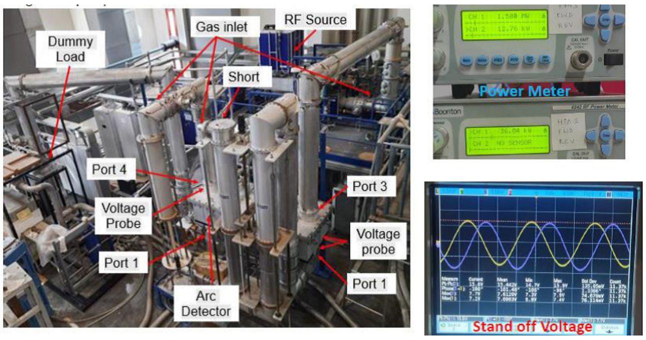


Figure B.1.18: Voltage stand off test of the indigenously fabricated combiner circuit.

In addition to the above in house developed torus type DPDT high power RF switch, figure B.1.19, has been fabricated and received in the lab for tests.

<u>*ECRH system:*</u> As a part of Indian in-kind contributions to ITER project, ITER-India has to deliver two high power Gyrotron RF source sets with state-of-the-art specifications (1MW/1000s, 170 GHz). These sources would be used for ECRH based plasma heating and current drive applications. The source system includes apart from the Gyrotron Tube several auxiliary systems such as power supplies, control system, cooling distribution system etc. The Gyrotron source performance not only depends upon the Gyrotron Tube but also performance of all the interfacing systems that drive and control the system. In order to establish the reliable integrated system performance, a Gyrotron test facility is developed at ITER-India, (figure B.1.20).

Figure B.1.19: Torus tye DPDT high power RF switch inhouse development.

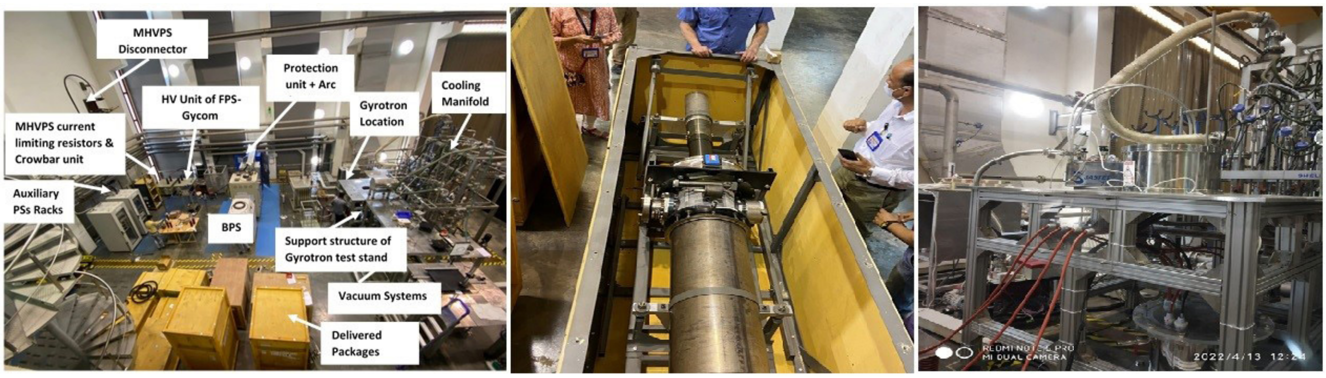


Figure B.1.20: Left to right; The gyrotron test facility at ITER India laboratory, unpacking of the 170 GHz 1 MW gyrotron and the superconducting magnet installed on its structure.

Prior to shipment of the 170 GHz 1 MW gyroton unit from M/S Gycom Russia the factory acceptance tests have been successfully completed with calorimetric power measurements performed at CW Dummy load : 1000s, 169.93 GHz, Average power of 946 kW for 5 successful pulses was obtained, figure B.1.21.

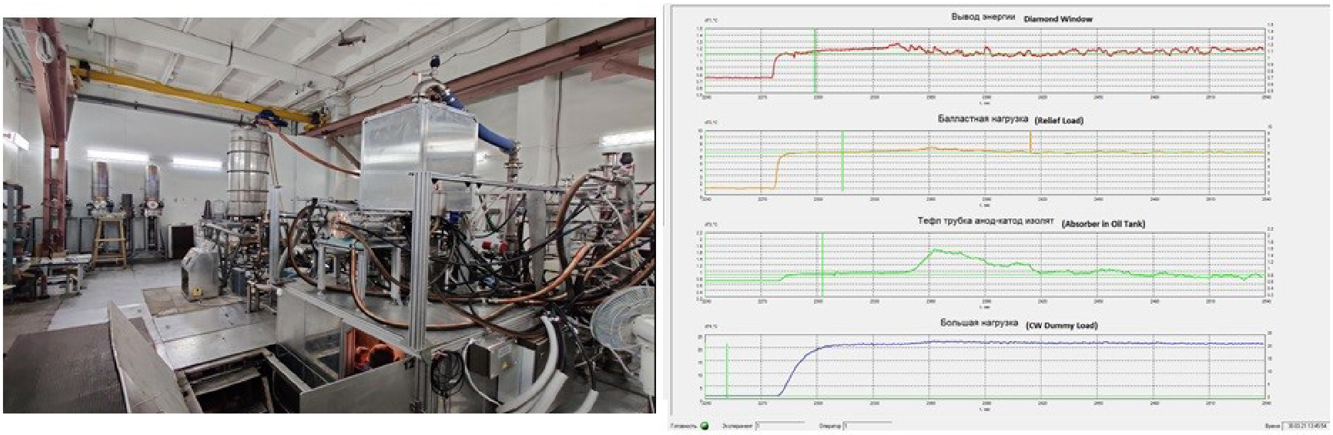


Figure B.1.21: Factory acceptance tests of the 170 GHz 1 MW gyrotron underway at the factory. 5 successful pulses of 946 kW achieved at 170 GHz for 1000 s.

Power supply systems: ITER-India Power Supply Group has developed and installed Main High Voltage (55kV, 6MW) Power Supply (MHVPS) for Gyrotron test facility of ITER-India and IPR, feeds cathode of Gyrotron. MHVPS is developed with specific feature of soft charging at input 22kVAC side to limit inrush charging current.

Power supply is based on PSM (Pulsed Step Modulation) technology; capable to feed settable voltage with ±0.5% accuracy from 10kV to 50kV. In-house developed Zynq 702 based controller controls power supply for operation, can switch off within less than 10µs in case of short circuit. Operation GUI runs on Siemens PLC 1500, which supports Ethernet interface to higher level (Gyrotron) controller.

MHVPS is successfully demonstrated for 50kV, 1kHz modulation along with protection and functional parameters in line with ITER specification of EC MHVPS. MHVPS is integrated with Electron Cyclotron system at ITER-India lab, operated remotely on equivalent load and achieved its preparedness for operation on 1MW Gyrotron, figure B.1.22.

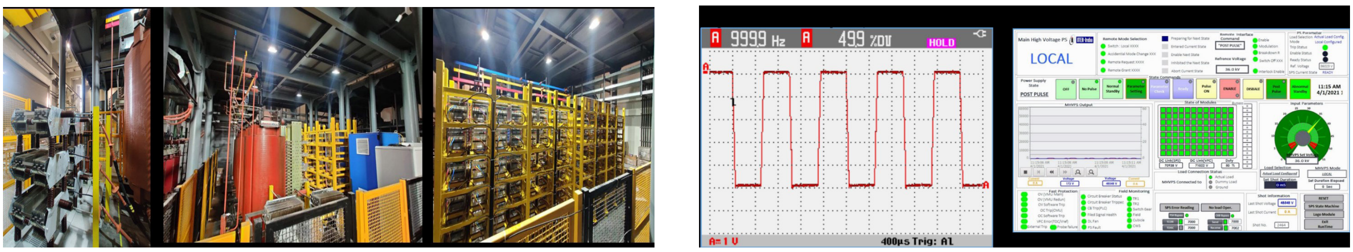


Figure B.1.22: Operations of the 55 kV, 6 MW MVHPS with the dummy load prior to its integration with the gyrotron

Further as a part of the 200 kW, 1 MHz RF generators for the diagnostic neutral beam source, the indigenously developed 40kW solid state RF generator (SSRFG) successfully integrated with the two RF drivers of the twin source. 39kW power was coupled to plasma load, figure B.1.23, with the two drivers connected to the single RF generator through a matching network in a configuration similar to the one to be used for the DNB source where 8 RF drivers shall be fed power through 4 RF generators. Based on the learnings an upscale version of 200kW SSRFG (1MHz) is being developed, contract is awarded to ECIL. Other application of SSRFG includes AM transmitters.

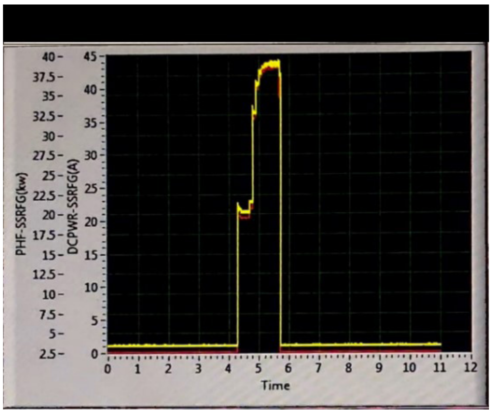


Figure B.1.23: SSRFG power 39kW to twin source.

In addition, 7.2MW, 100kV AGPS supplied by ITER-India has successfully completed 2 years of integrated operation on SPIDER experiments at NBTF, Padua, Italy site with remote support from ITER-India. AGPS is an in-kind supply under ITER package manufactured by M/s. ECIL. An alternate controller firmware is successfully developed through ECIL to resolve issues related to proprietary hardware. The controller has feature of optical interfaces and compliant with European code (CE certified).

Upper port 09 diagnostics: Design integration review for In vessel Port has been completed. Preparation of PDR is underway for the Upper Port 9, figure B.1.24. Approximate 70% documents are approved. Preparation for prototype and manufacturing related activities are being started.

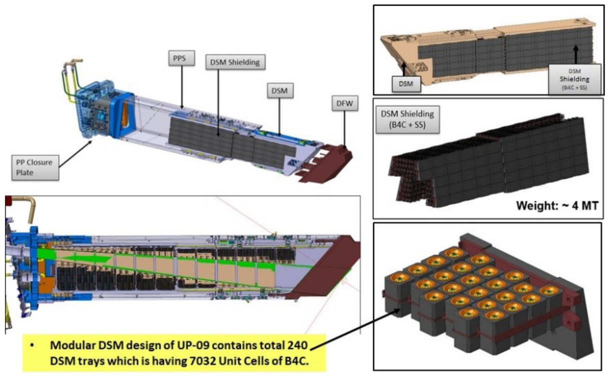


Figure B.1.24: Port plug 09 in vessel integration.

XRCS Survey: Order has been placed for procurement of Site Tube Material for XRCS Survey Spectrometer, figure B.1.25. Procurement of various components for prototype XRCS survey spectrometer has been initiated. The purchase request of a high energy detector for X-ray spectrometer has been given.

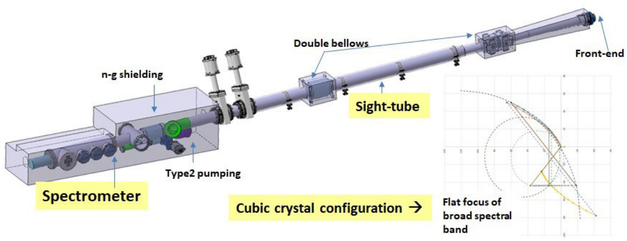


Figure B.1.25: XRCS survey spectrometer for ITER.

XRCS Edge: Design and component lay out is fixed for XRCS Edge Spectrometer. Procurement activity for the prototype components are being initiated.

CXRS Pedestal: Manufacturing of Fiber bundle assembly for CXRS pedestal prototype is going on.

ECE: PDR closure for ECE diagnostic is expected very soon. Moving towards final design phase. Procurements for prototype activities are in progress.

Development of Indigenous State-of-the-Art Code Suites for Nuclear Activation Analysis: Rigorous and accurate nuclear analysis is necessary for nuclear fusion machines from design, safety, maintenance, material damage, de-commissioning and radiation waste disposal considerations. Two classes of codes are needed, viz., neutron transport codes and nuclear activation codes. Indian labs have limited access to nuclear activation codes. Hence to make us self-reliant, a state of the art computer code suite for nuclear activation analysis called ACTYS family of codes have been developed. ACTYS performs nuclear activation calculations with one material and one neutron spectrum, ACTYS-1-GO is for a complete geometry with many materials and spatially varying neutron field with an option for first-level material composition optimization, and ACTYS-ASG is for activated gamma source generation. All the codes are well validated at various levels. ACTYS has been found to be superior to the well-known FISPACT-2007 in some respects. Recently ACTYS has been qualified and approved by the Nuclear Integration Unit, ITER for all ITER related nuclear activation calculations, which include calculations that lead to nuclear safety related reports. Figure B.1.26a and B.1.26b show the code results for the relative contribution to the dose from each element of SS316 L(N)-IG irradiated with ITER SA2 scenario with a maximum flux of $1x10^{12}$ $n/m^2/s$ and the impact of each element to the total dose respectively.

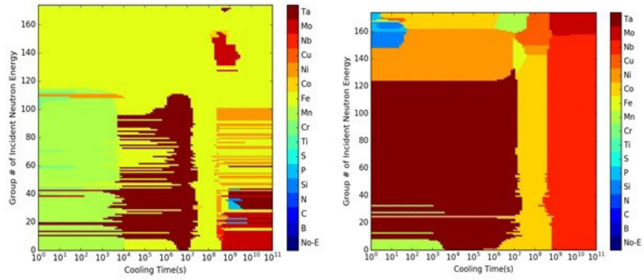


Figure B.1.26: a) relative contribution to the dose from each element of SS316 L(N)-IG irradiated with ITER SA2 scenario with a maximum flux of 1E12 $n/m^2/s$ b) impact of each element to the total dose.

Contributions to the ITER related modelling efforts for disruption prediction and VDE's: As a continued effort from the previous year, simulations related to disruptions and VDE events for ITER are have been completed using the TSC code through a dedicated task agreement. This involves development of a new halo current model in TSC, which calculates the halo width and temperature self-consistently using open field line transport in the halo region. This model has been validated against earlier similar simulations carried out using the DINA code and further simulations for mitigation with various concentrations of injected Neon and Deuterium is being carried out. The final report of the task agreement has been accepted by ITER and the TA has titled "ITER Disruption Simulations with Code TSC" has been closed formally.

Knowledge management: The Indian in-kind contribution to the ITER project is only about 9% of the overall ITER cost and in-kind components, whereas the rest of the >90% of ITER components are also equally critical, some in fact more complex in their design and manufacturing. As a part of the continued efforts in learning, understanding and assessing the critical components which are not in the scope of ITER India, the Knowledge Management group continued to analyse the design documents of ITER vacuum vessel, magnets and their power supplies, blankets modules, divertor cassettes and Remote Handling System. These are critical ITER components whose knowledge base is critical for our own future fusion reactors. The progress has been satisfactory despite the Covid situation and two of the personnel being deputed to ITER Organization recently.

B.2 Laser Interferometry Gravitational Wave Observatory (LIGO - India)

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

The LIGO Division at the institute is responsible for following works:

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

Activities towards development of Vacuum and Mechanical systems: The outgassing measurement system is necessary to qualify stainless steel material that goes into the fabrication of LIGO-India beam tube. Small Coupons of steel cut from steel coil after air baking at 440 ^{0}C. The expected outgassing rate of steel is < 10^{14} mbar l/s/cm^2. The outgassing measurement test facility has been setup in LIGO laboratory at the institute (figure B.2.1).

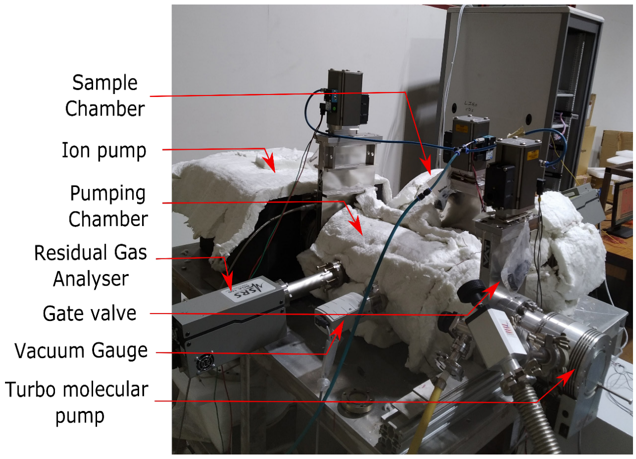


Figure B.2.1: Outgassing measurement system setup in LIGO Laboratory.

After successful factory acceptance testing, Basic Symmetric Chambers (BSC) and Horizontal Access Module (HAM) 1:1 size prototype chambers (1 each) are delivered at RRCAT (figure B.2.1). This task has been accomplished within delivery schedule despite COVID'19 pandemic. The final acceptance at RRCAT site after delivery is successfully completed in coordination with RRCAT colleagues.

The procurement for setting up LIGO-India – Vacuum Integrated System Test Assembly (LI-VISTA) facility has been initiated by LIGO-Division (figure B.2.3). Procurement tenders for supply of 20m Integrated Vacuum Vessel and 80K Cryo-pump assembly had been launched and finally awarded to Indian companies. The work for both the tenders is in progress and delivery at the institute is expected in 2023.

Successful effort have been made to develop two prototype (scale 1:1) bellows of SS304L for LIGO India beam tube. This fabricated bellow is of non-conventional type in terms of thickness and size, fabricated by expanding mandrel forming process.

Figure B.2.2: BSC and HAM (1:1) size prototype chambers (1 each) recently delivered at RRCAT.

The space in New Laboratory building has been provided to setup LIGO-Laboratory where Out-gassing measurement test setup, Baking Furnace. SOLIDWORKS based CAD facility, CDS/VCMS prototype test racks with computers/workstations have been established. The LI-VISTA facility will be established after culmination of ongoing procurement tenders in delivery of the supplies.

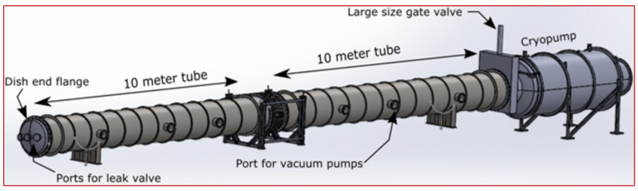


Figure B.2.3: Proposed LI-VISTA Test Facility at the institute (under procurement).

Activities towards development of Control and Data System (CDS): LIGO Division prepared a technical document titled "LIGO-India Control and Data System & Interfaces", and has been submitted to LIGO India Project Management Board. The interface document between CDS and Civil/ Electrical infrastructure system has been prepared. Similarly another interface between CDS and Data and Computing System (DCS) have been prepared to elaborate the interface requirements between the systems.

Figure B.2.4: Preliminary CDS Test rack setup in LIGO Lab at the institute.

As a part of prototyping activities for control and data system for LIGO India the CDS Test Rack is developed in-house (figure B.2.4). It includes IO chassis loaded with data acquisition hardware and front-end computers as per LIGO configuration. Installed, configured and built real-time LIGO CDS software on Debian-10 Linux OS using Cymac package and tested the CDS test rack successfully for stand-alone operation. This will facilitate working with LIGO Control basic tools using configured CDS Workstation for analysing engineering channels' data.

A prototype Vacuum Control and Monitoring System (VCMS) Rack for Vacuum Setups at the institute, following LIGO, USA slow controls configuration, has been developed and tested. After procurement of 'Beckhoff' make automation hardware along with 'TwinCAT3' Software, a suitable hardware and software interface has been developed for monitoring of vacuum parameters and discrete control of vacuum equipment. Further the EPICS interface with TwinCAT-IOC software required for slow controls, using software packages from LIGO software repositories is under testing and will be implemented for remote monitoring and control.

CHAPTER C & D

C. Academic Programme

D. Technical Services

C. ACADEMIC PROGRAMMES

C.1 DOCTORATE PROGRAMME

Twenty one (21) new students with Physics (15) and with different Engineering background (06) have joined this programme during this year and are going through the course work. Overall there are total Ninety Seven (97) PhD students enrolled at present in HBNI including some institute employees.

Ph.D. THESIS SUBMITTED (during April 2021 - March 2022)

Study of in Situ Measurement of Work Function and Caesium Dynamics
Pranjal Singh
Homi Bhabha National Institute, 2021

Non-Neutral Sheath Region around Surfaces in Low Temperature Plasma Containing Negative Ions
Avnish Kumar Pandey
Homi Bhabha National Institute, 2021

Computational Modeling of Tritium Release from Porous Ceramic Pebbles
Chandan Danani
Homi Bhabha National Institute, 2021

Effect of Short Gas-puff Pulses and Biasedelectrode on Transport, MHD Instabilities, Plasma-Wall Interaction and Runaway Electrons in ADITYA-U Tokamak
Tanmay Macwan
Homi Bhabha National Institute, 2022

Studies of Cavity Modes on Plasma and its Influence on Ion Beam in a Microwave Ion Source
Chinmoy Mallick
Homi Bhabha National Institute, 2022

Experimental Investigation of Complex Plasma Crystals in a DC Glow Discharge Plasma
Hariprasad MG
Homi Bhabha National Institute, 2022

C.2 SUMMER SCHOOL PROGRAMME (SSP)

This programme was not conducted in this year

C.3 UG/PG ACADEMIC PROJECTS FOR EXTERNAL STUDENTS

Around 21 students, pursuing Under Graduate (UG)/ Post Graduate (PG) courses in science and engineering, were engaged to do various academic projects with institute's faculties under their course curriculum in different fields of science and technology from various Colleges/Universities/ Institutes during April 2021 to March 2022.

D. Technical Services

D.1. Computer Division - IT Services and Infrastructure

Computer Division provides state-of-art Infrastructures in the areas of High Performance Computing (HPC) Systems, Computer Networking, Network Security, Information Security, Centralized Data Storage & Advanced Database Systems, Data Communication and other emerging areas of IT applications to scientific community. Division also provides and manages the IT services and infrastructure at institutes main campus, FCIPT and CPP-IPR. The IT infrastructure is deployed and configured for High Availability (HA) with the facility for remote management for all IT services including Website, Webmail, Intranet services (E-office, IDRMS, E-cloud), critical Network services including video conferencing and broadcasting services. Computer Division has a state-of-the-art Data Center (DC) to house all the critical IT infrastructure and HPC clusters which are monitored and maintained 24x7 inside DC. Computer Division ensures that all the employees work smoothly utilizing the IT services. During the lockdown in 2021, the facility was setup for all the employees to securely access all critical IT services from their homes and to continue their official work.

The major activities during the period from April 2021 to March 2022 are given in the bullets below:

Data Center (DC):
• 100 % uptime was achieved.
• Commissioning of two new Gateway Routers (Make-In-India).
• Procurement of BSNL Internet bandwidth.
• Containerized Data Center: Public Tender is under process for housing the upcoming/planned IT infrastructure.

Email and Website Services:
• 100% uptime was achieved for Email and Website services.
• Procurement, installation and testing of new server hardware for BRNS portal upgrade completed.
• Adding new pages in the website R&D work, HPC newsletter etc.
• Managing intranet site

Intranet Web Services:
• In-house developed E-office: Development of Model-View-Controller (MVC) based web applications, replacing existing form-based web applications for administrative services.
• On-premises private cloud-based file-sync data service named ECLOUD/MEGH was made avail-

able to Users for sharing big-size files and working collaboratively within the Institute.
• IP Address Management (IPAM) System portal for registering devices (mobile, laptop, desktop, tablet, etc.)

