

# ANNUAL REPORT

## 2013-2014



प्लाज़्मा अनुसंधान संस्थान

Institute for **Plasma Research**

Bhat, Gandhinagar 382428

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## EXECUTIVE SUMMARY

On 20th June, 2013 the first plasma was obtained successfully in the Steady-state Superconducting Tokamak-1 (SST-1) after an elaborate and extensive engineering validations. With this feat, India has joined an elite club of countries (after Russia, France, Japan, China and Korea) having superconducting tokamaks capable of steady-state operation. After the first plasma, experimental efforts are being continued to boost the plasma parameters. A maximum plasma current of 51 KA with a Toroidal Field (TF) of 0.75 T and 75 KA with TF of 1.5 T at the plasma centre SST-1 have been achieved. The testing experiments of Lower Hybrid Current Drive (LHCD) systems for real steady state operation has also been started and progressing well.

ADITYA was engaged in carrying out dedicated experiments on runaway mitigation, disruption control along with Electron (ECRH) and Ion (ICRH) Cyclotron Resonances Heating experiments. The second