Network and Video Conference Services:
• Configuration and deployment of new VC service (JITSI meet) to add new features like recording, lobby area, streaming, etc. in line with the other available commercial software.
• Using virtualization technology for running IT services like Webmail, Intranet web services, Proxy, VPN, etc.

Centralized Procurement of new systems and Disposal of end-of-life systems:
• Procurement and installation of three steel porta cabins, two for e-waste and one for IT Support contract staff seating completed.
• Procurement and installation of 50 new Multi-Function Machines throughout the campuses completed.
• Procurement and installation of desktop computers in batches for employees.
• Centralized storage tender is under process.
• Removal of approx. 200 old desktop PCs under the e-waste category

D.2. SIRC (Library) Services

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

During the year 2021-22 a total budget of Rs. 35528547.00 was utilized and added the following to its collection during the year 2021-22: Books – 60 and eBook collection of IOP Evidence Based Acquisition (EBA) model with access to 340 eBooks for the year 2022-23; Scientific & Technical Reports from other institutes – 42; Reprints – 218; Pamphlets – 46.

The library subscribed to 105 periodicals and added 1 new online journal title to the e-collection and continued to subscribe to major databases such as SCOPUS, APS-ALL, Online Archives of core journals, and it has access to SCIENCEDIRECT as part of the DAE Consortium, NUCNET News service, and also added electronic back files of one journal.

Keeping the scientific community updated, the Library continued to provide Current Awareness Services by delivering email-based Fusion News Alerts and REcent Articles to Discover (READ) services to the institute, CPP and ITER-India users. Total 224 News items were sent/displayed and archived as an Alerting Service. Scientific News in Hindi language are also displayed on the library noticeboard, a total of 37 news items were displayed during the year.

Library continued to collaborate with DAE units and other National and International libraries to provide Inter-Library Loan (ILL) services. 95% of the requests made by staff members were satisfied through ILL service. Library provided documents to other institutes against their queries and 100% of the total need were satisfied.

In 2021-22, Library provided 21906 photocopies/ prints and 10343 scanned copies to the users.

Publication Management Services were carried out efficiently and SIRC continued to subscribe to anti-plagiarism software tool for checking similarity index of the publications. SIRC published the following during the year 2021-22: Internal Technical Reports – 47; Internal Research Reports – 137; Publications in Journals – 221; Publications in Conference Proceedings – 16; Book Chapters – 5.

A total of 416 manuscripts (Abstract/Papers) and 05 Patent information were broadcasted to the Staff through the Pre-Publication Broadcasting System and Pre-Patent Broadcasting System respectively on the Intranet portal.

Hands-on Training was imparted to the four library trainees recruited for a period of one year. Online Internship was provided to two library science graduate students from CUG, Gandhinagar. 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.

D.3. Automatic Power Factor Compensation System

Automatic Power Factor Correction System of rating 1600 KVAr at 11kV was successfully installed. The main purpose of automatic power factor correction (APFC) system is to help correcting the excess reactive power generated by inductive loads in the electrical distribution network. With an efficient use of this device, the electrical network can improve efficiency by reducing losses and reduced apparent power demand charges. Thus APFC is used to improve the power factor, whenever required, by switching ON and OFF the required capacitor bank units automatically.

The APFC is mainly equipped with automatic power factor controller, vacuum contractor switch, series reactor and power capacitor units. Each step consists of HT HRC fuse for protecting the capacitor bank, the vacuum contractor switch is followed by fuse and series reactor is followed with switch and the capacitor unit. The highly accurate current and voltage transformer are used for measuring & protection purpose.

There are four stages of capacitor units two of rating 500 KVAr and two of rating 300 KVAr. Each unit of power capacitor consist with a discharge resistor that will reduce the residual voltage to 50V after five minutes when the power is disconnected from the unit. Each capacitor unit consist of three units of single phase capacitor with very low losses and heat dissipation quality. These capacitors have

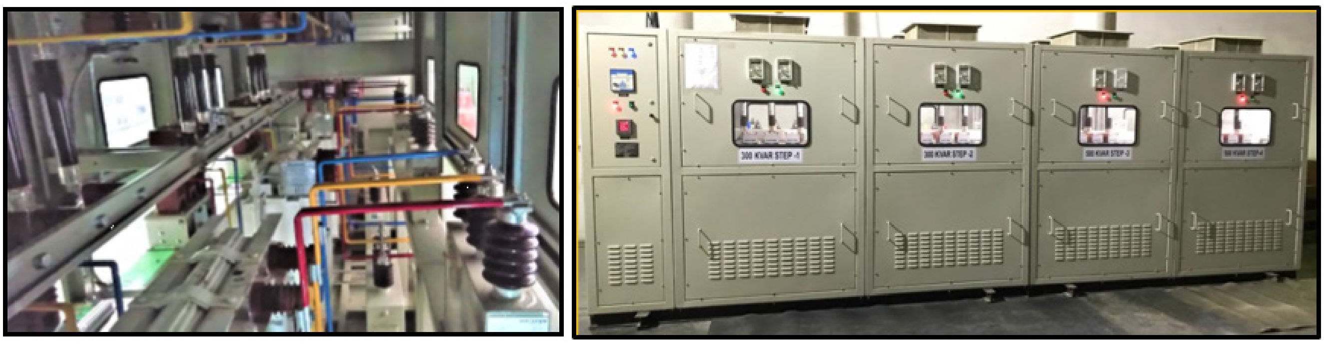


Figure D.1: Automatic power factor compensation system.

long life and extremely stable electrical characteristics.

The capacitor banks draws high inrush current during switching and hence they consists of series reactor (2x23KVAr and 2 x 29 KVAr) which limits inrush current, resonance and protections the capacitor bank during switching. These reactors also suppresses the harmonic levels.

The microprocessor based APFC relay controls the power factor by giving signals to switch ON or OFF the capacitors. Calculation of power parameters is based on stored sampled data of voltage and current inputs by the APFC relay. When p.f. falls below setting, the capacitors are switched ON. The relay will determine the correct amount of capacitors required at any time for maintaining target p.f. by switching in and out capacitors accordingly. The performance of the APFC System is found satisfactory and is helping in reduction in Energy Bill.

D.4. Electronics & Instrumentation Division

Division is focused in self-reliance and developing customized front end electronics, indigenous data acquisition systems and automated systems required for various physics experiments in Institute. In SST-1 and Aditya Tokamak, signal conditioning and data acquisition systems are separate units interconnected with cables. This year we have integrated signal conditioning electronics & data acquisition in 3U chassis to achieve compact system with high performance in terms of noise and throughput. The Data Acquisition System is realized with latest generation Zynq FPGA System on Chip (SoC). The ARM processor inside SoC use Direct Memory Transfer (DMA) Engine on AXI bus to transfer ADC data to DDR memory with throughput of 16MB/s. This Ethernet based SoC system can acquire 32 isolated channels simultaneously at 500kSPS per channel for 5 seconds.

Around 150 electronics channel has been developed with innovative design to achieve small size, low power and remotely controlled parameters to measure signal of sensors for different plasma diagnostics. The various sensors interfaced to electronics are AXUV diode, Schottky diode, Photo multiplier tubes, Magnetic probes and Langmuir probes. As per requirement, design includes channel to channel isolation, bandwidth and gain control, differential drivers, high voltage amplification and biasing, sweep generation and online processing for real time control applications. To meet control and processing requirements we have developed systems based on FPGA, cRIO, DSP and Microcontroller. The FPGA based timing system is expanded for additional sub-systems and Gas Feed controller is upgraded with latest technology for additional features in Aditya-U.

The existing single board computer based indigenous data acquisition system is up-graded in design for small size and low power. The upgraded portable system is acquiring data of 32 channels with sampling rate of 100kSamples/sec/channel. The indigenous developed PLC system is being used and customized for performing deterministic task in real time for different experiments. The high end FPGA hardware platform based on Xilinx Kintex series FPGAs with 800K Logic Cells is developed for exploring high speed signal processing and numerical calculations.

D.5. Radio Frequency and Microwave Services

Radio Frequency and Microwave Services (RFMS) Section is engaged in providing technical help in RF and Microwave areas to the groups who do not have dedicated RF and Microwave persons. Some of the technical help provided during April 2021 to

March 2022 to various groups are: (a) performing measurement of S-parameter of power divider of cryo-pump and injector system division, (b) testing of low noise amplifier and high power RF amplifier for the procured specifications for RF plasma application Division in VHF and UHF range, (c) installation and operation of 2 kW, 2.45 GHz RF source in Aditya for electron cyclotron resonance discharge cleaning and successful wall condition was done, (d) simulation studies were performed for various types of antennae at 13.56 MHz for fundamental plasma experiment division, (e) 2.45 GHz, 1.0 kW source was developed for basic science division for their experiment on BETA machine, (f) Microwave measurements were performed with directional coupler and isolator for plasma surface engineering division for microwave plasma production experiment.

D.6. Data Acquisition and Control System

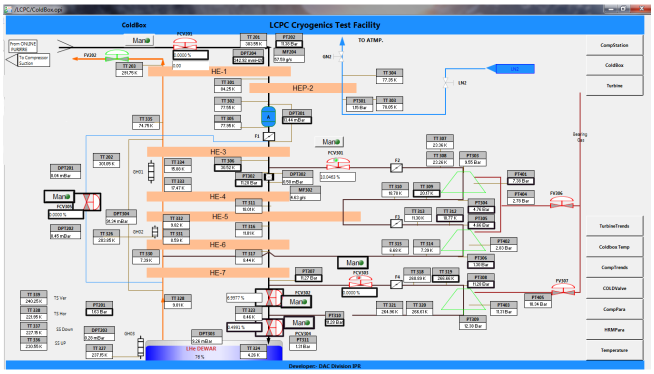


Figure D.2: Monitoring and control for large cryogenic plant system.

For Large Cryogenics Plant System (LCPS) the first phase control system at par with the industrial level control is developed using open source software system and successfully demonstrated cool down upto 4.3 ^{0}K.

CHAPTER E & F

E. Publications and Presentations

F. Other Activities

E. PUBLICATIONS AND PRESENTATIONS

E.1 Articles Publications

E.1.1 Journal Articles

Radioactivation Analysis of 14 MeV Neutron Generator Facility
H.L. SWAMI, S.VALA, M. ABHANGI, RATNESH KUMAR, C. DANANI, R. KUMAR, R. SRINIVASAN
Fusion Engineering and Design, 165, 112229, April 2021

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ROHIT KUMAR, PRAMILA GAUTAM, SHIVAM GUPTA, R.L.TANNA, PRAVEENLAL EDAPPALA, MINSHA SHAHA, VISMAY RAULJI, K.A.JADEJA, K.M.PATEL, TANMAY MACWAN, RANJANA MANCHANDA, M.B. CHOWDHURI,NANDINI YADAV, KUNAL SHAHA, M.N. MAKWANA, V.BALAKRISHNAN, C.N. GUPTA, SUMAN AICH, Y.C.SAXENA, the ADITYA-U TEAM
Fusion Engineering and Design, 165, 112218, April 2021

SERS Based Detection of Dichlorvos Pesticide Using Silver Nanoparticles Arrays: Influence of Array Wavelength/Amplitude
SEBIN AUGUSTINE, K.P. SOORAJ, VIVEK PACHCHIGAR, C. MURALI KRISHNA, MUKESH RANJAN
Applied Surface Science, 544, 148878, April 2021

Revisiting the Photochemistry 2, 5-Dihydroxy Benzoic Acid (Gentisic Acid): Solvent and pH Effect
MEENA ADHIKARI, NEERAJ K. JOSHI, HEM C. JOSHI, MOHAN S. MEHATA, HIRDYESH MISHRA, SANJAY PANT
Journal of Physical Organic Chemistry, 34, e4168, April 2021

Sticky Islands in Stochastic Webs and Anomalous Chaotic Cross-Field Particle Transport by E x B Electron Drift Instability
D. MANDAL, Y. ELSKENS, X. LEONCINI, N. LEMOINE, F. DOVEIL
Chaos, Solitons & Fractals, 145, 110810, April 2021

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VIJAY SHANKAR, N. BISAI, SHRISH RAJ and A. SEN
Nuclear Fusion, 61, 066008, April 2021

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SUBRAT KUMAR DAS, ARKAPRAVA DAS, MATTIA GABOARDI, SIMONE POLLASTRI, G. D. DHAMALE, C. BALASUBRAMANIAN and BOBY JOSEPH
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SAYANTAN MUKHERJEE, SMITA RANI PANDA, PURNA CHANDRA MISHRA and PARITOSH CHAUDHURI
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PRASHANTH SHIVANOOR RAVIKUMAR, SENTHIL KUMAR ARUMUGAM, RANJANA GANGRADEY, SAMIRAN MUKHERJEE, KASTHURIRENGAN SRINIVASAN, SREEJA SADASIVAN, VISHAL GUPTA and MAHESH C. AGGARWAL
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Physics of Plasmas, 28, 042101, April 2021

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NAND KUMAR, B. GANGULI, BIDESH ROY and BACHU DEB
Transactions of the Indian Institute of Metals, 74, 799, April 2021

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PARVATHY NANCY, JIYA JOSE, NITHIN JOY, SIVAKUMARAN VALLUVADASAN, REJI PHILIP, RODOLPHE ANTOINE, SABU THOMAS and NANDAKUMAR KALARIKKAL
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YOGESH M. JAIN, SHREY THAKKER, P. K. SHARMA and HARISH V. DIXIT
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U. KUMAR, R. GANESH, Y. C. SAXENA, D. RAJU and S. G. THATIPAMULA
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J. GHOSH, R. L. TANNA, P. K. CHATTOPADHYAY, A. SEN, HARSHITA RAJ, PRAVESH DHYANI, SUMAN DOLUI, S. V. KULKARNI, K. MISHRA, RAJ SINGH, SUNIL KUMAR, S. B. BHATT, K. A. JADEJA, K. M. PATEL, C. N. GUPTA, MOTI M. MAKWANA, K. SHAH, CHHAYA CHAVDA, V. K. PANCHAL, N. C. PATEL, J. V. RAVAL, SHISHIR PUROHIT, S. JOISA, C. V. S. RAO, RAJU DANIEL, SAMEER K. JHA, B. K. SHUKLA, E. V. PRAVEENLAL, V. RAULJI, R. RAJPAL, P. K. ATREY, U. NAGORA, R. MANCHANDA, N. RAMAIYA, M. B. CHOWDHURI, R. JHA, Y. C. SAXENA, and R. PAL
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VIKAS RATHORE, DIVYESH PATEL, SHITAL BUTANI and SUDHIR KUMAR NEMA
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OMSTAVAN SAMANT, JAYA KUMAR ALAGESHAN, SARVESHWAR SHARMA and ANIMESH KULEY
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K. DEKA, S. ADHIKARI, R. MOULICK, S. S. KAUSIK and B. K. SAIKIA
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SATADAL DAS and S. K. KARKARI
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Journal of Electrical and Electronics Engineering, 14, 53, May 2021

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A. SIRCAR, V. G. DEVI, D. YADAV, J. S. MISHRA, R. J. G. GANGRADEY, R. TOMAR, P. B. DHORAJIYA, P. DAVE
Fusion Engineering and Design, 166, 112308, May 2021

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Effect of Movable Anode on Plasma Parameters in Multi-Dipole Discharge
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Design and Simulation of 3.7-GHz, 8-kW CW, and 16-kW CW Magnetrons for LHCD System of Tokamaks
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Sputtering Yield and Nanopattern Formation Study of $BnSiO_2$ (Borosil) at Elevated Temperature Relevance to Hall Effect Thruster
BASANTA KUMAR PARIDA, K.P. SOORAJ, SUKRITI HANS, VIVEK PACHCHIGAR, SEBIN AUGUSTINE, T. REMYAMOL, M. R. AJITH and MUKESH RANJAN
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Bispectral Analysis of Nonlinear Mixing in a Periodically Driven Korteweg-de Vries System
AJAZ MIR, SANAT TIWARI and ABHIJIT SEN
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A Comparative Study of Dielectric Barrier Discharge Plasma Device and Plasma Jet to Generate Plasma Activated Water and Post-Discharge Trapping of Reactive Species
VIKAS RATHORE and SUDHIR KUMAR NEMA
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E.1.2 Conference Papers

Analysis of Thermal Stresses and its Effect in the Multipass Welding Process of SS316L
H. VEMANABOINA, S. AKELLA, A. C. UMA MAHESHWER RAO, E. GUNDABATTINI, R. K. BUDDU
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Exploiting the Challenges of Copper to Austenitic Stainless Steel Bimetallic Joining by Gas Tungsten Arc Welding: A Fluid Flow Perspective
RAGHAVENDRA S. DARJI, GAURANG R. JOSHI, ANKIT D. OZA and VISHVESH J. BADHEKA
IOP Conference Series: Materials Science and Engineering, 1146, 012011, May 2021

On Performance Enhancement of Molecular Dynamics Simulation using HPC Systems
TEJAL RATHOD, MONIKA SHAH, NIRAJ SHAH, GAURANG RAVAL, MADHURI BHAVSAR, RAJARAMAN GANESH
Proceedings of 2nd International Conference on Computing, Communications, and Cyber-Security, 1031, May 2021

Physics Driven Scaling Laws for Fusion Reactors
F P ORSITTO, M ROMANELLI, VINAY MENON
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Estimation of Inter-Conductor Stray Capacitance for HVDC Transmission Line of Negative Neutral Beam Injector
M. N. VISHNUDEV, DEEPAK PARMAR, HARDIK SHISHANGIYA, AGRAJIT GAHLAUT, V. MAHESH, M. BANDYOPADHYAY and ARUN CHAKRABORTY
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Experimental Results of 40 kW, 1 MHz Solid State High Frequency Power Supply With Inductively Coupled Plasma
S. GAJJAR, D. UPADHYAY, N. SINGH, M. SINGH, A. GAHLAUT, K. PANDYA, M. BHUYAN, R. YADAV, H. TYAGI, M. VUPPUGALLA, A. THAKAR, A. PATEL, B. RAVAL, R. DAVE, H. DHOLA, K. MEHTA, N. GOSWAMI, V. GUPTA, M. BANDYOPADHYA, A. CHAKRABORTY and U. BARUAH
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The Feasibility of Resonance Induced Instabilities in the Magnetic Filter Region of Low Temperature Plasma Based Negative Ion Sources
MIRAL SHAH, BHASKAR CHAUDHURY, MAINAK BANDYOPADHYAY and ARUN CHAKRABORTY
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Correction Algorithm for Cavity Ring-Down Based Anion Density Measurement in a Negative Ion Source Having Continuously Fed Cesium Vapor
D. MUKHOPADHYAY and M. BANDYOPADHYAY
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Noise Mitigation Techniques in Thermocouple signals in Negative ion sources with RF and HV transients
HIMANSHU TYAGI, KARTIK PATEL, RATNAKAR YADAV, HIREN MISTRI, AGRAJIT GAHLAUT, KAUSHAL PANDYA, MANAS BHUYAN, MJ SINGH,
MAINAK BANDYOPADHYAY and ARUN CHAKRABORTY
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Design of FPGA-based Triggering and Synchronization System for Laser Photo Detachment Diagnostic in ROBIN
HIMANSHU TYAGI, RATNAKAR YADAV, KAUSHAL PANDYA, HIREN MISTRI, KARTIK PATEL, MAINAK BANDYOPADHYAY,

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Probe for in situ Measurement of Work Function in Correlation with Cesium Dynamics Suitable for Ion Source Applications
PRANJAL SINGH and MAINAK BANDYOPADHYAY
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Prediction of Negative Hydrogen Ion Density in Permanent Magnet-Based Helicon Ion Source (HELEN) using Deep Learning Techniques
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Development of Plasma System for the Seeds Treatment to Improve Germination and Growth
KUNDAN VILIYA, UTTAM SHARMA, S.S. CHAUHAN, J. SHARMA, R. RANE, J. GHOSH, K.N. GURUPRASAD
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Comparative Study of Mixed Metal Cation Lead-Free Perovskites for Visible Light Photodetection
AMREEN A. HUSSAIN
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Design and Simulation of a Water Based Polarization-Insensitive and Wide Incidence Dielectric Metasurface Absorber for X-, Ku- and K-Band
Priyanka Tiwari, Surya Kumar Pathak
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Design and Simulation of a Polarization-Independent Switchable Metasurface Rasorber/ Absorber
Priyanka Tiwari, Surya Kumar Pathak
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Synthesis, Optimization and Characterization of Zinc Oxide Nanoparticles prepared by Sol-Gel Technique
MUDIT SINGH, DIPALI VADHER, VISHWA DIXIT, CHETAN JARIWALA
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Polarization-Insensitive Metasurface based Switchable Absorber/ Rasorber
PRIYANKA TIWARI, SURYA KUMAR PATHAK
IEEE Asia-Pacific Microwave Conference (APMC), 359-361, January 2022

E.1.3 Book Chapters

Experimental Investigations on Bubble Detection in Water-Air Two-Phase Vertical Columns
ABHISHEK SARASWAT, ASHOK K. PRAJAPATI, RAJENDRAPRASAD BHATTACHARYAY, PARITOSH CHAUDHURI, SATEESH GEDUPUDI
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Joining of Heat Sink with Structural Material for

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K.P. SINGH, ALPESH PATEL, KEDAR BHOPE and S.S. KHIRWADKAR
Joining Processes for Dissimilar and Advanced Materials, Woodhead Publishing Reviews: Mechanical Engineering Series, 513-526, November 2021. ISBN: 9780323853996

Atmospheric Pressure Plasma therapy for Wound Healing and Disinfection - A Review
ALPHONSA JOSEPH, RAMKRISHNA RANE and AKSHAY VAID
Wound Healing Research: Current Trends and Future Directions, pp 621-641, Springer, Singapore, 2021. ISBN: 9789811626760

Study of Ion-Acoustic Waves in Two-Electron Temperature Plasma
G. SHARMA, K. DEKA, R. PAUL, S. ADHIKARI, R. MOULICK, S. S. KAUSIK, B. K. SAIKIA
Selected Progresses in Modern Physics (Springer Proceedings in Physics, Vol 265), pp 355-361, Springer, January 2022. ISBN: 9789811651403

Study of Plasma Sheath in the Presence of Dust Particles in an Inhomogeneous Magnetic Field
K. DEKA, R. PAUL, G. SHARMA, S. ADHIKARI, R. MOULICK, S. S. KAUSIK and B. K. SAIKIA
Selected Progresses in Modern Physics (Springer Proceedings in Physics, Vol 265), pp 363-373, Springer, January 2022. ISBN: 9789811651403

E.2 INTERNAL RESEARCH AND TECHNICAL REPORTS

E 2. 1 Research Reports

NUMERICAL SIMULATION OF A BI-DIRECTIONAL PLASMA THRUSTER FOR SPACE DEBRIS REMOVAL
V. SAINI and R. GANESH
IPR/RR-1265/2021 APRIL 2021

DEVELOPMENT OF COMPACT MULTIVARIABLE SENSOR PROBE FOR TWO-PHASE DETECTION IN HIGH-TEMPERATURE PbLi-ARGON VERTICAL COLUMNS
ABHISHEK SARASWAT, ASHOKKUMAR PRAJAPATI, RAJENDRAPRASAD BHATTACHARYAY, PARITOSH CHAUDHURI and SATEESH GEDUPUDI
IPR/RR-1266/2021 APRIL 2021

DPEX-II: A NEW DUSTY PLASMA DEVICE CAPABLE OF PRODUCING LARGE SIZED DC COULOMB CRYSTALS
SARAVANAN ARUMUGAM, P. BANDYOPADHYAY, SWARNIMA SINGH, M. G. HARIPRASAD, DINESH RATHOD, GARIMA ARORA and A. SEN
IPR/RR-1267/2021 APRIL 2021

CONTROLLING THE ROTATION OF DRIFT TEARING MODES BY BIASED ELECTRODE IN ADITYA-U TOKAMAK
TANMAY MACWAN, KAUSHLENDER SINGH, SUMAN DOLUI, ANKIT KUMAR, HARSHITA RAJ, P. GAUTAM, PRAVEENLAL EDAPPALA, J. GHOSH, R. L. TANNA, ROHIT KUMAR, K. A. JADEJA, K. M. PATEL, SUMAN AICH, S. K. JHA, D. RAJU, P. K. CHATTOPADHYAY, A. SEN, Y. C. SAXENA, R. PAL and ADITYA-U TEAM
IPR/RR-1268/2021 APRIL 2021

DEMONSTRATION OF HEAT FLUX UNIFORMITY BY INFRARED IMAGING IN HIGH HEAT FLUX TEST FACILITY AT IPR
KEDAR BHOPE, SUNIL BELSARE, SAMIR KHIRWADKAR, VINAY MENON, MAYUR MEHTA, RAJAMANNAR SWAMY, NIKUNJ

PATEL, TUSHAR PATEL, SUDHIR TRIPATHI, K. P. SINGH and PRAKASH MOKARIYA
IPR/RR-1269/2021 APRIL 2021

THE STUDY OF THE EFFECT OF COMPRESSIVE STRESS ON CRITICAL CURRENT OF HIGH TEMPERATURE SUPERCONDUCTING TAPES
ANEES BANO, UPENDRA PRASAD, ARUNSINH ZALA and R. SRINIVASAN
IPR/RR-1270/2021 APRIL 2021

EMERGENCE OF DIRECTED MOTION IN A 2D SYSTEM OF YUKAWA PARTICLES ON 1D ASYMMETRIC RATCHET
ANSHIKA CHUGH and RAJARAMAN GANESH
IPR/RR-1271/2021 APRIL 2021

GAS-PUFF INDUCED COLD PULSE PROPAGATION IN ADITYA-U TOKAMAK
TANMAY MACWAN, HARSHITA RAJ, KAUSHLENDER SINGH, SUMAN DOLUI, SHARVIL PATEL, ANKIT KUMAR, P. GAUTAM, J. GHOSH, R. L. TANNA, K. A. JADEJA, K. M. PATEL, ROHIT KUMAR, SUMAN AICH, V. K. PANCHAL, UMESH NAGORA, M. B. CHOWDHURI, R. MANCHANDA, NANDINI YADAVA, RITU DEY, KIRAN PATEL, J. RAVAL, S. K. PATHAK, M. K. GUPTA, K. TAHILIANI, P. K. CHATTOPADHYAY, A. SEN, Y. C. SAXENA, R. PAL and ADITYA-U TEAM
IPR/RR-1272/2021 APRIL 2021

PRELIMINARY ESTIMATION OF RADIONUCLIDES GENERATION IN A FUSION REACTOR ENVIRONMENT FOR MEDICAL AND INDUSTRIAL APPLICATIONS
SHRICHAND JAKHAR
IPR/RR-1273/2021 APRIL 2021

ION ENERGY DISTRIBUTION FUNCTION IN VERY HIGH FREQUENCY CAPACITIVE DISCHARGES EXCITED BY SAWTOOTH WAVEFORM
SARVESHWAR SHARMA, NISHANT SIRSE, ANIMESH KULEY and MILES M. TURNER
IPR/RR-1274/2021 APRIL 2021

EXCITATION OF ELECTROSTATIC STANDING WAVE IN THE SUPERPOSITION OF TWO COUNTER PROPAGATING RELATIVISTIC WHISTLERWAVES
MITHUN KARMAKAR, SUDIP SENGUPTA and BHAVESH PATEL
IPR/RR-1275/2021 APRIL 2021

POROUS STRUCTURE AND ITS IMPACT ON HYDROGEN ADSORPTION IN ACTIVATED CARBONS
ARUP SARKAR, J. S. MISHRA, R. GANGRADEY, P. PANCHAL,S. MUKHERJEE, P. NAYAK and V. GUPTA
IPR/RR-1276/2021 MAY 2021

POLARIZATION INDEPENDENT MULTI-BAND META-SURFACE ABSORBER
B. RISCOB, N. RAJAN BABU, ABHISHEK SINHA, VARSHA SIJU and S. K. PATHAK
IPR/RR-1277/2021 MAY 2021

RCS REDUCTION USING RESISTIVE-INK BASED METASURFACE ABSORBER
PRIYANKA TIWARI, SURYA KUMAR PATHAK and VARSHA SIJU
IPR/RR-1278/2021 MAY 2021

DESIGN, DEVELOPMENT AND CHARACTERIZATION OF BROADBAND POLARIZATION-INSENSITIVE METASURFACE ABSORBER USING FOUR GAMMA-SHAPED RESISTIVE ARMS FOR RCS REDUCTION

PRIYANKA TIWARI, SURYA KUMAR PATHAK and VARSHA SIJU
IPR/RR-1279/2021 MAY 2021

PERFORMANCE ASSESSMENT OF A COMPACT VOLUMETRIC NEUTRON SOURCE AS A BREEDER
VINAY MENON, UPENDRA PRASAD, HEMANG AGRAVAT, DEEPTI SHARMA, H. L. SWAMI and R. SRINIVASAN
IPR/RR-1280/2021 MAY 2021

EFFECT OF HEATING RATE AND PRECURSOR COMPOSITION ON SECONDARY PHASE FORMATION DURING CZTS THIN FILM GROWTH AND ITS PROPERTIES
SAGAR AGRAWAL, BALASUBRAMANIAN C., SUBROTO MUKHERJEE, RINKAL KANANI, KISHORE K. MADUPU and SANDIP DHARA
IPR/RR-1281/2021 MAY 2021

STUDY OF THE PLASTIC PELLET TRANSFER CHARACTERISTIC THROUGH THE CURVED GUIDE TUBE
JYOTI SHANKAR MISHRA, DHAVAL NIMAVAT,RANJANA GANGRADEY, SAMIRAN MUKHERJEE, VISHAL GUPTA, PRATIK NAYAK and PARESH PANCHAL
IPR/RR-1282/2021 MAY 2021

TRAPPED PARTICLE INSTABILITY IN: I HOMOGENEOUS VLASOV PLASMAS
SANJEEV KUMAR PANDEY and RAJARAMAN GANESH
IPR/RR-1283/2021 MAY 2021

TRAPPED PARTICLE INSTABILITY IN: II INHOMOGENEOUS VLASOV PLASMAS
SANJEEV KUMAR PANDEY and RAJARAMAN GANESH
IPR/RR-1284/2021 MAY 2021

CHARACTERIZATION OF A MULTICUSP ION SOURCE WITH TWO GRID EXTRACTION SYSTEM FOR STUDYING EXTRACTION AND TRANSPORT OF ION BEAM
BHARAT SINGH RAWAT, S. K. SHARMA, B. CHOKSI, P. BHARATHI, B. SRIDHAR, L. N. GUPTA, D. THAKKAR, S. L. PARMAR, V. PRAHLAD and U. K. BARUAH
IPR/RR-1285/2021 JUNE 2021

ANALYSIS OF POST OPERATION RADIATION HAZARDS IN IECF NEUTRON SOURCE FACILITY AT CPP-IPR
H. L. SWAMI, S. R. MOHANTY, S. VALA, R. SRINIVASAN and R. KUMAR
IPR/RR-1286/2021 JUNE 2021

SPOT FORMATION IN 3D YUKAWA LIQUID
SURUJ KALITA and RAJARAMAN GANESH
IPR/RR-1287/2021 JUNE 2021

CURRENT DRIVE EXPERIMENTS IN SST1 TOKAMAK WITH LOWER HYBRID WAVES
P.K. SHARMA, D. RAJU, S.K. PATHAK, R. SRINIVASAN, K. K. AMBULKAR, P.R. PARMAR, C.G. VIRANI, J. KUMAR, S. SHARMA, C. SINGH, A.L. THAKUR, V.L. TANNA, U. PRASAD, Z. KHAN, D.C. RAVAL, C.N. GUPTA, B. KRISHNAN, S. NAIR, D.K. SHARMA, B. DOSHI, M. VASANI, K. MAHAJAN, R. RAJPAL, R. MANCHANDA, K. ASUDANI, M.K. GUPTA, M.B. CHOWDHURI, R.L. TANNA and SST-1 & DIAGNOSTIC TEAMS
IPR/RR-1288/2021 JUNE 2021

WIDEBAND CIRCULARLY POLARIZED CONCENTRIC CYLINDRICAL DIELECTRIC RESONATOR ANTENNA EXCITED BY HELIX
AJAY KUMAR PANDEY and SURYA KUMAR PATHAK
IPR/RR-1289/2021 JUNE 2021

REFLECTION OF A DUST ACOUSTIC SOLITARY WAVE IN A WEAKLY COUPLED DUSTY PLASMA
KRISHAN KUMAR, P. BANDYOPADHYAY, SWARNIMA SINGH, GARIMA ARORA and A. SEN
IPR/RR-1290/2021 JUNE 2021

EFFECT OF PARTICLE MASS INHOMOGENEITY ON THE TWO-DIMENSIONAL RAYLEIGH-BERNARD SYSTEM OF YUKAWA LIQUIDS: A MOLECULAR DYNAMICS STUDY
PAWANDEEP KAUR and RAJARAMAN GANESH
IPR/RR-1291/2021 JUNE 2021

STUDIES ON THE ROLE OF ION MASS AND ENERGY IN THE DEFECT PRODUCTION IN IRRADIATION EXPERIMENTS IN TUNGSTEN
P. N. MAYA, S. MUKHERJEE, P. SHARMA, V. KARKI, M. SINGH, S. JULIE, P. KIKANI, A. SATYAPRASAD, C. DAVID, P. K. PUJARI and S. P. DESHPANDE
IPR/RR-1292/2021 JUNE 2021

TERAHERTZ EMISSION FROM LASER INTERACTION WITH NANO-PARTICLES EMBEDDED ARGON (Ar) GAS
P. VARSHNEY, A. P. SINGH, M. KUNDU and K. GOPAL
IPR/RR-1293/2021 JUNE 2021

A DIAGNOSTIC FOR MEASURING RADIAL PROFILE OF VISIBLE CONTINUUM RADIATION FROM ADITYA-U TOKAMAK PLASMAS
M. B. CHOWDHURI, R. MANCHANDA, J. GHOSH, N. YADAVA, KINJAL PATEL, N. RAMAIYA, S. PATEL, M. SHAH, R. RAJPAL, U. C. NAGORA, S. K. PATHAK, J. RAVAL, M. K. GUPTA, ROHIT KUMAR, SUMAN AICH, K. A. JADEJA, R. L. TANNA and ADITYA-U TEAM
IPR/RR-1294/2021 JUNE 2021

IMPROVED-CONFINEMENT WITH VARYING TOROIDAL ROTATIONS IN NEON-SEEDED ADITYA-U PLASMAS
M. B. CHOWDHURI, K. SHAH, J. GHOSH, G. SHUKLA, R. L. TANNA, K. A. JADEJA, R. MANCHANDA, N. YADAVA, N. RAMAIYA, S. PATEL, K. M. PATEL, TANMAY MACWAN, U. C.NAGORA, S. K. PATHAK, J. V. RAVAL, M. K. GUPTA, S. K. JHA, M. V. GOPALAKRISHNA, K. TAHILIANI, ROHIT KUMAR, SUMAN AICH, SUMAN DOLUI, KAUSHLENDER SINGH, N. BISAI, V. BALAKRISHNAN, C. N. GUPTA and ADITYA-U TEAM
IPR/RR-1295/2021 JUNE 2021

EXPERIMENTAL VALIDATION OF UNIVERSAL PLASMA BLOB FORMATION MECHANISM
N BISAI, SANTANU BANERJEE, S. J. ZWEBEN and A. SEN
IPR/RR-1296/2021 JUNE 2021

EFFECT OF PLASMA ACTIVATED WATER ON GERMINATION AND PLANT GROWTH OF DRIED WHITE PEA (PISUM SATIVUM L.) SEEDS
VIKAS RATHORE, BUDHI SAGAR TIWARI and SUDHIR KUMARNEMA
IPR/RR-1297/2021 JUNE 2021

POWER EXTRACTION FROM COMPACT TOKAMAK FUSION TEST REACTORS
PIYUSH PRAJAPATI and SHISHIR DESHPANDE
IPR/RR-1298/2021 JUNE 2021
KELVIN-HELMHOLTZ INSTABILITY OF A ROTATING STRONGLY COUPLED DUSTY PLASMA AND TRACER TRANSPORT

VIKRAM DHARODI and BHAVESH PATEL
IPR/RR-1299/2021 JULY 2021

NUMERICAL SIMULATION OF DIESEL COMBUSTION PASSING THROUGH HIGH POWER ARC REGION IN A PLASMA FUEL SYSTEM
SUNIL BASSI, S. K. NEMA, A. SANGHARIYAT, C. PATIL, P. V. MURUGAN and SHASHANK CHATURVEDI
IPR/RR-1300/2021 JULY 2021

PERFORMANCE TESTING OF PERMEATION BASED HYDROGEN ISOTOPE SENSOR IN HYDROGEN GAS
RUDREKSH B. PATEL, SUDHIR RAI, PRAGNESH B. DHORAJIYA, P. A. RAYJADA and AMIT SIRCAR
IPR/RR-1301/2021 JULY 2021

DEVELOPMENT OF A NOVEL SPIRAL ANTENNA SYSTEM FOR LOW LOOP VOLTAGE CURRENT START UP AT STEADY STATE SUPERCONDUCTING TOKAMAK (SST-1)
DEBJYOTI BASU, DANIEL RAJU, RAJ SINGH, APARAJITA MUKHERJEE, MANOJ PATEL, DHARMENDRA RATHI, R. G. TRIVEDI, KIRIT VASAVA, K. A. JADEJA, SNEHA P. JAYASWAL, VIJAYKUMAR N. PATEL, S. K. PATNAIK, PARESH VASAVA, AJESH SUBBARAO, BHAVESH KADIA, KIRIT PARMAR, SIJU GEORGE, YUVAKIRAN PARAVASTU, KALPESH R. DHANANI, CHIRAG BHAVSAR, SUDHIR SHARMA, M. V. GOPALAKRISHNA, MAINAK BANDYOPADHYAY, MINSHA SHAH, PRAMILA GAUTAM, HIREN D.NIMAVAT, PRASHANT L. THANKEY, ZIAUDDIN KHAN and DILIP RAVAL
IPR/RR-1302/2021 JULY 2021

ANALYTICAL AND NUMERICAL STUDY OF LEAKY MODE CHARACTERISTICS OF DNG METAMATERIAL-BASED COAXIAL WAVEGUIDE FROM GHZ TO THZ FREQUENCY RANGE
A. GAUR and S. K. PATHAK
IPR/RR-1303/2021 JULY 2021

EQUILIBRIUM POTENTIAL PROFILE ACROSS MAGNETIC FIELD IN NON-HOMOGENEOUS ELECTRONEGATIVE PLASMA
PAWANDEEP SINGH, SWATI and SHANTANU KARKARI
IPR/RR-1304/2021 JULY 2021

PHYSICS STUDIES OF ADITYA & ADITYA-U TOKAMAK PLASMAS USING SPECTROSCOPIC DIAGNOSTICS
R. MANCHANDA, M. B. CHOWDHURI, J. GHOSH, N. RAMAIYA, N. YADAVA, S.PATEL, G. SHUKLA, K. SHAH, R. DEY, K. A. JADEJA, K. M. PATEL, R. L. TANNA, S. K. PATHAK, B. V. NAIR, C. N. GUPTA and ADITYA-U TEAM
IPR/RR-1305/2021 JULY 2021

(SOLITARY) ELECTRON AND ION HOLE EXCITATION IN CURRENT-DRIVEN PLASMAS -A STATUS REPORT WITH NEW PERSPECTIVES PART 2 -SIMULATIONS
DEVENDRA SHARMA and DEBRAJ MANDAL
IPR/RR-1306/2021 JULY 2021

DEUTERIUM ION IRRADIATION IMPACT ON THE CURRENT-CARRYING CAPACITY OF DI-BSCCO TAPE
M. RAJPUT, H. L. SWAMI, R. KUMAR, A. BANO, S. VALA, M. ABHANGI, UPENDRA PRASAD, RAJESH KUMAR and R. SRINIVASAN
IPR/RR-1307/2021 JULY 2021

UNAMBIGUOUS STABILITY OF ULTRA

SLOW ELECTRON HOLES AND THEIR CHARACTERISTICS IN THE NOVEL STABILITY REGIME
D. MANDAL and D. SHARMA
IPR/RR-1308/2021 JULY 2021

INVESTIGATION OF ROLE OF PLASMA FORMING GASES ON CHEMICAL SPECIES FORMED AND THEIR EFFECT ON PROPERTIES OF PLASMA ACTIVATED WATER
VIKAS RATHORE and SUDHIR KUMAR NEMA
IPR/RR-1309/2021 JULY 2021

ESTIMATION OF STORED ENERGY FOR TWIN SOURCE HVDC TRANSMISSION LINE
M.N. VISHNUDEV, DEEPAK PARMAR, HARDIK SHISHANGIYA, SANTOSH C. VORA, AGRAJIT GAHLAUT, MAINAK BANDYOPADHYAY and ARUN CHAKRABORTY
IPR/RR-1310/2021 JULY 2021

MEASUREMENT OF EFFECTIVE THERMAL CONDUCTIVITY OF LITHIUM METATITANATE PEBBLE BEDS BY STEADY-STATE RADIAL HEAT FLOW METHOD
MAULIK PANCHAL, VRUSHABH LAMBADE, VIMAL KANPARIYA, HARSH PATEL and PARITOSH CHAUDHURI
IPR/RR-1311/2021 JULY 2021

TEMPERATURE-INDUCED TRANSITION OF TRIANGULAR FEATURES TO CORRUGATED PATTERNS ON ION BOMBARDED SI (100) SURFACES
SUKRITI HANS, BASANTA KUMAR PARIDA, VIVEK PACHCHIGAR, SEBIN AUGUSTINE, MAHESH SAINI, SOORAJ K. P. and MUKESH RANJAN
IPR/RR-1312/2021 JULY 2021

EVOLUTION OF RADIATION BURST FROM A MULTI-PEAK SOLITON IN THE LASER-PLASMA SYSTEM
DEEPA VERMA, RATAN KUMAR BERA, BHAVESH G. PATEL and AMITA DAS
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SENSING A CHANGE IN SIZE OF A CIRCULAR TOKAMAK PLASMA USING A SINGLE MAGNETIC PROBE: A PRAGMATIC APPROACH
SUMAN AICH, JAHAAN THAKKAR and JOYDEEP GHOSH
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DYNAMICS OF NANOSCALE TRIANGULAR FEATURES ON GE SURFACES PRODUCED BY LOW ENERGY XE ION IRRADIATION
SUKRITI HANS, BASANTA KUMAR PARIDA, VIVEK PACHCHIGAR, SEBIN AUGUSTINE, SOORAJ K. P. and MUKESH RANJAN
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ABSOLUTE DENSITY AND DIVERGENCE OF FREE HELIUM JET FROM A PARABOLIC NOZZLE PROFILE BASED ON VIRTUAL SOURCE CONCEPT OF FREE EXPANSION
M. PATEL, J. THOMAS and H. C. JOSHI
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A CRITERION TO AID DIRECT TRACKING OF PLASMA BLOBS IN A TOKAMAK
N. BISAI and A. SEN
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MICROSCOPIC STRUCTURE OF ELECTROMAGNETIC WHISTLER WAVE DAMPING BY KINETIC MECHANISMS IN HOT MAGNETIZED VLASOV PLASMAS
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BRAJ KISHORE SHUKLA, JOYDEEP

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SIGNATURES OF AN ENERGETIC CHARGE BUNCH MOVING IN A PLASMA
VIKRAM DHARODI, ATUL KUMAR and ABHIJIT SEN
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LARGE AREA MULTI-FILAMENTARY PLASMA SOURCE FOR LARGE VOLUME PLASMA DEVICE-UPGRADE
A. K. SANYASI, P. K. SRIVASTAVA, AYAN ADHIKARI, L. M. AWASTHI, P. LEUVA, P. SANTRA, B. DOSHI, M. K. GUPTA and R. SUGANDHI
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ASHA ADHIYA, MINSHA SHAH, ANKUR PANDYA and RAJWINDER KAUR
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ELECTROMAGNETIC PINNED SOLITONS FOR SPACE DEBRIS DETECTION
ABHIJIT SEN, RUPAK MUKHERJEE, SHARAD K. YADAV, CHRIS CRABTREE and GURUDAS GANGULI
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STUDY OF MAGNETIZED MULTI-COMPONENT PLASMA SHEATH CONTAINING CHARGED DUST PARTICLE IN PRESENCE OF OBLIQUE MAGNETIC FIELD: A FLUID APPROACH
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IPR/RR-1398/2022 MARCH 2022

AU/AG SERS ACTIVE SUBSTRATE FOR BROADER WAVELENGTH EXCITATION
SEBIN AUGUSTINE, MAHESH SAINI, SOORAJ K. P., BASANTA KUMAR PARIDA, SUKRITI HANS, VIVEK PACHCHIGAR and MUKESH RANJAN
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TRITIUM-TITANIUM TARGET DEGRADATION DUE TO DEUTERIUM IRRADIATION FOR DT NEUTRON PRODUCTION
M. RAJPUT, H. L. SWAMI, S. VALA, M. ABHANGI, RATNESH KUMAR and R. KUMAR
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3D THERMO-FLUID MHD ANALYSIS OF THE TEST MOCK UP WITH MULTICHANNEL FLOW CONFIGURATIONS
A. PATEL and R. BHATTACHARYAY
IPR/RR-1401/2022 MARCH 2022

E 2. 2 Technical Reports

Non-isothermal CFD Simulation of Solid Hydrogen Flow Through the Single-screw Extruder
VISHAL GUPTA, RANJANA GANGRADEY,

SAMIRAN S. MUKHERJEE, SHASHIKANT VERMA, J. MISHRA, PARESH PANCHAL and PRATIK A. NAYAK
IPR/TR-623/2021 (April 2021)

Thermo-fluid MHD Analysis of a Circular U-bend
A. PATEL and R. BHATTACHARYAY
IPR/TR-624/2021 (April 2021)

Development of LabVIEW based Software for Interfacing of High Speed Camera in Machine Vision Application
V. CHAUDHARI, SURAJ GUPTA and MANOJ KUMAR
IPR/TR-625/2021 (April 2021)

Thermal Conductivity Measurement of Thermal Insulation Materials using Transient Hot-wire Technique
MAULIK PANCHAL, HARSH PATEL, ATIK MISTRY and PARITOSH CHAUDHURI
IPR/TR-626/2021 (April 2021)

Thermal Analysis of Braking System for Pulsed Alternator
A. AMARDAS and RAMBABU SIDIBOMMA
IPR/TR-627/2021 (April 2021)

Preliminary Design of a Permanent Magnet based Electromagnetic Pump for Pb-Li Applications
S. SAHU, R. BHATTACHARYAY and A. PRAJAPATI
IPR/TR-628/2021 (May 2021)

Design and Implementation of FPGA-SoC based Timing Measurement System for Thomson Scattering Laser Sub-system
V. CHAUDHARI, JINTO THOMAS, KIRAN PATEL, PABITRA MISHRA, NEHA SINGH and H. C. JOSHI
IPR/TR-629/2021 (May 2021)

Design and Development of W-band Trans-Receiver System
VARSHA SIJU and S. K. PATHAK
IPR/TR-630/2021 (May 2021)

System Requirement Document of 27kV, 105A and 14kV, 20A (Dual output), 3115kW HVDC Power Supply for 1.5MW RF Generator of ICRH System
BHAVESH R. KADIA, SUNIL KUMAR and ICRH GROUP
IPR/TR-631/2021 (June 2021)

System Requirement Document for -70kV, 40AHVDC Power Supply of LHCD System
SAIFALI SHARMA, P. K. SHARMA and LHCD GROUP
IPR/TR-632/2021 (June 2021)

Applications of Scanning Raman Spectrophotometer system Procured at FCIPT
SOORAJ K. P., MUKESH RANJAN and ALPHONSA JOSEPH
IPR/TR-633/2021 (June 2021)

Development of Stainless Steel-Aluminum Dissimilar Circular Pipe Joints using Modified Milling Machine
DILIP C. RAVAL, KUSH P. MEHTA, RAJMAL JAIN, HARDIK VYAS and ZIAUDDIN KHAN
IPR/TR-634/2021 (June 2021)

Design, Fabrication and Functional Testing of the Magnetic Probe Movement System (MPMS)
A. PRAJAPATI, A. PATEL and R. BHATTACHARYAY
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FEA Investigations of the Support Structures for the Magnet Test Facility
HEMANG AGRAVAT, MAHESH GHATE, ARVINDKUMAR TOMAR, DHAVAL BHAVSAR, UPENDRA PRASAD and R.

SRINIVASAN
IPR/TR-636/2021 (June 2021)

Development of Simple Tight Aspect Ratio Machine Assembly (STARMA) for Basic Plasma Studies
JAGABANDHU KUMAR, T. RAM, K. K. AMBULKAR, C. SINGH, A. L. THAKUR, P. R. PARMAR, C. G. VIRANI, SAIFALI SHARMA, V. VASAVA, B. ARAMBHADIYA, V. D.RAULJI, P. K. SHARMA and D. RAJU
IPR/TR-637/2021 (July 2021)

System Requirements Document for 80K Cryopump
NARESH CHAND GUPTA
IPR/TR-638/2021 (July 2021)

Design, Simulation, Fabrication & Testing of LIM for EML
PRASADA RAO P., ARVIND KUMAR, ANANYA KUNDU, ANKUR JAISWAL, VILAS CHAUDHARI, SIDIBOMMA RAMBABU, Y. S. S. SRINIVAS and E. RAJENDRAKUMAR
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Design of a Pneumatically Operated Bellow Sealed Valve for High Temperature Liquid Metals
A. PRAJAPATI, S. SAHU, DEEPAK SHARMA and R. BHATTACHARYAY
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RCS Reduction of a Metallic Target using Plasma Panel
HIRAL B. JOSHI, N. RAJAN BABU, AGRAJIT GAHLAUT, BISHAL DAS, RAJESH KUMAR and ASHISH R. TANNA
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Numerical Studies for Bath Cooled Heat Exchangers in Sub-Cooled LN2 for Cryogenic Cooling of Gaseous Helium
HEMANG AGRAVAT, ARVINDKUMAR TOMAR, MAHESH GHATE, UPENDRA PRASAD and R. SRINIVASAN
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Assembly, Testing, and Performance Validation of Vacuum System for Magnet Test Facility
MAHESH GHATE, DHAVAL BHAVSAR, F. S. PATHAN, DEVEN KANABAR, MAILA PARMESH, UMESH PAL, ARVIND TOMAR, NAYAN SOLANKI, ARUN PANCHAL, HEMANG AGRAVAT, GATTU RAMESH, ARUN PRAKASH, PRASHANT THANKEY, KALPESH DHANANI, UPENDRA PRASAD and R.SRINIVASAN
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Validation of 2D DIC Technique with Strain Gauge for Cantilever Displacements
KEDAR BHOPE, MAYUR MEHTA, SUNIL BELSARE, TUSHAR PATEL, NIKUNJ PATEL and SAMIR KHIRWADKAR
IPR/TR-644/2021 (August 2021)

Installation and Testing of Automatic Capacitance and Tan Delta Testing Facility
C. DODIYA, A. MAKWANA, U. PRASAD and R. SRINIVASAN
IPR/TR-645/2021 (August 2021)

Pneumatic Calibrator for Heterodyne Interferometer
KIRAN PATEL, UMESH NAGORA, H. C. JOSHI and SURYA PATHAK
IPR/TR-646/2021 (September 2021)

Design and Analysis of a 100 W at 77 K Gamma-type Reverse Stirling Cycle based Cryocooler for Cryopumps
ROHAN DUTTA, VISHAL GUPTA, HEMANG S. AGRAVAT, PARESH PANCHAL, SAMIRAN

MUKHERJEE and RANJANA GANGRADEY
IPR/TR-647/2021 (October 2021)

Development of an Experimental Setup to Measure Emissivity at Low Temperature: Role of Low and High Emissive Heat Radiators
AVIJIT DEWASI, RANJANA GANGRADEY, SAMIRAN SHANTI MUKHERJEE, VISHAL GUPTA, ROHAN DUTTA, JYOTI SHANKAR MISHRA, PARESH PANCHAL and PRATIK A. NAYAK
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Performance Testing of Cryo Distribution with Cryogenics Valves and other Instruments for 80 K Thermal Shields of Large Magnet Test Facility (MTF) at IPR
ROHIT PANCHAL, DEVEN KANABAR, ARVIND TOMAR, MAHESH GHATE, PANKAJ VARMORA, HEMANG AGRAVAT, DHAVAL BHAVSAR, PIYUSH RAJ, BHADRESH PARGHI, ARUN PANCHAL, ANEES BANO, FIROZ KHAN, UPENDRA PRASAD, VIPUL TANNA and R. SRINIVASAN
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Inventory and Tritium Residence Time in Indian Lithium Titanate Blanket
CHANDAN DANANI, DEEPAK AGGARWAL, MANOJ WARRIER and R. SRINIVASAN
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Recent Upgrade and Modification in 24.8MHz ICRH DAC Software
RAMESH JOSHI, H. M. JADAV, MANOJ PARIHAR, SUNIL KUMAR and HIGH POWER ICRH SYSTEMS DIVISION
IPR/TR-651/2021 (December 2021)

Fabrication of Chemical Compatibility Test Set Up For High-Temperature Interaction Study between Li2TiO3 and Indian RAFMS
VRUSHABH LAMBADE, AROH SHRIVASTAVA and PARITOSH CHAUDHURI
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Sticking Coefficient for Xenon Gas on Charcoal Coated and Bare Copper Panel at 20 Kelvin in Pumping Environment
PRATIK A. NAYAK, RANJANA GANGRADEY, SAMIRAN MUKHERJEE, JYOTI SHANKAR MISHRA, PARESH PANCHAL and VISHAL GUPTA
IPR/TR-653/2021 (December 2021)

Real-time Density Feedback Control on the ADITYA-U Tokamak
KIRAN PATEL, UMESH NAGORA, H. C. JOSHI, SURYA PATHAK, K. A. JADEJA, KAUSHAL PATEL, CHETAN VIRANI, ANKIT PATEL, R. L. TANNA, ROHIT KUMAR, SUMAN AICH, JOYDEEP GHOSH and ADITYA-U TEAM
IPR/TR-654/2021 (December 2021)

Conceptual Design of Large Cryopumping Test Facility (LCTF)
SAMIRAN MUKHERJEE, HEMANG S. AGRAVAT, PARESH PANCHAL, VISHAL GUPTA, PRATIK NAYAK, JYOTI SHANKAR MISHRA and RANJANA GANGRADEY
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Multi-pulse Operation of 42GHz Gyrotron
BRAJ KISHORE SHUKLA, JATIN PATEL, HARSHIDA PATEL, DHARMESH PUROHIT, SHARAN DILIP, MAHESH KUSHWAH, K. G. PARMAR, HARDIK MISTRY, LAXMIKANT RAO, VIPAL RATHOD, N. P. SINGH, P. K. ATREY and RAJAN BABU
IPR/TR-656/2022 (January 2022)

Preliminary Design of a Multichannel Test Mock

up for Thermofluid MHD Experimental Studies
A. PATEL, S. VERMA, A. SARASWAT, R. BHATTACHARYAY and A. PRAJAPATI
IPR/TR-657/2022 (January 2022)

Design and Development of PLC Based Offline Impedance Matching System for ICRH Experiment
RAMESH JOSHI, H. M. JADAV, MANOJ PARIHAR,KISHOREMISHRA,DHARMENDRA RATHI, ATUL VARIA, SUNIL KUMAR and HIGH POWER ICRH SYSTEMS DIVISION
IPR/TR-658/2022 (January 2022)

Design and Development of Broadband UV and Temperature Sensor Probe for Plasma Sterilization
KUSHAGRA NIGAM and G. RAVI
IPR/TR-659/2022 (January 2022)

Temperature Monitoring System for Large Volume Plasma Device Upgrade
D. KHANDURI, R. SUGANDHI, P. K. SRIVASTAVA, A. BALAJI, U. PALLAPOTHU, A. ADHIKARI, A. K. SANYASI and L. M. AWASTHI
IPR/TR-660/2022 (February 2022)

Installation and Performances of Temperature Sensors during Cryogenic Testing of Magnet Test Facility
PIYUSH RAJ, PANKAJ VARMORA, DEVEN KANABAR, BHADRESH PARGHI, HEMANG AGRAVAT, ANEES BANO, MONI BANUDHA, MAHESH GHATE, YOGENDRA SINGH, CHIRAGKUMAR DODIYA, UPENDRA PRASAD and R.SRINIVASAN
IPR/TR-661/2022 (February 2022)
Simplifying IP Address Management
SHARAD JASH, ARVIND M. SINGH, VIJAY K. PATEL, CHINTAN SUTARIA, PADMINI JADEGA and R. GANESH
IPR/TR-662/2022 (February 2022)

Detailed Engineering, Erection, Testing and Commissioning of 11kV, 1600KVAr, Automatic Power Factor Correction (APFC) System at 132kV IPR Substation
CHANDRA KISHOR GUPTA, SUPRIYA NAIR, PRAKASH PARMAR and CHIRAG BHAVSAR
IPR/TR-663/2022 (February 2022)

Collision Cross Sections and Swarm Parameters of Charged Species in Air
SHAHRUKH BAREJIA, JYOTI AGARWAL, R. SRINIVASAN and S. JAKHAR
IPR/TR-664/2022 (February 2022)

Recovery of Electromagnetic Coils Insulation under Varying Conditions in ADITYA-U Tokamak
ROHIT KUMAR, J. GHOSH, R. L. TANNA, SUMAN AICH, TANMAY MACWAN and ADITYA-U TEAM
IPR/TR-665/2022 (February 2022)

Liquid Nitrogen Distribution System for NBI Cryopumps with a Phase Separator
CH. CHAKRAPANI, B. SRIDHAR, B. CHOKSI, KARISHMA Q., V. PRAHLAD, SANJAY L. PARMAR, NILESH CONTRACTOR, VIJAY VADHER, L. K. BANSAL, PARESH PATEL and U. K. BARUAH
IPR/TR-666/2022 (February 2022)

EPICS OPC for SST-1 Cryogenics Plant
V. B. PATEL, A. L. SHARMA, H. H. CHUDASMA, H. MASAND, I. A. MANSURI, J. J. PATEL, M. K. BHANDARKAR, P. GADDAM, P. N. PANCHAL, R. J. PATEL, T. S. RAO, V. L. TANNA and K. MAHAJAN
IPR/TR-667/2022 (March 2022)

Measurement of Electron Temperature by Soft X-Ray Diagnostics in Aditya-U Tokamak
A. ADHIYA, S. PUROHIT, M. K. GUPTA, P.

KUMARI, R. RAJPAL, R. TANNA, J. GHOSH and ADITYA TEAM
IPR/TR-668/2022 (March 2022)

Performance Testing of the Liquid Nitrogen Cooled Sorption Cryopump for Application in SST-1 Tokamak
VISHAL GUPTA, RANJANA GANGRADEY, SAMIRAN S. MUKHERJEE, JYOTI SHANKAR MISHRA, PRATIK A. NAYAK, PARESH PANCHAL, VIPUL L. TANNA, YUVAKIRAN PARAVASTU, DILIP C. RAVAL, ZIAUDDIN KHAN, SIJU GEORGE, ATUL GARG, SRIKANTH L. N., AVIJIT DEWASI, SHASHI KANT VERMA, ROHAN DUTTA and HEMANG AGRAVAT
IPR/TR-669/2022 (March 2022)

E 3. CONFERENCE PRESENTATION

Plasma Processing and Technology International Conference (Plasma Tech 2021), Paris, 7-9 April 2021

Oxygen Plasma Treatment on Silicone Catheter Surface for Enhancement of Antifouling Properties
Purvi Dave, Ashutosh Kumar, Abdulkhalik M., Balasubramanian C., Sukriti Hans and S. K. Nema

28th IAEA Fusion Energy Conference (FEC2020), Virtual, 10-15 May 2021

Overview of Recent Experimental Results from the ADITYA-U Tokamak
R. L. Tanna, J. Ghosh, R. Kumar, T. Macwan, H. Raj, S. Aich, K. Jadeja, K. Patel, K. Singh, S. Dolui, D. Varia, D. Sadharakiya, B. K. Shukla, P. K. Chattopadhyay, M. M. Makwana, K. S. Shah, S. Gupta, B. V. Nair, C. N. Gupta, V. K. Panchal, P. Edappala, B. Arambhadiya, M. Shah, P. Gautam, R. Raulji, P. K. Shukla, R. Rajpal, N. Yadava, S. Patel, N. K. Ramaiya, M. B. Chowdhuri, R. Manchanda, R. Dey, N. K. Bisai, P. Atrey, S. K. Pathak, U. K. Nagora, K. Patel,V. Siju, J. Raval, S. Purohit, M. Kumar, K. Tahiliani, D. Kumawat, S. K. Jha, M. V. Gopalakrishna, D. Raju, Y. Saxena, A. Sen, R. Pal and S. Chaturvedi

Fusion Technology Development to Ensure ITER Deliverables: Indian Experience
M. Singh, U. Baruah, A. K. Chakraborty, G. Gupta, A. Kumar, V. K. Srivastava, A. Mukherjee, H. K. Pandya, S. Padasalagi, S. L. Rao, N. P. Singh, R. G. Trivedi, H. Vaghela and I. Bandyopadhyay

Physics Studies of ADITYA & ADITYA-U Tokamaks Plasmas using Spectroscopic Diagnostics
R. Manchanda, M. B. Chowdhuri, J. Ghosh, N. K. Ramaiya, N. K. Ramaiya,N. Yadava, S. Patel, G. Shukla, K. Shah, R. Dey, A. Bhattacharya, A. Kanik, S. Banerjee, K. Jadeja, K. Patel, R. L. Tanna, S. K. Pathak, V. Balakrishnan and C. N. Gupta

Current Drive Experiments in SST1 Tokamak with Lower Hybrid Waves
P. K. Sharma, D. Raju, S. K. Pathak, R. Srinivasan, K. K. Ambulkar, P. R. Parmar, C. G. Virani, J. Kumar, S. Sharma, C. Singh, A. L. Thakur, V. L. Tanna, U. Prasad, Z. Khan, D. C. Raval, C. N. Gupta, V. Balakrishnan, S. Nair, D. K. Sharma, B. Doshi, M. M. Vasani, K. Mahajan, R. Rajpal, R. Manchanda, K. Asudani, M. K. Gupta, M. B. Chowdhuri and R. L. Tanna (SST1 and Diagnostic Teams)

Study of Runaway Electron Dynamics at the ASDEX-Upgrade Tokamak during Impurity Injection using Fast Gamma-Ray Spectrometry
A. Shevelev, E. Khilkevitch, M. Iliasova, S. P. Pandya et.al. (ASDEX Upgrade and EURO fusion MST1 Teams)

Lithium Wall Conditioning Techniques in ADITYA-U Tokamak for Impurity and Fuel Control
K. Jadeja, J. Ghosh, K. Patel, K. Patel, R. L. Tanna, B. Arambhadiya, T. Macwan, R. Manchanda, M. B. Chowdhuri, M. Shah, N. Yadava, S. Patel, N. K. Ramaiya, K. Shah, B. K. Shukla, S. Aich, R. Kumar, V. K. Panchal, J. Raval, M. Kumar, U. K. Nagora, P. Atrey, S. K. Pathak, R. Rajpal, K. Tahiliani, M. V. Gopalakrishna, D. Kumawat, M. M. Makwana, K. S. Shah, S. Gupta, C. N. Gupta, V. Balakrishnan, P. K. Chattopadhyay and B. R. Kataria

Investigation of Toroidal Rotation Reversal in Impurities Seeding ADITYA-U Tokamak Plasmas
M. B. Chowdhuri, G. Shukla, J. Ghosh, K. Shah, R. L. Tanna, K. Jadeja, R. Manchanda, N. Yadava, N. K. Ramaiya, S. Patel, K. Patel, T. Macwan, U. K. Nagora, S. K. Pathak, J. Raval, M. K. Gupta, M. V. Gopalakrishna, K. Tahiliani, R. Kumar, S. Aich, S. Dalui, K. Singh, N. K. Bisai, V. Balakrishnan and C. N. Gupta

Observation of Electrostatic Confinement of Runaway Electrons using a Biased Electrode in ADITYA-U Tokamak
T. Macwan, J. Ghosh, H. Raj, K. Singh, S. Dolui, D. Nath, R. Ganesh, R. L. Tanna, R. Kumar, S. Aich, K. Jadeja, K. Patel, P. Edappala, V. K. Panchal, J. Raval, S. Purohit, M. K. Gupta, R. Manchanda, M. B. Chowdhuri, U. K. Nagora, P. Atrey, S. K. Jha, D. Raju and R. Pal

Novel Concept for Disruption Mitigation in the ADITYA-U Tokamak by Fast Time Response Electromagnetic Driven Pellet Impurity Injector
J. Ghosh, S. Pahari, B. Doshi, R. L. Tanna, K. Jadeja, K. Patel, R. Kumar, T. Macwan, S. Aich, D. Kumawat, M. M. Makwana, K. S. Shah, S. Gupta, B. V. Nair, C. N. Gupta, V. K. Panchal, P. Edappala, M. Shah, S. Aditya Nandan, R. P. P., P. K. Maurya, S. K. Jha, M. K. Raghavendra, N. Shiv, N. Belli, S. Mahar, S. V. V. Illa, H. Hemani, B. Kadia, N. Yadava, M. B. Chowdhuri, R. Manchanda, G. Shukla, N. K. Ramaiya, J. Raval, M. Kumar, U. K. Nagora, S. K. Pathak, K. Tahiliani, P. K. Chattopadhyay, P. Chaudhuri, M. Padivattathumana, R. Goswami, A. Sen, R. Pal and S. Chaturvedi

Investigation of Self-Absorbed Lithium Spectral Line Emissions during Li_2TiO_3 Injection in ADITYA-U Tokamak
N. Yadava, J. Ghosh, M. B. Chowdhuri, R. Manchanda, R. Dey, S. K. Punchithaya, Ismayil, N. K. Ramaiya, S. Pahari, B. Doshi, P. Chaudhuri, T. Macwan, S. Aich, R. Kumar, R. L. Tanna, K. Jadeja, K. Patel, S. Patel, G. Shukla, S. Dolui, K. Singh, D. Kumawat and C. N. Gupta

Initial Results of Plasma Potential and its Fluctuation Measurements in SOL Region of ADITYA-U Tokamak by Laser Heated Emissive Probe
A. Kanik, A. Sarma, J. Ghosh, T. Macwan, M. Shah, R. L. Tanna, J. Raval, U. K. Nagora, S. Pandya, P. Pandit, K. Jadeja, K. Patel, N. Yadava, N. K. Ramaiya, S. Patel, R. Manchanda, M. B. Chowdhuri, R. Kumar, K. Singh, S. Aich, S. Dolui and V. K. Panchal

Novel Approach to Estimate Plasma Current Density Profile with Magnetic Probes in ADITYA-U
S. Aich, J. Ghosh, S. Patel, T. Macwan, D. Kumawat, R. Kumar, R. L. Tanna, D. Raju, S. K. Jha, P. K. Chattopadhyay, P. Gautam, P. Edappala, K. Jadeja, K. Patel, K. Singh, S. Dolui and J. Thakkar

First Laboratory Observation on Controlled Mitigation of Energetic Electrons by Whistlers
A. K. Sanyasi, L. Awasthi, P. K. Srivastava, R. Sugandhi and D. Sharma

A Nonlinear Simulation Study of the Effect of Toroidal Rotation on RMP Control of ELMs
D. Chandra, A. Sen and A. Thyagaraja

A Machine Learning Approach for Data Visualization and Parameter Selection for Efficient Disruption Prediction in Tokamaks
I. Bandyopadhyay, Y. K. Meghrajani, S. Patel, J. Patel, H. S. Mazumdar, L. Desai, V. K. Panchal, R. L. Tanna, and J. Ghosh (ADITYA Team)

Numerical Simulation of RE Deconfinement Experiment using Local Magnetic Field Perturbation in ADITYA Tokamak
S. Dutta, J. Ghosh, R. L. Tanna, R. Srinivasan and P. K. Chattopadhyay

Burning Plasma Transport Simulation for Axisymmetric Tokamaks with Alpha-Particle Heating
U. Maurya, S. Bainjwan and R. Srinivasan

Experimental Validation of Universal Plasma Blob Formation Mechanism
N. K. Bisai, S. Banerjee, S. Zweben and A. Sen

Understanding Reactor Relevant Tokamak Pedestals
C. Ham, A. Bokshi, D. Brunetti, G. Bustos Ramirez, B. Chapman, J. Connor, D. Dickinson (The Jet Contributors) et. al.

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A. Kuley, T. Singh, A. Jaya Kumar, S. Sharma, D. Sharma, K. Mishra and A. Sen

Investigation of Multiscale Ion Temperature Gradient Instabilities and Turbulence in the ADITYA-U Tokamak
A. K. Singh, J. Mahapatra, J. Chowdhury, R. Ganesh, W. Wang, L. Villard and S. Ethie

Studies on Impurity Seeding in a Tokamak Plasma: Simulation and Comparison with ADITYA-U Experiments
N. K. Bisai, S. Raj, V. Shankar, T. Macwan, K. Singh, S. Dolui, H. Raj, R. Dey, N. Yadava, M. B. Chowdhuri, R. Manchanda, J. Raval, U. K. Nagora, K. Jadeja, K. Patel, R. Kumar, S. Aich, R. L. Tanna, J. Ghosh and A. Sen

Magnetic Island Coalescence using Reduced Hall MHD Model
J. Mahapatra and R. Ganesh

A Numerical Simulation of Self Consistent Dynamo using a New GPU-Based 3D MHD Solver
S. Biswas, R. Mukherjee, N. V. Vydyanathan and R. Ganesh

Status of the ITER Neutral Beam Test Facility and the First Beam Operations with the Full-Size Prototype Ion Source
G. Serianni, V. Toigo, D. Boilson, C. Rotti, T. Bonicelli, M. Kashiwagi and M. Singh

Reliability of Electrodeposited Components for Fusion Application: A Process Evaluation of the First Kind
J. Joshi, A. Yadav, A. K. Chakraborty, H. K. Patel and M. Singh

Role of Core Radiation Losses from Plasma and its Impact on ST Reactor Design Parameter Choices
S. Deshpande, P. Maya, A. Tyagi, U. Prasad, P. Chaudhuri and S. Padasalagi

Status of the Design Optimization, Analysis and R&D Activities of Indian HCSB Blanket Program
P. Chaudhuri, D. Sharma, B. K. Yadav, A.

Shrivastava, M. Panchal, C. S. Sasmal, A. Gandhi, R. Patel, A. Saraswat and A. Sircar

Cryogenics System Performance Enhancement and Attempt towards Shaped Plasma Operation in SST-1
V. L. Tanna, U. Prasad, P. Panchal, R. Panchal, D. Sonara, R. Patel, G. Mahesuria, A. Garg, G. L. N. Srikanth, D. Christian, R. Sharma, N. Bairagi, H. Nimavat, K. Patel, P. Shah, G. Purwar, A. Panchal, P. Raj, N. Kumar, S. Roy, C. Dodiya, A. Makwana, Z. Khan, D. C. Raval, P. Thankey, F. K. S. Pathan, Y. Paravastu, B. Doshi, P. Biswas, H. Patel, D. Sharma, S. Nair, R. Srinivasan and D. Raju

Analysis of Heat Transport and Pipe-Routing Considerations for Blanket to Steam Generator for a Fusion Reactor
P. Prajapati, P. Chaudhuri, D. Sharma, S. Padasalagi and S. Deshpande

A Solution to Evacuate Enormous Gas Load in a Fusion Machine during Baking and Plasma Operation: Cryopump
R. Gangradey, S. S. Mukherjee, V. Gupta, J. S. Mishra, P. A. Nayak and P. Panchal

Implementation of Novel Technique to Support the Electromagnetic Forces and to Ensure the Structural Reliability of Refurbished Toroidal Field Magnet System of the ADITYA-U Tokamak
B. Doshi, J. Ghosh and R. L. Tanna

Entrapment of Impurities inside a Cold Trap: A Purification Process for Removal of Corrosion Impurities from Molten Pb-16Li
A. Deoghar, A. Saraswat, H. Tailor, S. Verma, S. Gupta, C. S. Sasmal, V. Vasava, S. Sahu, A. Prajapati and R. Bhattacharyay

Reduction of Critical Heat Flux due to Steep Power Transients on PFCS
V. Menon, M. Sharma, S. Khirwadkar, K. S. Bhope, S. Belsare, S. Tripathi, N. P. Patel, M. Mehta, P. K. Mokaria, T. H. Patel, R. Swamy and K. Galodiya

Novel Surface Assisted Volume Negative Ion Source: Concept to Reality
M. Bandyopadhyay, B. Kakati, S. S. Kausik, A. Gahlaout, B. K. Saikia and N. Das

Performance of High Heat Flux Test of Positive Ion Neutral Injector Ion Source Back Plate
M. R. Jana, S. Belsare, K. S. Bhope, B. Choksi, N. S. Contractor, S. Khirwadkar, P. K. Mokaria, N. P. Patel, T. H. Patel, R. Swamy and S. Tripathi

Role of PKA Spectrum and PKA Density in Defect Production and Implications for H-Isotope Trapping in Tungsten
P. Maya, P. Sharma, S. S. Mukherjee, S. Akkireddy, S. Balaji, C. David, A. R. Gautam, P. Kikani, P. K. Pujari and S. Deshpande

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S. Pillai, P. Chaudhuri, C. Sasmal, M. Rajput, H. K. Patel and P. Maya

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Spatial Variation of Plasma Parameters in a Pulsed Plasma Accelerator
Sumit Singha, Azmirah Ahmed, Suramoni Borthakur, Nirod Kumar Neog, Tridip Kumar Borthakur

Design of the time-of-flight low-energy neutral

particle analyzer for Aditya-U Tokamak
Snehlata Aggarwal, Santosh P. Pandya, Kumar Ajay

Computational modeling on Cu-Ni alloy evaporation in DC free burning arc plasma
G. D. Dhamale, Subrat Kumar Das, Satya Prakash Reddy Kandada, R. Abiyazhini, K. Ramachandran and C Balasubramanian

Numerical study on the effect of plasma density on Runaway Electron suppression in the ADITYA-U Tokamak
Ansh Patel, Santosh P. Pandya, Tanmay M. Macwan, Umeshkumar C. Nagora, Jayesh V. Raval, K.A. Jadeja, Sameer Kumar Jha, Rohit Kumar, Suman Aich, Suman Dolui, Kaushlender Singh, K. M. Patel, Kumudni Tahiliani, Surya Kumar Pathak, Rakesh L. Tanna, Joydeep Ghosh, Manoj Kumar, ADITYA-U team
First results of recently developed prototype Magneto-Optic Current Sensor (MOCS) diagnostic for plasma current measurements in ADITYA-U Tokamak
Santosh P. Pandya, Kumudni Tahiliani, Praveenlal E. V., Sameer Kumar Jha, Lavkesh T. Lachwani, Suman Aich, Surya Kumar Pathak, Rakesh L. Tanna, Joydeep Ghosh and ADITYA-U team

Conceptual Design of Multichannel FEB Detection System to Study Suprathermal Electron Dynamics during Lower Hybrid Current Drive (LHCD) in ADITYA-U Tokamak
Jagabandhu Kumar
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Diagnostics progress of IN-DA
Bharathi Magesh

Development and Qualification of Shielding Material (B4C) by IN-DA
Bhoomi Sandip Gajjar and ITER-India Diagnostics Team

National Conference on Emerging Trends in Physics (NCETP-2021), Tezpur University, Assam, 16 June 2021

Particle-in-cell Simulation of Plasma Species in an Inertial Electrostatic Confinement Fusion Device at High Voltage Operation
Darpan Bhattacharjee, S. Adhikari, and S.R. Mohanty

47th Conference on Plasma Physics by European Physical Society, (Virtual), 21-25 June 2021

The study of unconventional boundary driven mechanism for generating magnetic field
Devshree Mandal, Ayushi Vashistha and Amita Das

Landau damping in 1D periodic inhomogeneous collisionless plasmas
Sanjeev Kumar Pandey and Rajaraman Ganesh

Effect of Ion Population in a Toroidal Electron Plasma
Swapnali Khamaru, Meghraj Sengupta and Rajaraman Ganesh
Sheet simulation of upper-hybrid oscillations in an inhomogeneous cold plasma in the presence of inhomogeneous magnetic field
Nidhi Rathee and Sudip Sengupta

Effect of external plate biasing and diverging magnetic field on radial characteristics of a back-diffused plasma column
Satadal Das and Shantanu Karkari

Can a small fraction of mass inhomogeneity decide

the fate of Rayleigh-Benard convection cells in 2D Yukawa liquids?
Pawandeep Kaur and Rajaraman Ganesh

Lower Hybrid Heating in Laser Plasma Interaction
Ayushi Vashistha, Devshree Mandal, Srimanta Maity, Amita Das

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CHF and OFI Experiments at the High Heat Flux Test Facility at IPR
Vinay Menon

30th ITPA meeting of TG SOL and Divertor physics, 5th July 2021

Plasma blob formation mechanism in SOL using 3D simulations and its experimental validation
Nirmal K Bisai

23rd Cryogenic Engineering Conference and International Cryogenic Materials Conference (CEC-ICMC 2021), (Virtual), Louisville, Colorado, USA, 19-23 July 2021

Indigenous Development of Epoxy Resin system for Cryogenic Services and Fusion Application
Rajiv Sharma

International Conference on Diagnostics for Fusion Reactors (ICFRD2020), 6th September 2021

Development of a compact multivariable sensor probe for two-phase detection in high-temperature PbLi-Ar columns
Abhishek Saraswat

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The Role of Wall Conditioning Procedures in Vacuum Vessel for ADITYA Upgrade Tokamak
K.A. Jadeja

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Effects of axial magnetic field in a magnetic multipole line cusp ion source.
Bharat Singh Rawat

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Blob Formation Mechanism from 3D Plasma Simulation in Scrape-off Layer Tokamak Plasmas
N Bisai

Discovery of a quiescent toroidal nonneutral plasma state at small aspect ratios
Swapnali Khamaru
Evolution of Plasma in the Influence of Varying Ratio of Transverse to Ambient Magnetic Field of LVPD-Upgrade
Ayan Adhikari, A. K. Sanyasi, L.M. Awasthi, P. K. Srivastava, Ritesh Sugandhi, and Mainak Bandyopadhyay

Large Area Multifilamentary Plasma Source in LVPD-Upgrade
A. K. Sanyasi, P. K. Srivastava, Ayan Adhikari, Pinakin Leuva, Prosenjit Santra, Ritesh Sugandhi, L. M. Awasthi, Bharat Doshi, and M. K. Gupta

Time-of-flight low-energy analyzer for Aditya-U Tokamak
Snehlata Aggarwal, Santosh P. Pandya, Kumar Ajay

Synergistic influence of equilibrium toroidal flows on RMP control of ELMs
Debasis Chandra

Studies on electromagnetic properties of multilayer/coaxial circular waveguide
Ankita Gaur

74th Annual Gaseous Electronics Conference (GEC 2021), Virtual, 4-8 October 2021

External plate biasing and diverging magnetic field effects on radial characteristics of back diffused expanding plasma column
Satadal Das, Shantanu Karkari

4DSpace Meetings on Computations, University of Oslo, Norway, 12th October 2021

Potential around a Dust Grain in Collisional Plasma
Rakesh Moulick

63rd Annual Meeting of the American Physical Society (APS) Division of Plasma Physics, 8-12th November 2021

Effect of radiation-reaction on charged particle motion in an intense focused light wave
Shivam Mishra, Sarveshwar Sharma, Sudip Sengupta

Electromagnetic Transparency in strongly magnetized plasmas
Devshree Mandal, Ayushi Vashistha, Laxman P Goswami, Amita Das

Theory of plasma blob formation and its experimental validation
Nirmal K Bisai

27th International Conference on Magnet Technology (MT27), Fukuoka, Japan, 15-19 November 2021

Preliminary design and analysis of 20 K helium cooled MgB_2 based superconducting current feeder system for Tokamak application
Nitin Bairagi, V. L. Tanna and D. Raju

Fabrication and Characterization of BSCCO-2223 Tape Based Compact Coils
Upendra Prasad

30th International Toki Conference on Plasma and Fusion Research (ITC30), National Institute for Fusion Science, Japan, 16-19 November 2021

Effects of transmutations in material damage for plasma-facing materials in fusion systems
Akash Garg

Experimental investigations on electrical-insulation performance of Al2O3 coatings for high-temperature lead-lithium liquid-metal applications
Abhishek Saraswat
Design and analysis of a plasma chamber for thermal processing applications
Deepak Sharma

International Conference on Advances in Physics and its Applications (APA2021), Duliajan College, Assam, 26-27th November 2021

A Table-top Neutron/X-ray Source for Near-term Applications
Darpan Bhattacharjee, Neelanjan Buzarbaruah, and Smruti Ranjan Mohanty

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Polarization-Insensitive Metasurface Based Switchable Absorber/ Rasorber
Priyanka Tiwari, Surya Kumar Pathak

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Boron Carbide as High Energy Shielding Material for ITER
Bhoomi S. Gajjar

Conceptual Design of Heat Extraction Test Reactor (HxTR) Systems
Piyush Prajapati

36th National Symposium on Plasma Science and Technology (PLASMA-2021), Birla Institute of Technology, Mesra, Jaipur, 13-15 December 2021

An Experimental Investigation of Oscillating Plasma Bubbles and its Non Linear Structure in a Magnetized Plasma System
Mariammal Megalingam and Bornali Sarma
Strong Magnetic Field Effects in the Strongly Coupled Rotating Dusty Plasma
Prince Kumar and Devendra Sharma

Study of MHD Activity and Runaway Electrons in the ADITYA and ADITYA-U Tokamak
S. Patel, J. Ghosh, M. B. Chowdhuri, K. B. K. Mayya, S. Purohit, T. Macwan, S. Aich, S. Dolui, K. Singh, R. L. Tanna, K. A. Jadeja, K. M. Patel, R. Kumar, N. Yadava, R. Manchanda, N. Ramaiya, K. Shah, A. Kumar, Y. S. Joisa, S. K. Jha, D. Raju, U. Nagora, P. K. Atrey, S. B. Bhatt, D. Chenna Reddy, Y. C. Saxena, ADITYA Team and ADITYA-U Team

Heat Transfer Analysis of PINI Ion Source Back Plate Using ANSYS
Tejendra Patel and M. R. Jana

Design Updates and Current Status of Installation Works of Experimental Helium Cooling Loop (EHCL)
B. K. Yadav, A. Gandhi, A. Saraswat, S. Verma, P. Chaudhuri

Towards a 3D Quiescent Nonneutral Plasma State in Small Aspect Ratio Torus - A Particle-In-Cell Simulation Study
Swapnali Khamaru, Rajaraman Ganesh, Meghraj Sengupta

Argon Impurity Transport in ADITYA-U Tokamak using Spectrosocpy
K. Shah, M. B. Chowdhuri, J. Ghosh, K. A. Jadeja, R. Manchanda, G. Shukla, S. Patel, N. Yadava, N. Ramaiya, R. Dey, T. Macwan, R. L. Tanna, R. Kumar, S. Aich, K. M. Patel, S. Purohit, M. K. Gupta, U. C. Nagora, S. K. Pathak, K. B. K. Mayya and ADITYA-U Team

Aditya Tokamak Plasma Disruption Characterization
S. Purohit, M. B. Chowdhuri, J. Ghosh, C. N. Gupta, S. K. Jha, D. Raju, K. A. Jadeja, M. K. Gupta, P. K. Atrey, S. K. Pathak, Y. S. Joisa, R. L. Tanna, P. K. Chattopadhyay and ADITYA Team
Shear Flow Effects on Magnetic Island Coalescence
Jagannath Mahapatra, Rajaraman Ganesh, Arkaprava Bokshi and Abhijit Sen

Pulsed Laser Deposition of CUO/CU_2O Films and their Application in Photocatalytic Dye Degradation
Rudrashish Panda, Milaan Patela, Jinto Thomas

Plasma Sterilization Application
Kushagra Nigam, G. Ravi and S.K. Nema

High Current Pulsed Power Supply System for Large Volume Plasma Device-Upgrade
P. K. Srivastava, R. Sugandhi, A. K. Sanyasi, A. Adhikari and L. M. Awasthi

Utilization of an Inertial Electrostatic Confinement Fusion Device as a Neutron and X-Ray Source
D. Bhattacharjee, L. Saikia and S. R. Mohanty

Effect of Multiple Grid Configuration on Plasma Parameters of an Inertial Electrostatic Confinement Fusion Device
L. Saikia, D. Bhattacharjee, A. Maurya and S. R. Mohanty

Prototype Automated Linear and Rotational Probe Drive for Large Volume Plasma Device- Upgrade
P. Chauhan, R. Sugandhi, A. K. Sanyasi, P. K. Srivastava, D. Khanduri, A. Adhikari, P. K. Leuva, M. K. Gupta, B. R. Doshi and L. M. Awasthi

Interaction of a Precursor Soliton with a Wake-Field in a Flowing Dusty Plasma
Krishan Kumar, Pintu Bandyopadhyay, Swarnima Singh, Abhijit Sen

Transition of a Monolayer Crystal to a Liquid-Solid Coexistence State in a Complex Plasma
Swarnima Singh, Krishan Kumar, M.G. Hariprasad, A. Saravanan, P. Bandyopadhyay and A. Sen

Novel Explanation of the Cold Pulse Propagation Phenomenon Induced by Gas Puff in ADITYA-U Tokamak
Tanmay Macwan, Harshita Raj, Kaushlender Singh, Suman Dolui, Sharvil Patel, Ankit Kumar, P Gautam, J Ghosh, R L Tanna, K A Jadeja, K M Patel, Rohit Kumar, Suman Aich, Umesh Nagora, M B Chowdhuri, R Manchanda, Nandini Yadava, Ritu Dey, Kiran Patel, S. K. Pathak, M. K. Gupta, K. Tahiliani, P. K. Chattopadhyay, A Sen, Y C Saxena, R Pal

Initial Plasma Experiments in Simple Tight Aspect Ratio Machine Assembly
T. Ram, Jagbandhu Kumar, P. K. Sharma, Raju Daniel

Exploring Possibility of ETG Suitable Profiles in Varying Ratio of Transverse to Longitudinal Magnetic Field in LVPD-U
Ayan Adhikari, A. K. Sanyasi, L.M. Awasthi, P. K. Srivastava, Ritesh Sugandhi and Mainak Bandyopadhyay

Understanding Density Depletion in Cross-Field Diffused Plasma of LVPD-U
Ayan Adhikar, A. K. Sanyasi, L. M. Awasthi, P. K. Srivastava, Ritesh Sugandhi and Mainak Bandopadhyay

Three Dimensional Dust Cloud in DC Glow Discharge Plasma
Sachin Sharma, G Veda Prakash, Meenakshee Sharma, Sayak Bose, Sanat Kumar Tiwari

Tweaking For Loop Voltage Profile of Ohmic Transformer Power Supply in ADITYA-U Tokamak
Shivam Kumar Gupta, Kunal S Shah, M N Makwana, B V Nair, S Nair, Rohit Kumar, R L Tanna, Joydeep Ghosh and ADITYA-U Team

Design of Support Structure for the Waveguide System for Michelson Interferometer System for SST-1
Pratibha Gupta, Manoj Kumar Gupta, Bharat Doshi, Abhishek Sinha, S.K.Pathak

Upgrade in Software Based Interlock for ICRH

M. B. Chowdhuri, Joydeep Ghosh, R. L.Tanna, R.Manchanda, Deepti Sharma, T. D. Rognlien

Installation and Commissioning of the Arc Detection System for PF Bus Bars in SST-1 Cryogenics Interface
H. Nimavat, H. Dalicha, N. Ramaiya, D. Sonara, R. G. Trivedi, R. Manchanda, V. L. Tanna and D. Raju

Piping Layout of Cryogenic Experimental Set-Up for 3-Stream Plate-Fin Heat Exchanger
O Chandratre, Vivek Sharma, A K Sahu, H Kavad

Parametrization of Ohmic Transformer Power Supply for ADITYA-U Tokamak
K S Shah, M N Makwana, Shivam Kumar Gupta, B V Nair, S Nair, R L Tanna, Joydeep Ghosh and ADITYA-U Team

Simulation of Uniaxial Compression Tests on Ceramic Pebble Beds for Its Mechanical Characterization
Maulik Panchal, Harsh Patel, Paritosh Chaudhuri
An Artificial Intelligence Based Solution for SST1 Tokamak Building Monitoring
Agraj Abhishek, Abhishek Sharma, Gaurav A. Garg, Hitesh H. Chudasama, Daniel Raju, Manika Sharma

UHV Testing of Prototype Steerable ECRH Launcher
Hardik Mistry, Dharmesh Purohit, Siju George, Harshida Patel, Jatin Patel, K G Parmar, Dilip Raval, Manoj Kumar Gupta, B K Shukla

Development of Calibration Unit for Calorimetric Pulsed Power Measurement of High Power Microwave Source
Hardik Mistry, Harshida Patel, Jatin Patel, Dharmesh Purohit, K G Parmar, B K Shukla

Implementation of Three-Dimensional Simulations for Scrape-Off Layer Transport in Inboard Limited ADITYA-Upgrade Plasma Configuration
Arzoo Malwal, Devendra Sharma

Performance Study of Metal Hydride Reactor Equipped with Spiral Heat Exchanger
Sudhir Rai, Amit Sircar

Conceptual Design of Glow Discharge Cleaning System for Small Scale-Spherical Tokamak
M. S. Khan, Ranjith Kumar, Shiju Sam, Y S S Srinivas, Ziauddin Khan, E. Rajendra Kumar

Layout of Critical Peripheral Equipment's For Indigenous Helium Refrigerator/Liquefier Plant
Hitesh R Kavad, A K Sahu, R Bhatasana, H Dave, O Chandratre, N Kumar, Prashant Singh, Priyanka Brahmbhatt

Status of Auxiliary Power Supplies for ITER Prototype RF Source
Hrushikesh Dalicha, Gajendra Suthar, Kartik Mohan, Rohit Agarwal, Rajesh Trivedi, Kumar Rajnish, Raghuraj Singh, Aparajita Mukherjee

Amplitude Andphase Control Using I-Q Modulator: A prototype Development
Dipalsoni, Kumar Rajnish, Sriprakash Verma, Raghuraj Singh, R.G. Trivedi and Aparajita Mukherjee

Testing of High-Power Amplifier at 1.5mw for Continuous Wave (CW) Operation Raghuraj Singh, Aparajita Mukherjee, R.G. Trivedi, Kumar Rajnish, Akhil Jha, Manoj Patel, Gajendra Suthar, Dipalsoni, Sriprakash Verma, Kartik Mohan, Rohit Agrawal, Rohit Anand, Hrushikesh Dalicha and Paresh Vasava

Development of Water-Cooled Bleeder Heatsink

Transmission Line
Vishnudev M N, Deepak Parmara, Hardik Shishangiya, Santosh C. Vora, Agrajit Gahlaut, Mainak Bandyopadhyay, Arun Chakraborty

Modification in Period of Sawtooth Oscillation after Gas Pulse Injection in ADITYA-U Tokamak
Suman Dolui, Tanmay Macwan, Kaushlender Singh, Ankit Kumar, Sharvil Patel, Suman Aich, Rohit Kumar, Laxmikant Pradhan, Ankit Patel, Kalpesh Gadoliya, K. A. Jadeja, K. M. Patel, R.L. Tanna, Joydeep Ghosh and ADITYA-U Team

Design of a Ball Pen Probe for the Measurement of Edge Ion Temperature in Aditya-U Tokamak
Ankit Kumar, Kaushlender Singh, Suman Dolui, Tanmay Macwan, Pramila Gautam, Rohit Kumar, Suman Aich, Laxmikant Pradhan, Ankit Patel, Kalpesh Gadoliya, K. M. Patel, K. A. Jadeja, R.L. Tanna, Joydeep Ghosh and ADITYA-U Team

Design and Installation of Triple Langmuir Probe for Direct Measurement of edge Density and Temperature in ADITYA-U Tokamak
Kaushlender Singh, Suman Dolui, Ankit Kumar, Tanmay Macwan, Pramila Gautam, Rohit Kumar, Suman Aich, Laxmikant Pradhan, Ankit Patel, Kalpesh Gadoliya, K. M. Patel, K. A. Jadeja, R.L. Tanna, Joydeep Ghosh, and ADITYA-U Team

Design of Laser Induced Breakdown Spectroscopy (LIBS) Based Wall Monitoringdiagnostics for ADITYA-U Tokamak
Bharat Hegde, Ashok Kumar, Ankit Kumar, Kaushlender Singh, Suman Dolui, Tanmay Macwan, Rohit Kumar, Suman Aich, Laxmikant Pradhan, Ankit Patel, Kalpesh Gadoliya, K.M. Patel, K. A. Jadeja, R.L. Tanna, Joydeep Ghosh and Aditya-U Team

Feasibility Study and Development of a Diagnostic for Measurement of Toroidal Asymmetry in the Radiation during Disruptions in ADITYA-U Tokamak
Ashok Kumar, Bharat Hegde, Ankit Kumar, Kaushlender Singh, Suman Dolui, Tanmay Macwan, Pramila Gautam, Rohit Kumar, Suman Aich, Laxmikant Pradhan, Ankit Patel, Kalpesh Gadoliya, K. M. Patel, K. A. Jadeja, R.L. Tanna, Joydeep Ghosh and ADITYA-U Team

Development and Measurement of 2.45 GHz, UHV Compatible RF Window for ECR System
K. K. Ambulkar, P. R. Parmar, A. L. Thakur, P. K .Sharma

Compensation of Fast Feedback Correction Magnetic Field on Magnetic Diagnostic in Aditya-U Tokamak
Rohit Kumar, Shivam Gupta, R.L Tanna, S.K Jha, Suman Aich, Tanmay Macwan, Kunal Shah, M.N Makwana, Supriya Nair, Kaushlender Singh, Suman Dolui, Kaushal Patel, Kumarpal Jadeja and J Ghosh
A Method for Preparation of Electrical Contact on Carbon Material
K.P Singh, Priyanka Patel, Tushar Patel, Samir S Khirwadkar, Amardas Alli
Emergence of Nanoscale Features Using Low-Energy Ions Produced By Plasma Source
Sukriti Hans, Mukesh Ranjan

Effect of Gas Environment During sulfurization Process of CZTS Thin Film on Solar Cell Performance
Sagar Agrawal, Rinkalkanani

An Active Arc Sensing and Controlling Technique for Plasma Nitriding Process
Keena Kalaria, Naresh Vaghela and Suryakant B. Gupta

Studies on the Role of Axial Magnetic Field for Line and Ring Cusp Magnetic Configurations in a Low Energy Ion Source
Bharat Singh Rawat, S. K. Sharma, B. Choksi, P. Bharathi, B. Sridhar, L.N. Gupta, D. Thakkar, S.L. Parmar, V. Prahlad and U.K. Baruah

Low Temperature Plasma Carburizing of Austenitic Stainless Steel 316l
Ghanshyam Jhala, Vijay Chauhan, Pravin Dwivedi and Alphonsa Joseph

Investigation of Gas Diffusion Barrier and Antifouling Properties of Plasma Treated Low Density Polyethylene for Packaging Applications
Purvi Dave, Balasubramanian C, Sukriti Hans and S. K. Nema

Study of Characteristics of Plasma Antenna
Manisha Jha, Nisha Panghal, Unnati Patel, Rajesh Kumar

Plasma Jet Interaction with GB-SCC (ITOC-03) Cell Line
A.Vaid, K. Pansare, S.Singh, R.Rane, A. Visani, M. Ranjan, C.Krishna, R. Sarin A. Joseph

Germination Enhancement of Tomato and Capsicum Seeds Using Dielectric Barrier Discharge (Dbd) Plasma Treatment
R.Rane, A. Vaid, R.Parihar, P.Maila, A. Visani, A. Vikram, A. Joseph, M.Kumar

Eliminating Flux Contributed By External Currents and Eddy Current from Magnetic Probe Measurement in Sst-1 Discharges
Sameer Kumar, Kumudni Tahiliani, Surya Kumar Pathak, Daniel Raju, Praveena Kumari, Vismaysinh D Raulji , Praveenlal Edappala, Ashish Ranjan, Jasraj Dongde and SST-1 Team

Denoising the Noisy Plasma Images Captured Through Wound Optical Fiber Bundle Abhishek Sharma, Agraj Abhishek, Gaurav A. Garg, Surajkumar Gupta, Manoj Kumar, Manika Sharma

Imaging Diagnostics in SST-1
Suraj Kumar Gupta, Vishnu Chaudhari, Manoj Kumar

Study of a Prototype Metal Foil Bolometer
Devilal Kumawat, Kumudni Tahiliani, Praveen Lal E.V, Prabal Biswas, Suresh I, Santosh P Pandya, Manoj K Gupta, S.K. Pathak

Initial Results Obtained From Near-Infrared Spectroscopic System on Aditya-U Tokamak
N. Ramaiya, R. Manchanda, M. B. Chowdhuri, N. Yadava, S. K. Pathak, R. L. Tanna, K. A. Jadeja, K. M. Patel, R. Kumar, S. Aich, and J. Ghosh

Fabrication, Installation, Data Acquisition of Diamagnetic Loop in Aditya-U Tokamak
S. Aich, K. Singh, S. Dolui, J. Ghosh, K. Galodiya, T. M. Macwan, R. L. Tanna, R. Kumar, H. Mandliya, A. Kumar, Praveenlal E. V., Ankit Kumar, K. A. Jadeja, K. Patel, and ADITYA-U team

Impurity Transport in Aditya-U Tokamak with Indigenously Developed Semi-Implicit Impurity Transport Code
Nandini Yadava, J. Ghosh, M. B. Chowdhuri, Ashoke De, R. Manchanda, N. Ramaiya, K. Shah, S. Patel, S. Purohit, M. K. Gupta, U. C. Nagora, S. K. Pathak, K. A. Jadeja, K. M. Patel, Ankur Pandya, R. Kumar, Tanmay Macwan, S. Aich, Suman Dolui, Kaushlender Singh, R. L. Tanna and Aditya-U Team

Study of Temporal Profiles of Electric Field and Plasma Temperature in SOL Region of Aditya-U Tokamak
Abha Kanik, Arun Sarma, Joydeep Ghosh, Tanmay

Macwan, Sharvil Patel, R. L. Tanna, Minsha Shah, Kalpesh Galodiya, Kumarpal Jadeja, Kaushalendra Singh, Suman Duloi, Ankit Kumar, Suman Aich, Rohit Kumar, Kaushal Patel and ADITYA-U Team

Observation of Anomalous Doppler Resonance Effect in Aditya-Upgrade
Varsha. S., Santosh Pandya, S.K. Pathak, Umesh Nagora, Jayesh Raval, M.K. Gupta, K. Tahiliani, R.L. Tanna, Rohit Kumar, Suman Aich, J. Ghosh and ADITYA-U Team

Plasma Position Measurements for SST1 Discharges Using Function Parameterization (FP) Method
Sameer Kumar, Kumudni Tahiliani, Daniel Raju, Surya Kumar Pathak, Jayesh Raval, Praveenlal Edappala, Suresh I, Devilal Kumavat, Ashish Ranjan, Jasraj Dongde and SST-1 Team

3d Simulation Studies of a Double-Sided Linear Induction Motor for Electromagnetic Launch Applications
Ananya Kundu, Arvind Kumar, Ankur Jaiswal, Prasad Rao P, Vilas C Chaudhari, Rambabu Sidibomma, Y.S.S. Srinivas, E. Rajendra Kumar
Influence of an Axial Magnetic Field on Pulsed Plasma Stream
A. Ahmed, S. Singha, S. Borthakur, N. K. Neog and T. K. Borthakur

Laser-Cluster Interaction in a Static Magnetic Field without Dipole Approximation
Kalyani Swain and Mrityunjay Kundu

Large Scale Magnetic Field Generation in a 3D MHD Plasma via Induction Dynamo Action: A Numerical Study
Shishir Biswas, Rajaraman Ganesh

Exotic Plasmas of the Neutron Star Atmosphere: Why Are They Interesting
Anoop Singh, Shishir P. Deshpande, Mrityunjay Kundu

IEEE Indian Conference on Antennas and Propagation (InCAP), Malaviya National Institute of Technology, Jaipur, 13-16 December 2021

Simulation study of Luneburg Lens on K-band horn antenna for FMCW Reflectometry Applications
Rohit Mathur, J. J. U. Buch, Surya K. Pathak

Design and Simulation of a Water Based Polarization-Insensitive and Wide Incidence Dielectric Metasurface Absorber for X-, Ku- and K-Band
Priyanka Tiwari, Surya Kumar Pathak

65th DAE Solid State Physics Symposium (DAE-SSPS 2021), Bhabha Atomic Research Centre, Mumbai, 15-20 December 2021

Surface modifications study of Si substrate in Ar/O_2 RF plasma for semiconductor device applications
Yogendra Kumar
IEEE MTT-S International Microwave and RF Conference (IMaRC 2021), Indian Institute of Technology, Kanpur, 17th-19th December 2021

Design and Simulation of a Polarization-Independent Switchable Metasurface Rasorber/Absorber
Priyanka Tiwari, Surya Kumar Pathak

Virtual National Conference on Plasma Science and Applications (PSA-2021), Sardar Vallabhbhai National Institute of Technology (SVNIT), Surat, 20-21 December 2021

THz field generation by Laser Beating in

Semiconductor Plasma
P. Varshney, A. P. Singh, A. Upadhayay, M. Kundu, and K. Gopal

Unstable evolution of electron holes inside subcritical regime of plasma instability and their effect on plasma turbulence
D. Mandal, D. Sharma, and H. Schamel

Algae growth enhancement and antialgae efficacy of Plasma Activated Water
Vikas Rathore, and Sudhir Kumar Nema

Surface engineering of AISI 304L austenitic stainless steel by plasma nitrocarburizing process
Jeet Vijay Sah, Pravin Kumari Dwivedi, Subroto Mukherjee, Ghanshyam Jhala and Alphonsa Joseph

Laser Photodetachment for the electron density measurements using Hairpin probe in the SPIN-eX Plasma device
E. Nageswara Rao, Pawandeep Singh, Y. Patil and S. K. Karkari

Estimation of Negative ion density of Oxygen DC magnetron plasma using Langmuir Probe
Y.Patil, E. Nageswara Rao, Pawandeep Singh, and S. Karkari

Effect of Magnetic Field on Hydrogen Plasma Characteristics in a Large Volume Plasma System
Shweta Sharma, D. Sahu, Ramesh Narayanan, S. Kar, R. D. Tarey, A. Ganguli, Mainak Bandyopadhyay, Arun Chakraborty and M.J. Singh

Measurement of fast electron bremsstrahlung emission (FEB) in the energy range of 20 to 350 keV from SST-1 tokamak employing CdTe detector
Jagabandhu Kumar, Santosh P. Pandya, A L Thakur, and P. K .Sharma

Pneumatic Calibrator for Heterodyne Interferometer
Kiran Patel

Modelling the electrostatic microturbulence transport in Aditya-U tokamak
Tajinder Singh, Deepti Sharma, Sarveshwar Sharma, Joydeep Ghosh, Abhijit Sen, Zhihong Lin, Animesh Kuley]

National Conference on Recent Trends in Materials Science and Technology (NCMST-2021), Department of Space, Thiruvananthapuram, 29-31 December 2021

Exploring dynamics of nanoscale features with different ion beam parameters to improve their efficiency in an application
Sukriti Hans

31st ITPA meeting of TG SOL and Divertor Physics, 18-26 January 2022

EC-wave experiments on SST-1
Braj Kishore Shukla

2nd International Conference on Nanomaterials for Energy Conversion and Storage Applications (NECSA-2022), Pandit Deendayal Energy University (PDEU), Gandhinagar, 22nd January 2022

Role of elemental composition of co-sputtered metallic thin film precursor in growth of CZTS layer
Sagar Agrawaal

DAE BRNS International Symposium on Vacuum Science and Technology and Its Applications in Accelerators, DAE Convention Centre, Anushakti Nagar, Mumbai, 16-19th February 2022

Vacuum, helium leak tightness and sealing aspects of high pressure helium gas storage vessels at IPR
Rajiv Sharma

Ion Beam produced nanopatterns: Experiment and simulation
Sukriti Hans

Workshop on Augmented Reality (AR)/ Virtual Reality (VR), AICTE Training and Learning (ATAL) Academy, NIT Nagaland, 21-25th February 2022

General Overview of VR & AR technology - History, Types, Concepts
Krishan Kumar Gotewal

Hardware and Software components in AR/VR
Naveen Rastogi
Practical applications in different industries: Robotics, Gaming, Healthcare, Entertainment, Construction, etc. Krishan Kumar Gotewal

Elements in VR & AR - Haptics, Tracking, Geometry transformations, Lights, optics, Audio
Naveen Rastogi
Hands on Training on VR/AR software
Naveen Rastogi

Visual Perception and visual rendering
Naveen Rastogi

VR & AR developments in IPR
Krishan Kumar Gotewal

AWARDS and ACHIEVEMENTS

Dr. Suryakant Gupta of FCIPT was one of the **Guest of Honour** at the project exhibition of final year UG and PG students of the L.D. Engineering College, Ahmedabad. The event, entitled “KAIZEN-Continuous improvement”, was held on 19th April, 2021. The aim of the event was to review, mentor and improve the project work done by the students based on understanding of fundamental concept, team work, prototype development, innovations in the project and presentation skills.

Ms. Hiral B. Joshi gave a talk on “Effect of enclosure geometries on the performance of plasmabased microwave absorber” at the National Conference on Advances in Materials science: Challenges and Opportunities (AMSCO-2021), held at Maharaja Krishnakumarsinhji Bhavnagar University on 21st September 2021 and received **1st prize** for her poster.

Ms. Sukiriti Hans gave a talk on “Formation of triangular features superimposed by nanoripples by low energy ion beam” under student category in the 6th International Virtual Conference on Nanostructuring by Ion Beams (ICNIB2021, 5-8 October 2021) jointly organized by IOP, Bhubaneswar and IUAC, New Delhi and received the **Best Flash Oral presentation Award** for her presentation.

Dr. Shantanu Kumar Karkari gave a talk on “Laboratory Experiments & Modelling of Low Temperature Magnetized Plasmas” at the 36th National Symposium on Plasma Science and Technology (PLASMA-2021) held Online during 13-15 December 2021, and have received the **Jaidutt Saraswati Sodha PSSI Plasma Award 2021** for presenting this talk.

Mr. Hariprasad M. G., gave a talk on “First Order Phase Transition and Crystal-Fluid Coexistence in a Complex Plasma System” at 36th National Symposium on Plasma Science & Technology (Plasma-2021), and received **Buti Young Scientist Award** during 13-15 December 2021.

Mr. Shishir Purohit, gave a talk on "Aditya tokamak plasma disruption characterization" at 36th National Symposium on Plasma Science & Technology (Plasma-2021), and have received **Oral Presentation Award** during 13-15 December 2021

Mr. Tanmay Macwan, gave a talk on "Novel Explanation of the Cold Pulse Propagation Phenomenon Induced by Gas Puff in ADITYA-U Tokamak" at 36th National Symposium on Plasma Science & Technology (Plasma-2021), and have received **Poster Presentation Award** during 13-15 December 2021

Mr. Mizanur Rahman, gave a talk on "Bulk Rate Synthesis of Metal-Oxide Nanomaterials for Treatment of Wastewater and Other Biomedical Applications" at 36th National Symposium on Plasma Science & Technology (Plasma-2021), and have received **Poster Presentation Award** during 13-15 December 2021 [Co-authors: Deepak B. Pemmaraju, Sarat Phukan and Mayur Kakati]

Ms. P. N. Maya, gave a talk on "Overview of the Recent Investigations on the Surrogate-Particle-Irradiation in Tungsten Plasma-Facing-Materials" at 36th National Symposium on Plasma Science & Technology (Plasma-2021), and have received **Poster Presentation Award** during 13-15 December 2021

Dr. Prateek Varshney, gave a talk on "Terahertz (THz) field generation by Laser Beating in Semiconductor Plasma" at the (Virtual) National Conference on Plasma Science and Application, organized by Sardar Vallabhbhai National Institute of Technology (SVNIT), Surat, and received the **Emerging Scientist Award**, during 20-21 December 2021 [Co-authors: A. P. Singh, A. Upadhayay, M. Kundu, and K. Gopal]

Mr. Ansh Patel, gave a talk on "Application of data driven techniques for plasma diagnostic signal analysis" and received **Best Oral Presentation Award** at Virtual National Conference on Plasma Science and Applications, Sardar Vallabhbhai National Institute of Technology (SVNIT), Surat, 20-21 December 2021 [Co-authors: J. Govindarajan, Santosh P. Pandya, Shwetang N. Pandya, Kumudni Tahiliani, Sameer Kumar Jha, Surya Kumar Pathak]

Mr. Vivek Pachchigar, gave a talk on "Wettability studies on PTFE surfaces using argon plasma produced ion beam irradiation" and received "**Oral presentation award**" at Virtual National Conference on Plasma Science and Applications, Sardar Vallabhbhai National Institute of Technology (SVNIT), Surat, 20-21 December 2021 [Co-authors: Sooraj K P, Sebin Augustine, Devilal Kumawat, Kumudni Tahiliani, Subroto Mukherjee and Mukesh Ranjan]

Dr. Mainak Bandyopadhyay has achieved IOP trusted reviewer status in recognition of an exceptionally high level of peer review competency on 23rd December 2021

Mr. Abhishek Saraswat was awarded the **Institute Research Award 2021-22** (Jul-Nov) by the Indian Institute of Technology Madras, for quality research work done by him during his M.S. study at IIT Madras. This award is one of the 50 awards given to M.S. scholars from research institutes in recognition of their excellent journal publications. The award consisted of a merit certificate and a cash award of Rs.10000. In 2019, he joined the Department of Mechanical Engineering, IIT Madras, as an external M.S. scholar under the supervision of Dr. Sateesh Gedupudi (IITM) and Dr. Paritosh Chaudhuri (IPR). His research focused on the development of a two-phase detection probe for lead-lithium liquid metal environment, relevant to applications in nuclear fusion power plants. His work has been disseminated as journal articles, a book chapter, and presentations at international conferences. Abhishek has an active interest in the interdisciplinary domain of breeding blanket technology development.

Mr. Hitensinh Vaghela, gave a talk on "Porous Media Approach in Hydraulic Performance Evaluation of Cable-in-Conduit Conductor in Superconducting Magnet Applications" and received the **"Best Paper of the Session Award"** at 48th National Conference on Fluid Mechanics and Fluid Power (FMFP-2021), BITS, Pilani Campus, Rajasthan, 27-29 December 2021, [Co-authors: Vikas Lakhera and Biswanath Sarkar]

E 4. INVITED TALK DELIVERED BY IPR STAFF

SURYAKANT GUPTA

Gave an expert talk on "Pulsed Power technology and its Pervasive use for Societal Applications" for the Post Graduate students of Electrical Engineering Department of Nirma University, Ahmedabad, on 11 May 2021

Gave an expert talk on "Research Activities and Opportunities at IPR" at Graduate School of Engineering and Technology, GTU, Ahmedabad, on 17 September 2021

Gave an invited talk on "Pervasive use of plasma technology for the societal benefit" at Science, Technology & Innovations: Making India Knowledge Driven Economy, Govt. Science College, Jabalpur, on 18 November 2021

Gave an invited talk on "Digital Empowerment & ICT - Enablement" at Vibrant Gujarat Summit on "International Conference of Academic Institutions" organized at Vigyan Bhavan, Science City, Ahmedabad, on 04 January 2022

Gave an invited talk on "Contribution of Environment Friendly Plasma Technology for the Social Benefit" at Hindi Day Celebration, Directorate of Purchase and Stores Department of Atomic Energy, Vikram Sarabhai Bhawan, Mumbai, on 11 January 2022

Gave an invited talk on "Applications of plasma Technology and career opportunities in DAE" at Silver Oak University, Ahmedabad, on 27 January 2022

Gave an invited talk on "SPIX-II, an experimental facility for electrostatic discharge detection on satellite solar panels" at DAE-BRNS International Symposium on Vacuum Science and Technology and its Application in Accelerators (VSTAA-2022), BARC, Mumbai, on 16 February 2022. [Co-authors: Keena Kalaria, Naresh Vaghela, Sudhirsinh Vala, Rajesh Kumar, Himanshu Tyagi, Hiren Mistri, and Mainak Bandyopadhyay]

Gave an invited talk on "Emerging role of bioelectric and plasma technology in medical science" at 6th International Conference NIPiCON-IPS-2022, Institute of Pharmacy, Nirma University, on 17 February 2022

SARVESHWAR SHARMA

Gave an invited talk on "Capacitively coupled plasma discharges excited by tailored waveform - a simulation study" (Co-authors: NISHANT SIRSE and MILES TURNER) at 2nd International Conference on Advances in Plasma Science and Technology (ICAPST-21), Sri Shakthi Institute of

Engineering and Technology, Coimbatore, 27-29 May 2021

Gave an invited talk on “Plasma: Key Tool for Energy Production and Industrial Applications” at National Webinar Series by Department of Physics on the Theme of Physics in Social Development, University Maharani College, Jaipur, 20 November 2021

MUKESH RANJAN

Gave an invited talk on “Anode fireball for making super-hydrophobic nanodot surfaces” at 2nd International Conference on Advances in Plasma Science and Technology (ICAPST-21), Sri Shakthi Institute of Engineering and Technology, Coimbatore, 27-29 May 2021

Gave an invited talk on “Nanopatterning induced Surface Wettability and its Applications” at E-Workshop on Energetic Beam Technology: From Materials Engineering to Diagnostics, Amity Institute of Nanotechnology, Uttar Pradesh, on 22 June 2021

Gave an invited talk on “Thermal Management of Engineering Systems via Spontaneous Drop Motion on Wettability Gradient Surfaces” at an Online International Symposium on Fluid and Thermal Engineering (FLUTE 2021), Department of Mechanical Engineering, Amity University Uttar Pradesh, on 22 July 2021

Gave an invited talk on “SERS-based detection for Food, Agriculture and Medical Science Application” at a webinar on Ion Beams in Sensor Development, organized by Inter-University Accelerator Centre (IUAC), 7-8 September 2021

Gave an invited talk on “Plasma Produced Patterns for Health and Food Applications” at Plasma Processing of Nanomaterial and Its Applications (PPNA)-2021, Organized by IPR, 3rd December 2021

Gave an invited talk on “Plasma for nanopatterning application” at “Metallurgy for All-2022”, Government Engineering College, Gandhinagar, 24th February 2022

Gave a popular talk on “Harnessing Plasmas for Societal Applications” at National Science Day 2022 (NSD-2022), CPP, Sonapur, 28th February 2022

SUDHIR KUMAR NEMA

Gave an invited talk on “Solid Waste Management using Environment Friendly Thermal Plasma Technology” at ATAL Faculty Development Program on “Emerging Technologies for Sustainable Environmental Management” on 2nd June 2021

Gave a plenary talk on “Advances in Non-thermal Plasma Technology and its Applications” at Virtual National Conference on Plasma Science and Applications (PSA-2021), Sardar Vallabhbhai National Institute of Technology (SVNIT), Surat, 20-21 December 2021

SHASHANK CHATURVEDI

Gave an online lecture entitled “Technological Applications of Plasmas” at UPES “Science Series”, the University of Petroleum and Energy Studies (UPES), Dehradun in association with Institute of Physics (IOP), Indian Physics Association (IPA) and the Indian Association of Physics Teachers (IAPT) on 10 June 2021

Gave a special talk on "Science-Based Development of Plasma and Fusion Technologies: Achievements and Challenges" at Celebration of Engineer's Day 2021, organized by Homi Bhabha National Institute on 20 September 2021

Gave a talk on "Deployable Technologies from Plasma Science: Present-day & Future" at 12th Indian Nuclear Society (INS) Webinar Series, on 25th December 2021

NAVEEN RASTOGI

Gave an invited talk on "Virtual reality applications in remote handling" at AICTE sponsored Faculty Development Program on "AR VR in Robotics" organised by Vimal Jyothi Engineering College, Kannur, Kerala, on 15th July 2021

ARUNSINH ZALA

Gave an invited talk on "XRD & SEM techniques - an overview" at National Webinar Series on Processing and Characterization of Materials (PCM-21), Metallurgy Department, Government Engineering College, Sector 28, Gandhinagar, Gujarat, 20-24 September 2021

Invited talks given at 5th Asia-Pacific Conference on Plasma Physics (AAPPS-DPP2021), Fukuoka, Japan, 26 September – 1 October 2021

PRINCE KUMAR gave an invited talk on "Weakly magnetized dust vortex flow analysis in the absence of non-conservative fields"

SATADAL DAS gave an invited talk on "Equilibrium properties of a magnetized plasma behind an insulating obstacle"

Invited talks given at 36th National Symposium on Plasma Science and Technology (PLASMA-2021): Plasma for Benefit of Mankind, Birla Institute of Technology, Mesra, Jaipur, 13-15 December 2021

DEVENDRA SHARMA gave an invited talk on "Why quasi-longitudinality is the order of the day in electromagnetic turbulence?"

SUDEEP BHATTACHARJEE, DEEPIKA BEHMANI, KALYANI BARMAN AND RAMKRISHNA RANE gave an Invited talk on "Understanding plasma adaptation for biomedical application: strong magnetic field effects and potential fluctuation dynamics"

A. K. CHAKRABORTY gave an invited talk on "Technology for Fusion Reactors – A Weave, Through the Interdisciplinary Spectrum"

JINTO THOMAS gave an invited talk on "Overview of SST-1 Thomson system: Installation calibration and operation"

ABHIJIT SEN

Gave an invited talk on "Data Driven Discovery of Model Equations" at Virtual National Conference on Plasma Science and Applications (PSA-2021), Sardar Vallabhbhai National Institute of Technology (SVNIT), Surat, 20-21 December 2021

Gave a Lecture on "Remote Sensing of Space Debris using Plasma Effects" at National Science Day 2022, GUJCOST, 28th February 2022

S.R. MOHANTY

Gave an invited talk on "Study of Neutron and X-ray Emission from Inertial Electrostatic Confinement Fusion Device and their Usage" at International Conference on Plasma Science and Application

2021 (ICPSA2021), Nanjing University of Science and Technology, China, 29th December 2021

RAKESH MOULICK

Gave an invited talk on "Scientific Significance of Shrimad Bagavad Gita" at a webinar organized by Rangapara College, Rangapara, Sonitpur, Assam, 29th December 2021

Gave an invited talk on "Fundamentals of Plasma Physics" at a Workshop on Thin Film Deposition and Device Fabrication, Vellore Institute of Technology, Vellore, 8th January 2022

SHWETANG N. PANDYA

Gave an invited talk on "Thermal Imaging - An Introduction" at the Webinar on Deep learning for Multi-spectral Imaging approach in Health Care Technology, SRM Institute of Science and Technology, Chennai & IGCAR, Kalpakkam, 9th February 2022

PINTU BANDYOPADHYAY

Gave a keynote talk on "Dusty Plasma: A model system to perform multidisciplinary research" at Sikkim Manipal Institute of Technology, Sikkim, 18th February 2022

RAJIV SHARMA

Gave an invited talk on "Composites Material Development for Superconducting Fusion Machine System and Cryogenic Applications" at a Webinar on "Aerospace Materials and Applications", at Shiv Nadar University, Greater Noida and Indian Space Industry Exhibitors (ISIE), 25-27 February 2022

NITIN BAIRAGI

Gave an invited talk on "Superconductors: Technology towards Sustainable Goals" at National E-conference on Sustainable Development and Environment Protection Technologies, ISBM University, Chhattisgarh, 28th February 2022

E.5 TALKS DELIVERED BY DISTINGUISHED VISITORS AT IPR

Dr. Bivash Dolai, Guru Ghasidas Vishwavidyalaya, Bilaspur, gave a talk on "The rotating Rayleigh-Taylor instability in a strongly coupled dusty plasma" on 9th April 2021

Dr. Vishant Gahlaut, Banasthali Vidyapith University, Rajasthan, gave a talk on "Thermo-Mechanical Analysis and Simulation of Helix TWTs" on 16th April 2021

Dr. Sandip Dalui, Jadavpur University, Kolkata, gave a talk on "Some Problems on Nonlinear Ion Acoustic Waves in Two Electron Temperature Plasma" on 21st June 2021

Dr. Anuj Ram Baitha, Indian Institute of Technology, Kanpur, gave a talk on "Production and study of a plasma confined in a dipole magnetic field and Studies on plasma diffusion and transport using probe and optical diagnostics" on 23rd June 2021

Dr. Praveen Devangad, Manipal Academy of Higher Education, Karnataka, gave a talk on "Study of Laser Induced Plasma Spectroscopy coupled with machine learning methods for various analytical applications" on 25th June 2021

Dr. Rasila Hirani, SVNIT, Surat, gave a talk on "Design, Optimization and Fabrication of Leaky Mode Plasma Antenna for Wideband Application at 2.45 GHz" on 2nd July 2021

Dr. Paramita Maiti, Institute of Physics, Bhubaneswar, gave a talk on "Molecular Beam Epitaxy (MBE) grown Molybdenum Oxide Nanostructures: Growth, Characterizations and Applications" on 9th July 2021

Dr. Isheta Majumdar, Helmholtz-Zentrum Berlin für Materialien und Energie (HZB), Germany, gave a talk on "Photoelectron spectroscopic studies of solar cell absorber materials" on 26th July 2021

Dr. Milind Kumar Singh, Banaras Hindu University, Varanasi, gave a talk on "Experimental and first principal studies on hydrogen desorption behaviour of graphene nanofiber catalyzed MgH_2" on 30th July 2021

Dr. Akanksha Gupta, IIT Kanpur, gave a talk on "Study of turbulent and shear flows in viscous and viscoelastic fluids" on 13th August 2021

Dr. Turaga Sairam, Jawaharlal Nehru University, New Delhi, gave a talk on "Ion induced molecular dynamics and development of deceleration facility at IUAC" on 27th August 2021

Dr. Mumtaz Ali Ansari, Indian Institute of Technology (BHU), Varanasi, gave a talk on "Dual-Band Operation of Relativistic Backward Wave Oscillators with Gaussian like Output for Directed Energy Weaponry Applications" on 8th September 2021

Dr. Tejal Barkhade, Central University of Gujarat, Gandhinagar, gave a talk on "Effect of Iron Content Titanium Dioxide Nanoparticles on Potential of Mitochondrial System" on 10th September 2021

Dr. Manishkumar K Singh, Indian Institute of Technology (BHU), Varanasi, gave talk on "Oxidation and Hot Corrosion Behavior of 904L Super Austenitic Stainless Steel" on 17th September 2021

Dr. Rohit Kumar Saini, IIT, Dhanbad, gave a talk on "Design and Characterization of High Performance Circularly Polarized Planar Antennas for Wireless Communication" on 1st October 2021

Dr. Shruti Priya, IIT, Dhanbad, gave a talk on "Self-Multiplexing Antennas using Substrate Integrated Waveguide" on 8th October 2021

Dr. Sayantan Mukherjee, KIIT, Bhubaneshwar, gave a talk on "Thermo-physical properties of nanofluids" on 14th October 2021

Dr. Prachi Orpe, Nirma University, Ahmedabad, gave a talk on "Thermal plasma synthesis of magnetic nanoparticles – Study of process parameters influencing the nanostructure and magnetism" on 22nd October 2021

Dr. Pawan Kumar, Associate Professor, Vignan's Foundation for Science Technology and Research, Jharkand, gave a talk on "Design and Development of Advanced Multiband Printed Antennas" on 29th October 2021

Dr. Vishal Dhamecha, SP University, Anand, Gujarat, gave a talk on "Studies on compound semiconductor (ZnGa2Se4) thin film electronic devices" on 18th November 2021

Dr. Razia Nongjai, Inter University Accelerator Centre (IUAC), New Delhi, gave a talk on "Defects related structural, electrical, optical and magnetic properties of metal oxides thin films" on 2nd December 2021

Dr. Anshu Verma, Indian Institute of Technology Delhi, gave a talk on "Exploring Thruster Potential of Compact ECR Plasma Source" on 22nd December 2021

Dr. Akash, Indian Institute of Technology (BHU), Varanasi, gave a talk on "High-Power Microwave / Millimeter wave Vacuum Electron Tubes and Passive Components" on 28th January 2022

Dr. Gaurav Shukla, Pandit Deendayal Energy University, Gandhinagar, gave a talk on "Measurement of intrinsic plasma rotation in Aditya-U tokamak" on 07th February 2022

Dr. Sandra KR, Indian Institute of Technology Madras, Chennai, gave a talk on "A Method for Non-intrusive Position Sensing using Multiple Mutually Coupled Planar Coils" on 18th February 2022

Dr. Sadaf Jethva, Saurashtra University, Rajkot, gave a talk on "Studies on Properties of Mixed Valent Oxides" on 25th February 2022

Dr. Prabhakar Tripathi, Indian Institute of Technology (BHU), Varanasi, gave a talk on "Investigation of Different aspects of the Side-Coupled Cavities type Interaction Structures for the Slow Wave High Power Electron Beam Devices" on 11th March 2022

Dr. Abin Rejeesh, Indian Institute of Technology Bombay, gave a talk on "MHD flow inside ducts: two phase flow analysis" on 21st March 2022

Dr. Sheena TS, Bharathidasan University, Tiruchirappalli, gave a talk on "Raman Spectroscopy for biological application: A promising tool for molecular discrimination of cells" on 25th March 2022

E.6 COLLOQUIA PRESENTED AT IPR

Dr. Anirban Polley, National Centre for Biological Sciences, Bangalore, gave a talk on "Soft Matter Physics with emphasis on Biological systems" on 1st July 2021 (Colloquium # 303)

Dr. S. Sunil, Institute for Plasma Research, Gandhinagar, gave a talk on "LIGO: An Observatory for Detection of Gravitational Wave" on 3rd September 2021, (Colloquium #304)

Prof. Avinash Khare, Sikkim Central University, Gangtok, gave a talk on "Gravitational collapse of dust in molecular clouds: Approach based on thermodynamics and Virial theorem" on 17th September 2021, (Colloquium #305)

Dr. Mukesh Ranjan, Institute for Plasma Research, Gandhinagar, gave a talk on "Harnessing Plasmas for Societal Applications" on 1st October 2021 (Colloquium #306)

Prof. Reji Philip, Raman Research Institute, Bangalore, gave a talk on "C.V. Raman: The Man, The Scientist" on 18th October 2021 (Colloquium #307)

Dr. Jay Kothari, Director and consultant at critical care Department, Apollo Hospital, Ahmedabad, gave a talk on "The new trends of Covid-19" on 06th January 2022 (Colloquium #308)

Prof. Kanak Saha, Inter-University Centre for Astronomy and Astrophysics (IUCAA), Pune, gave a talk on "Extreme-UV photons from distant galaxies" on 24th January 2022 (Colloquium #309)

Prof. B. S. Murty, Indian Institute of Technology, Hyderabad, gave a talk on "The exciting world of Materials" on 10th February 2022 (Colloquium #310)

Dr. K.S. Ganesh Prasad, Institute for Advanced Research, Gandhinagar, gave a talk on “Cold plasma approach for reduction of waste in Chemicals manufacturing” on 23rd February 2022 (Colloquium #311)

Dr. Sujay Bhattacharya, Director, Reactor Projects Group, BARC, gave a talk on “Design and construction of Research reactor- A perspective in Indian scenario” on 02nd March 2022 (Colloquium #312)

Dr. Nirmal Bisai, Institute for Plasma Research, Gandhinagar, gave a talk on “Plasma blob formation and its experimental validation” on 17th March 2022 (Colloquium #313)

E 7. SCIENTIFIC MEETINGS HOSTED BY IPR

Workshop on Parallel Computing @ IPR

Considering the importance of High-Performance Computing (HPC) facilities capable of achieving tens or hundreds of petaflops, we are currently at a unique point where there is a need to understand and improve the performance of applications which can reach a significant value of that peak performance. With researchers at IPR having the expertise of writing their own codes, it is important that they are exposed and provided with the tools that are needed to scale these inhouse developed codes to a large no. of CPU cores for performing fast calculations. This workshop was conducted to help the users in making the transition from running serial codes on laptops or workstations to running them on the cluster architecture using the parallel capabilities of the cluster. The HPC team working closely with the HPC users identified the gaps to efficiently write the parallel computing algorithms and planned along with the experts from Locuz Inc. to have a parallel computing workshop covering all related topics.

The main objective was to introduce researchers to exploit the parallel capabilities of the HPC hardware, learning the parallel programming tools and paradigms for CPUs for running their codes in an HPC environment to accelerate their scientific simulation work with the availability of the HPC resources at IPR. This workshop introduced the fundamental concepts of shared memory (OpenMP) and message-passing (MPI) programming models. The Intel optimization tools for understanding the performance of parallel applications were also covered. To get familiar with the main concepts of OpenMP and MPI, and the process of how to build, compare and improve the performance, mostly hands-on lab sessions were carried out. Day-1 and Day-2 focussed on openMP and MPI with lab sessions on profiling such execution modes in some basic tutorial problems. The participants followed a step-by-step approach to learn the concepts and how they can be applied in their scientific codes by using the Intel profiling tools. All the participants were given access to IPR’s HPC facility, ANTYA cluster. Day-3 started with introducing the idea version control using git by Dr Arkaprava Bokshi highlighting the various useful features which can immensely help the users in keeping a track of the development cycle of their codes and to avoid any conflict with the collaborators. Later on Day-3, a new Intel tool, OneAPI was introduced which is to build applications across CPU/GPU/FPGA architectures using this single tool only and will replace the existing Intel Cluster Studio which is currently being used in ANTYA.

This 3-day workshop was held during 13th, 15th and 16th April 2021. The workshop sessions were completely online and took place in the morning half days using the IPR VC facility, JITSI. The workshop brought together more than 35 participants over the course of 3 half-days out of a total of 48 registrations received from various divisions in IPR, FCIPT, CPP-IPR, and ITER-India having expertise with different domains/ programming languages.

International Yoga Day 2021

The 7th edition of International Yoga Day was celebrated with great enthusiasm by IPR staff. Because of the Covid-19 restrictions, no physical yoga meet was organized on campus. However, IPR Staff Club organized a “Yoga & me” campaign on this occasion wherein IPR staff members posted photos of themselves and/or their family members performing yoga exercises and a detailed description of the asana. A virtual yoga session was also organized on 21 June 2021 by yoga trainer Shri. Vivek Sharma. A slogan writing competition for IPR staff members and/or their family members was also organized as part of the IYD 2021. The theme for the slogan competition was “Yoga for better immunity” in Hindi, Gujarati or English.

International Yoga Day 2021 @ CPP-IPR

The Covid-19 restrictions in Guwahati did no permit the IYD-2021 to be celebrated on campus. Staff members participated in the “Yoga & me” campaign and Shri Manoj Kumar Deva Sarma of CPP-IPR, who practices yoga on a regular basis gave a full demonstration of various asanas relevant to our day to day life.

IPR Outreach Activities (July-September 2021)

With the onset of academic sessions in schools and colleges, IPR outreach webinar programmes also have begun. The webinars conducted in the month of July 2021:32 students of BSc Physics and 2 teachers of Department of Physics, Marwadi University, Rajkot, participated in 2-day, 4 hour webinar on “Plasma & its applications” for BSc/ MSc students on 13-14 July, 2021. 56 students of BSc Physics and 10 teachers of Department of Physics, Motilal Nehru College, New Delhi, participated in 2-day,4 hour webinar on “Plasma & its applications” for BSc/MSc Physics students on 19-20 July, 2021. 39 students of class 11 and 12 and 2 teachers of Shivneri School, Khanapur, Pune, participated in 1-day, 2 hour webinar “Plasma & its applications” for class 11-12 students on 23-July, 2021.

The webinar Programmes conducted by Outreach Division during the month of August 2021 under the auspices of 75 years of Independence are as follows: 68 students and 2 teachers of Mount Carmel School, Gandhinagar, participated in 1-day, 2 hour webinar on “Plasma & its applications” for class 11-12 students on 30 July 2021. 22 students and 2 teachers of Christ College, Rajkot, participated in 2-day, 4 hour webinar on “Plasma & its applications” for BSc Physics students on 4-5 August, 2021. 80 students and 2 teachers of Kadi Sarva Vishwavidyalaya, Gandhinagar participated in 2-day, 4 hour webinar on “Plasma & its applications” for BSc Physics students on 12-13 August, 2021. 15 students and 1 teacher of Delhi Public School, Bopal, Ahmedabad, participated in 1-day, 2 hour webinar on “Plasma & its applications” for class 11-12 students on 20 August, 2021. 68 students and 2 teacher of KIIT School-I, Bhubaneswar, participated in 1-day, 2 hour webinar on “Plasma & its applications” for class 11-12 students on 26 August, 2021. 108 students and 3 teacher of KIIT School-II, Bhubaneswar, participated in 1-day, 2 hour webinar on “Plasma & its applications” for class 11-12 students on 27 August, 2021

The webinar Programmes conducted by Outreach Division during the month of September 2021 under the auspices of 75 years of Independence are as follows: 100 students of B. Tech (multiple streams) and 3 teachers of L D College of Engineering, Ahmedabad, participated in 2-day webinar on “Plasma, its applications and Fusion” for B. Tech students on 2-3 September, 2021. 70 students and 3 faculty members of D K V Arts and Science College, Jamnagar, participated in 2-day webinar on “Plasma, its applications and Fusion” for BSc/MSc students on 16-17 September, 2021. 78 students and 1 teacher of Gujarat Refinery English Medium School, Vadodara, participated in 1-day webinar on “Plasma, its applications and Fusion” for Plus 2 students on 23 September 2021. 60 students and 2 teachers of Kotak Science College, Rajkot, participated in 2-day webinar on “Plasma, its applications and Fusion” for BSc students on 23-24 September 2021.

Second GPU Programming Bootcamp at IPR

With the ongoing effort to efficiently utilize the GPUs and make our in-house developed applications/codes ready for the emerging computational architectures, HPC Team of IPR, along with the help from Nvidia Team conducted this 2-Half day GPU Bootcamp virtually on 20-21 October 2021. No GPU programming knowledge was required for the participants. All the participants were given access to IPR’s 1 PetaFlop HPC Cluster, ANTYA for carrying out the hands-on lab sessions. Day-1 started with an introduction to GPU programming using OpenACC, stdpar, Fortran Do-Concurrent, and a hands-on session to learn how to analyze GPU-enabled applications. For the lab sessions, a demonstration was shown on how to launch a “headless” Jupyter Notebook as a batch job in ANTYA and access the Graphical User Interface (GUI) in the Local user machine’s (Desktop/Laptop) web browser. Day-2 focussed on the latest GPU architecture, how to run Python on GPUs (CUDA Python), and the newly emerging PINN (physics informed neural network) approach using NVIDIA SimNet (an AI-driven multi-physics simulation framework). This process gave the participants insight into how GPUs can be used in their applications and how they can start using them from scratch. The level of engagement of the participants with the trainers showed their enthusiasm and eagerness to learn GPU programming and its application to accelerate their work. During the 1st GPU Bootcamp, many good quality In-house developed codes (serial as well as parallel) spanning Computational Fluid Dynamics (CFD), Molecular Dynamics (MD), Particle-in-Cell (PIC), etc. domains have been ported successfully and achieved initial performance enhancement as shown in the number of applications registered for 2nd Bootcamp. This Bootcamp brought together more than 25 participants for two half-days from various divisions in IPR, FCIPT and ITER-India having expertise with different domains/ programming languages.

IPR Outreach Activities

As part of the Azadi Ka Amrit Mahotsav activities, IPR staff were encouraged to conduct webinar programmes for the school/college where they studied. Shri Amadas Alli, Scientific Officer F, in association with the Outreach Division, conducted a 2-day webinar on Plasma and its Applications for the students and staff of his alma mater the Zilla Parishad High School, Velpur (Telangana). 50 students and 4 teachers participated in this event. On 22nd and 25th October 2021.

Vigilance Awareness Week 2021

Vigilance Awareness Week-2021 (VAW) was observed at IPR from **26 October to 2 November, 2021**. The theme of this year’s VAW was

'Independent India @ 75: Self Reliance with Integrity'. As part of this, an "Integrity Pledge" was undertaken by the employees on 26th October 2021, with Dr. Shashank Chaturvedi, Director and Dr. Anitha V P (CVO, IPR) leading the pledge. In view of COVID-19 pandemic related restrictions, the ceremony was conducted via web-livestream, while very few Officials were physically present. An online talk on "Creating a Life of Integrity" was delivered by Sri Stanly M K, System Administrator, Controllers Office, BARC on 28th October 2021. A "Nukkad Natak" with title "Daftar ki Dastak" was enacted by IPR staff within IPR campus (on 27th October 2021) as well as at Bhat village to the Gram Panchayat members and students of Sarvodaya Vidya Mandir School at Bhat Village on 28th October 2021. Quiz, Poster and Slogan competitions were also held for the employees and prizes were awarded to the winners.

Communal Harmony Campaign Week 2021 @ IPR

Communal Harmony Campaign Week & Flag Day 2021 was observed at IPR during 19-25 November 2021.To spread the message of Communal Harmony, various activities were carried out through-out the week. Essay Writing and Poem competitions on the theme "Communal Harmony for National Development" were conducted. A Webinar talk on "Sampradayik Sadbhav aur Rashtriya ekta" by Dr. Ramgopal Singh, Prof. & Head, Hindi Department, Gujarat Vidyapeeth was arranged on 23 November 2021. Flag Day was observed on 25 November 2021 where the staff were encouraged to come in traditional attire and flag stickers were distributed among the staff. A voluntary fund raising campaign was also carried out by keeping donation boxes in IPR, FCIPT and ITER-India campuses.

Plasma Processing of Nanomaterials & its Applications (PPNA) 2021

A one-day Industry – Academia online meeting was organised on **3rd December 2021** by IPR under the auspices if "Azadi ka Amrit Mahotsav" to deliberate and disseminate latest developments in plasma based nanomaterials synthesis process and technology. A total of 9 talks were delivered by field experts from R&D labs/Institutes (BARC, IIT-Gandhinagar, IPR), Universities (Bharatiyar Univ., Savitribai Phule Pune University) as well as Industry R&D heads (Plasvac, Saveer Matrix Nano). A total of 150+ participants had registered and participated in the online program. Participants included research scholars, senior scientists, industrial houses as well as young entrepreneurs interested in start-up companies. Dr. Shashank Chaturvedi, Director IPR, delivered the inaugural address. Talks covered various aspects of thermal plasmas, torches used in material processing as well as synthesis of different types of materials and applications of some of the nanomaterials. Industry heads presented the commercial and business opportunities related to nanomaterials usage and also challenges facing by Indian industries in mass production of nanomaterials. These were deliberated. The final vote of thanks was delivered by Dr. S.K. Nema, Head, Atmospheric Plasma Division of IPR.

IPR @ Plasma-2021

The 36th National Symposium on Plasma Science & Technology (Plasma-2021) was organized by PSSI and BIT Mesra, Jaipur Campus during 13-15 December 2021. This conference was conducted completely as an online event. The conference was inaugurated at BIT Mesra Jaipur campus and Prof. Prabhat Ranjan, Vice Chancellor, DYPIU, Pune delivered the Keynote Address. Dr. Shashank

Chaturvedi, Director, IPR also addressed the participants. Dr. Devendra Sharma and Dr. Jinto Thomas of IPR and Shri Arun Chakraborty of ITER-India delivered invited talks in Basic plasma, Plasma Diagnostics and Fusion Technology sessions respectively. Around 141 participants from IPR, CPP-IPR, ITER-India contributed 110 posters, and 7 oral presentations in the symposium.

Azadi Ka Amrit Mahotsav Outreach Activities of IPR

As part of the Azadi Ka Amrit Mahotsav activities, IPR Outreach Division undertook several training programmes between **20-24 December 2021** in "Plasma & its Applications and Energy from Nuclear Fusion" under the auspices of the Indian Science Congress Association, Bhubaneswar Chapter, for science teachers, research scholars and high school students of Kalinga Institute of Social Sciences (KISS-DU) and Kalinga Institute of Industrial Technology (KIIT-DU), Deemed Universities, Bhubaneswar. The training programme for teachers and students had popular talks and hands on exhibits of various types of plasma, its applications and models of a generic tokamak. Over 120 teachers and research scholars from KISS-DU and KIIT-DU, teachers and students from Trident Academy of Technology, College of Engineering & Technology, Bhubaneswar, Bhadrak Autonomous College, and P.N. College and Haladia College, Khordha also attended the programme. The programme was inaugurated by Prof. Asoka Das, ex-Scientist, BARC and currently Vice Chairperson, Odisha State Higher Education Council. He also inaugurated the hands-on exhibition on plasma and its applications. The exhibition was also visited by Prof. B.B. Mishra, President of Odisha Vigyan Academy (Dept of S&T, Govt of Odisha). A special session for research scholars was also held at Ravanshaw University, Cuttack on 23rd December. The programme was coordinated by Dr. Kajal Parashar of KIIT-DU, and Convener, ISCA, Bhubaneswar Chapter.

Talks and hands-on experiments were delivered by members of IPR Outreach Division. 14 experiments/exhibits were transported to Bhubaneswar from IPR for this event. Over 600 tribal students studying in the 9, 10, 11 and 12th standards of KISS-DU also attended a special lecture on plasma and spent time interacting with IPR Outreach staff and the interactive experiments.

A special training session on plasma & its applications was arranged for the students and researchers of Ravenshaw University, at Cuttack on 23rd December. Due to a special request from doctors from the Kalinga Institute of Medical Sciences (KIMS) as well as Kalinga Institute of Dental Sciences (KIDS), a special talk on "Biomedical Applications of Plasma" was delivered by Dr Ravi A V Kumar on **24th December 2021**. The doctors who attended the talk also visited the hand-on exhibits.

IPR Scholars' Alumni Meeting

Past and Current Scholars met virtually for the second IPR Research Scholars' Reunion on **26th December 2021**. The objective of the event was to connect with one another and to discuss the opportunities to act as the volunteers, mentors, employers, ambassadors, collaborators to support each other and students of IPR. The alumni scholars reminisced and shared the stories from IPR days along with the various job and collaboration opportunities available for the current scholars in Academia as well as Industry. The current scholars update about life, in general, at IPR. The participants included Shreekrishna, Dastgeer, Deepak, Mani, Ganesh, Vipin, Neeraj Jain, Rajneesh, Vikrant, Kishor, Sharad, Gurudatt, Rameswar, Sanat, Kshitish, Sushil, Manjit, Sayak, Veda, Neeraj Chaubey, Meghraj, Akanksha, Roopendra, Arghya, Umesh, Amit, Prabhakar, Debraj, Pallavi, Jervis, Sonu, Soumen, Mayank, Garima, Swarnima, Anshika, Nidhi, Jagannath, Swati, Suruj, Pranjal, Shirish, Avnish, and Pawandeep.

National Science Day (NSD -2022) @ IPR

The National Science Day 2022 was conducted as part of the Azadi ka Amrut Mahotsav celebrations during 1-4 February, 2022 as an online event. Competitions were held in both offline (Poster and Essay) as well as online (Quiz, Skit, Eloquence and Science models) modes. Around 324 students and 15 teachers from 67 schools across Gujarat state participated in the various competitions that were conducted online over a week. Students and teachers from 23 schools won a total of 42 prizes. As part of AKAM, a comic book for children on plasma was created by Outreach Division in English and this was also translated into 13 Indian languages by IPR staff members. This comic book was released by Director, IPR during the concluding session of NSD-2022. The comic book in all the translated languages are available on the IPR Outreach website.

National Science Day @ CPP -IPR

Centre of Plasma Physics - Institute for Plasma Research (CPP-IPR) observed the National Science Day, 2022 as a part of "AZADI KA AMRIT MAHOTSAV" on 24th, 25th and 28th February 2022, under the theme "Integrated Approach in Science and Technology for a Sustainable Future". Keeping in mind the Covid scenario the events have been organized online. Several competitions were conducted among students of various academic levels, including the students of schools, colleges, and universities. The competitions include Essay Writing, Drawing, Poster, Science Model, Eloquence, Quiz etc. The program concluded with a popular talk on "Harnessing Plasmas for Societal Applications" by Dr. Mukesh Ranjan, of FCIPT, IPR.

Swachhta-Pakhwada @ IPR

"Swachhta-Pakhwada" was observed at IPR during 16-28 February, 2022. This year it has been observed under the umbrella of Azadi ka Amrit Mahotsav. As part of this drive, all IPR staff members actively participated with a lot of enthusiasm.
The following activities have been carried out during the Swachhta Pakhwada-2022:

- Removal of all unwanted waste items collected from offices, laboratories and various open spaces of the institute, segregated and disposed of them properly.
- Survey of all the offices, laboratories, canteens, guest houses, kitchens, and lavatories to check proper cleaning and waste disposal.
- Clean Campus Initiative with "Best out of Waste": Using scapped oil drums for tree plantation.
- Online Quiz, Eloquence competition for school students from Ahmedabad and Gandhinagar
- Slogan and Video Making competition for IPR Staff members and their family
- A webinar on "Cold plasma approach for reduction of waste in Chemicals manufacturing" by Dr. K.S. Ganesh Prasad, Institute of Advanced Research, Gandhinagar

A Swachhata walk was conducted from IPR campus to the ITER-India campus and the participants of the walk picked up all the waste plastic materials along the path. Staff from IPR and ITER-India actively took part in this event to ensure that the road from IPR to ITER-India was free of plastic waste materials.

AKAM Science Exhibition @ Gujarat University
As part of the Azadi Ka Amrit Mahotsav (AKAM) celebrations, IPR participated in the Science Exhibition organized by Gujarat University, Ahmedabad, under the "Vigyan Sarvatra Pujyate" Science communication Popularization & its Extension programme supported by Ministry of Science & Technology, Government of India. This exhibition was conducted at the Computer Science Building of Gujarat University during 22-28 Feb, 2022. IPR exhibited 14 working and non-working models, posters as well as distributed resource materials related to plasma and its applications. Over 10,000 students visited the exhibition.

AKAM Rural Scientific Outreach Activity @ Bhanvad

As part of the Azadi Ka Amrit Mahotsav (AKAM) celebrations, IPR will be conducting a series of scientific outreach activities in schools of rural schools of different districts of Gujarat. The first such event was conducted during 1-4 March, 2022 at the Purusharth Saikshanik Sankul, Bhanvad, Devbhumi Dwaraka District. This is a Guajarati medium residential school with over 750 students studying in classes 1-12. The 4-day event consisted of a popular talks on plasma and its applications and exhibition of over 15 working models related to plasma and its applications. Over 500 students of the host school as well over 500 students and 70 teachers from ten other schools in Bhanvad taluka as well as several officers from district and taluka administration also visited the exhibition. The event was inaugurated by the Taluka Education Officer, Bhanvad Taluka. The event was also visited by District Education Officer, Taluka Mamlatdar, Taluka Revenue Officer, and Principals of schools and colleges in Bhanvad and neighboring taluks. As part of the event, the Gujarati version of the children's comic book on plasma "The Wonderful World of Plasma" was also distributed to all the participating students and teachers. A set of 10 posters on plasma and a popular book on plasma "Living with Plasma" were also distributed to the visiting schools for display in their school's library. IPR Outreach proposes to conduct such events in rural schools of Surat, Bhuj and Banaskantha districts in the coming months

51st National Safety Week – 2022 @ IPR

The 51st National Safety Week was celebrated at IPR from 4-10 March 2022. This year's theme was "Nurture Young Minds, Develop Safety Culture" Due to COVID-19 pandemic situation, the institute organized various competitions online during this week to create safety awareness among its employees. Competitions were organized on Slogan in Gujarati, Hindi & English, Online Quiz and Essay Writing in Gujarati, Hindi & English based on decided topics for the employees of IPR, FCIPT & ITER-India. In addition to this, safety division also conducted an awareness program on Road Safety for contract drivers, demonstration of fire fighting equipment for security personnel and a training session for safety co-ordinators during this week.

The concluding session of the NSW was conducted on 10th March, with the following activities;

- Welcome address by Shri Sunil Kumar, Chairman, IPR Safety Committee
- A talk on "Periodic hydrostatic pressurization test and inspection of high pressure helium gas storage vessels at IPR" by Shri Rajiv Sharma
- Thoughts on safety delivered by Dr. S. Mukherjee, Dean (Admin.)
- Safety Pledge read out by the Dr. P. K. Atrey, Dean (R&D)

- Message on safety by Director, IPR. He emphasised the need for strong commitment towards safety and the need to improve the safety culture in the campus, keeping in mind the importance of the fact that "Nothing is of greater importance than the protection of human life"
- Vote of thanks by Shri D Modi

International Women's Day @ IPR

The International Women's Day was celebrated with great enthusiasm at IPR and FCIPT campuses on 8th March, 2022. The programmes at IPR began with a tribute to the legendary nightingale of India, Lata Mangeshkar who passed away on 6th February, 2022. This was followed by a talk on "Women Health and Wellness" by Dr. Nidhi Jain, eminent gynecologist and specialist doctor on IPR's CHSS panel. An exhibition of books authored by women was also kept on display. Women staff of IPR presented quotes by eminent women from various fields of life and also shared their experience of balance of work and home. At FCIPT, a similar event was organized. On this occasion, Dr. Sudhir Nema gave away gift hampers to the women housekeeping staff at FCIPT. Around 125 women staff members of IPR/FCIPT participated in the IWD event.

One-day workshop on Plasma Polarization

CPP-IPR also conducted a one-day workshop on Plasma Polarization at the St. Joseph's College (SJC), Jakhama, Nagaland on 19th March 2022. The event began with a welcome speech by the Principal, Fr. Dr. George K. Angami, and was followed by two scientific lecture sessions. In the first session Dr. Rakesh Moulick, SO-D, CPP-IPR presented his talk on Fundamentals of Plasma Physics while in the second session, Dr. Ng. Aomoa, SO-D, CPP-IPR presented experimental perspectives of Plasma Physics. In addition, there was a live demonstration session in which students were able to visualize Plasma and interact with the scientists. The event ended with a valedictory from Fr. Peter Solo, Dean of Sciences, SJC.

F. Other Activities

F.1 Outreach

During this period, institute's Outreach Division conducted the following events, which include events conducted under the umbrella of Azadi Ka Amrut Mahotsav.

Table F.1: Events conducted by outreach division is tabulated.

Event	Number of instances	Approximate Number of participants
Online Webinar on plasma, its applications and nuclear fusion (with interactive exhibits) for +2, BSc, MSc and B.Tech students as well as +2 and UG science teachers (conducted from IPR)	16	1,075
National Science Day 2022 (Conducted as on-line event at IPR)	01	300
Training program-cum-exhibition on plasma and its applications held at KIIT University, Bhubaneswar and Ravenshaw University, Cuttack (Odisha)	01	1,200
Rural Scientific Outreach Programme – Purusharth Saikshanik Sankul, Bhanvad, Devbhumi Dwaraka District, Gujarat	01	1,000
National Tokamak Gaming competition, conducted online in association with Aryabhatt Science Club, Ranka, (Jharkhand).	01	200
Science & Technology Exhibition on plasma and its applications under the "Vigyan Sarvatra Pujyate" event held at Gujarat University.	01	10,000

• The infrastructure for organizing on-line events was further upgraded to improve the quality of the online events.
• Apart from the above events, institute's Outreach also published online, a comic book on plasma for children. The comic, which is the first in the series named "Wonderful world of Plasma" was also translated into 13 Indian languages by institute's staff members. Over 1000 copies of this comic book in English, hind and Gujarati have hence been distributed to children at the various outreach events.
• Three new exhibits on plasma, viz., Inertial Electrostatic Confinement, Plasma crackle tube and Terella were also added to the outreach exhibit inventory. Procurement of two new models viz, cryo-pump as well as Lithium blanket were also initiated.
• AKAM banners were designed, printed and installed at institute's main gate as well as two other locations in the main campus. Similar design stickers were also printed and installed on lamp posts along the institute campus roads.
• Discussions were initiated with Gujarat Science City for establishment of a permanent exhibition of DAE as well as institute at the Science City Ahmedabad and appropriate area was also allotted for the same.
• There were no educational visits to the institute during this period due to the covid restrictions that were in force.

F.2 Official Language Implementation

As per the instructions of the Government of India, continuous efforts are being made for the smooth implementation of the Official Language Policy in the Institute, the details of which are given below:

<u>*Incentive Scheme:*</u> Under the ATOLIS incentive scheme of Department of Atomic Energy, employ-

ees/officers are enthusiastically participating in the incentive scheme to do official work in Hindi and are getting cash prizes.

Hindi Magazine: An edition of the Institute's Hindi home magazine 'Plasma Jyoti' was published during this period. The 29th edition of 'Plasma Jyoti' (e-published) was published and a soft copy link was sent to all the offices/organizations of the department and member offices of TOLIC, Gandhinagar.

Translation work: Completed translation work of annual reports, activity reports, abstracts of technical/scientific articles, section 3(3) documents and other documents, letters, forms etc. received from different sections of the Institute.

Shri Rajiv Sharma, Scientific Officer-D of the institute has received the Consolation prize in the Hindi quiz competition organized by the Institute of Hotel Management, Gandhinagar under the auspices of Town Official Language Implementation Committee on 7th April, 2021.

Institute received the first prize for the year 2020 for the best performance in the field of Official Language at TOLIC, Gandhinagar level during the half yearly meeting of TOLIC, Gandhinagar held on 16 April 2021.

The staff of the Institute participated in the webinar on 'Memory Based Translation Tool – Kanthstha' organized at TOLIC level. The employees of the institute also participated in various activities and workshops organized at TOLIC level.

On the occasion of World Environment Day - 2021, Shri Rajnikant Bhatasana, Scientific Assistant-C of the Institute participated in Hindi Poetry writing competition organized by Gujarat Environmental Management Institute (GEMI) and won second prize.

Three lectures were organized on various technical/scientific topics under the series "Taknik ke Saath, Vigyan Ki Baat".

Hindi officer of the institute participated in the five-day Faculty Development Program from 4 October to 8 October 2021, organized by Administrative Training Institute, DAE, Mumbai and Hindi Section, DAE, Mumbai. This program was specially organized for the Hindi cadre officers of the Department of Atomic Energy.

On the occasion of Vigilance Awareness Week, a Hindi drama "Daftar Ki Dastak" was presented by the staff members of the institute on 27th October, 2021.

Vigilance Awareness Week was observed in the institute from 26 October to 1 November 2021. During this period, poster and slogan writing competition in Hindi was organized.

Official language inspection of the institute was conducted on 29th October 2021 by the first subcommittee of the Hon'ble Parliamentary Committee on Official Language. On 29th October 2021, the Institute organized an official language exhibition at the inspection meeting site, in which the material related to the inspection and the propagation and achievements of the official language of the institute was displayed. In the inspection meeting, director of the institute gave a power point presentation on the activities of the institute, in which the special efforts being made in the field of official language along with the technical / scientific activities of the institute were also mentioned. The Hon'ble Parliamentary Committee appreciated the efforts and achievements of the Institute in the implementation of Official Language and gave guidance for its smooth implementation in the future also.

The translation work of the Institute's Annual Report from English to Hindi for the year 2020-21 was completed and published.

A lecture in Hindi on "National Integration and Communal Harmony" was organized by the Institute during the week of Communal Harmony Campaign observed from 19 November to 25 November 2021 in which Dr. Ram Gopal Singh, Division Head, Department of Hindi, Gujarat Vidyapeeth was invited. During "Communal Harmony Campaign Week", Hindi poster, Hindi essay and Hindi poetry writing competitions were organized on the theme of "Communal Harmony for National Development".

An article written by Ms. Pratibha Gupta, Scientific Officer-F of Institute on the topic "Exoplanet - the world beyond our solar system" has been published in 'Vaigyanik' magazine of Hindi Vigyan Sahitya Parishad, Mumbai.

Under the Central Hindi Training Institute, 18 officers/employees of Institute for Plasma Research were nominated for Hindi language training (Prabodh-2, Praveen-6, Pragya-2, Parangat-8) organized by Hindi Teaching Scheme in January-May, 2022 session.

In the All India Hindi Webinar organized by IGCAR, Kalpakkam during January 10-11, 2022, Shri Raj Singh, Scientific Officer-H of the institute gave the invited talk on the topic "Fusion Revolution - How much trust worthy?" and Shri Rajeev Sharma, Scientific Officer-D gave a contributory presentation on the topic "Indigenous development of neutron resistant insulation material for superconducting fusion magnets."

On the occasion of World Hindi Day on 10th January 2022, a lecture on "Benefits of Retirement" was delivered by Shri Niranjan Vaishnav, Chief Administrative Officer. Also a Quiz competition was organized on technical/scientific activities of the institute. On the occasion of World Hindi Day, the first issue of "Plasma Samachar" of Hindi monthly news of the institute was released by the Director and later on uploaded on the website. Three issues have been e-published till March 2022.

Hindi seminar was organized in the institute on 21st January 2022, in which presentation was given in simple Hindi language by 6 scientific officers on technical/scientific activities of the institute.

5 Office Clerks of the Institute have passed the Hindi Word Processing Typing Test on Computer conducted by the Central Hindi Training Institute in February-July 2021 session.

The employees/officers of the Institute enthusiastically participated in various competitions conducted under the aegis of TOLIC, Gandhinagar, viz. online General Knowledge Competition organized on 01.02.2022 by Bank of India, Zonal Office, Gandhinagar "Online Official Language Quiz Competition" organized by Bank of Maharashtra, Gandhinagar Branch on 09.02.2022, lecture on "Spring in the Age of Epidemic" organized by UCO Bank on 16th February, 2022, webinar on "Official Language in Banks/Offices: Relevance" organized by Indian Overseas Bank on 21st February 2022, Hindi workshop organized by the Institute of Hotel Management, Ahmedabad on 24 February 2022 on the topic 'Official Correspondence as per the rules of Official Language 3(3)', Webinar organized specially for women by Union Bank Limited on 10th March 2022, and in the workshop organized by National Seeds Corporation Limited, Gandhinagar on 25 March 2022 on the topic 'Implementation of

Official Language in Offices.

The program of National Science Day 2022 was organized online by the institute during 1-4 February 2022 under Azadi ka Amrit Mahotsav celebrations. In this program poster, essay, quiz, skit, speech and science model competitions were organized in Hindi, Gujarati and English languages through offline / online mode.

To explain children about Plasma candidly, a comic book was prepared in English by the Public Awareness Division of the Institute under the Azadi ka Amrit Mahotsav celebrations, and then translated into Hindi and 12 other Indian languages by the staff members of the Institute. This comic book was released by the Director during the concluding session of National Science Day-2022. This comic book is available in Hindi language along with other translated languages on institute's Outreach website.

Under “Vigyan Sarvatra Puyate” Science Exhibition organized by Gujarat University from 22 February to 28 February 2022, 15 technical models based on the scientific activities of the institute were displayed and information about it was given in Hindi language apart from English and Gujarati language by Public Awareness Division of the institute.

Various activities were organized during the Swachhta Pakhwada from 16-28 February, 2022. Slogan writing competition in Hindi on the theme “Clean City, the City of My Dreams” and a short video competition in Hindi on the theme “Cleanliness is not a campaign, it should be a part of lifestyle” was organized. Apart from the employees of the Institute, a speech competition in Hindi was organized online on 25 February 2022 for the students of the schools of Gujarat state.

On 28th Feb, 2022 on National Science Day, a graphic book entitled “Meet Greet and Tweet with PlasmaToons”, having captions both in Hindi and English languages was released by Dr. Jitendra Singh, Hon. Minister of State for the Ministry of Science & Technology, Earth Science and Minister of State for Prime Minister's Office, Personnel, Public Grievances & Pensions, Department of Atomic Energy and Department of Space at the Vigyan Bhawan New Delhi. The book has been authored by Dr. B. S. Munjal (Ex-ISRO Scientist) and Dr. Suryakant Gupta from the institute. This pictorial representation of complex Plasma Technology was developed with the motivation to draw the attention of young minds. This graphical representation of PlasmaToons focuses on explaining some of the basic and interesting aspects of plasma to young minds using the medium of cartoons.

A Hindi workshop organized through online mode under the aegis of TOLIC, Gandhinagar on March 4, 2022. Mr. Raj Singh, Scientific Officer – H of the institute delivered a lecture on the topic "Is it really difficult to adopt official language Hindi?”. Employees of the member offices of the TOLIC, Gandhinagar actively participated in this workshop.

Various competitions were organized in Gujarati, Hindi and English languages on the occasion of 51st National Safety Week. Slogan writing and essay writing competitions were organized in these three languages. In the concluding function of the National Safety Week, Shri Rajiv Sharma delivered a lecture in Hindi on "Periodic hydrostatic pressurization test and inspection of high pressure helium gas storage vessels at the instute.

A Hindi lecture was organized on the health problems of women on the occasion of International Women's Day.

During this period 143 technical abstracts were translated and displayed in the library.

A talk on 'Implementation of Official Language in Offices' was delivered by Dr. Sandhya Dave, Hindi Officer of the instute in the Hindi webinar organized by National Seed Corporation Limited, Gandhinagar under the aegis of Town Official Language Implementation Committee, Gandhinagar on March 25, 2022.

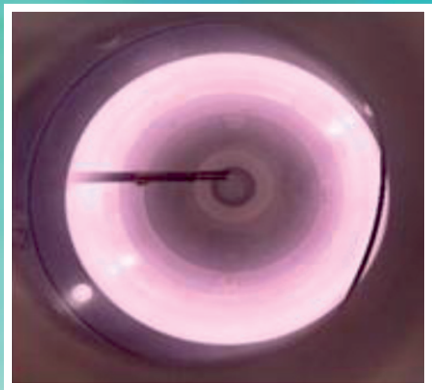
Figure F.1: Captured photos at various activities carried out by official language implementation section.

F.3 Right To Information

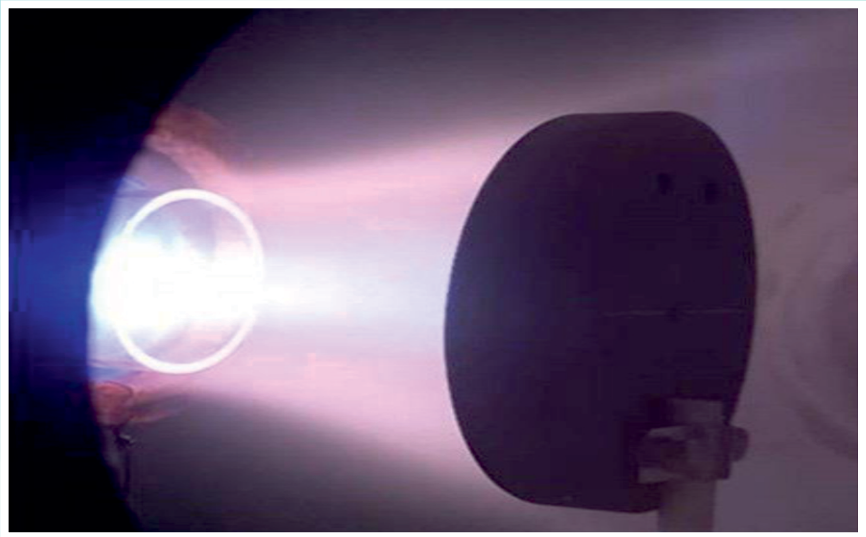
During the report period of 2021-22, a total of 62 RTI applications were received, out of which 56 were new RTI Applications, while 4 were Appeals to the Appellate Authority and 2 were Appeals to the CIC.

All of the above have been disposed off by the Public Information Officer and Appellate Authority within the prescribed time-limit.

स्वदेश में विकसित वैक्यूम बैरियर
Indigenously developed Vacuum Barrier



बीईएएम प्रयोगात्मक प्रणाली में वास्तविक प्लाज़्मा
Actual plasma in BEAM experimental system



संचालनरत हेलिकॉन थ्रस्टर
Helicon Thruster under operation

लाइगो-भारत परियोजना के लिए बीएससी और एचएएम प्रोटोटाइप वेसल
BSC and HAM prototype vessel for LIGO-India Project

29 अक्टूबर 2021 को संस्थान के राजभाषा निरीक्षण
के दौरान माननीय संसदीय समिति की उपसमिति
Hon'ble Parliamentary Committee during the Official Language Inspection of the Institute on 29th October 2021

राष्ट्रीय विज्ञान दिवस-2022 के दौरान कॉमिक पुस्तक
"प्लाज़्मा की अद्भुत दुनिया" का लोकार्पण किया गया
A comic book “Wonderful World of Plasma” released during the NSD-2022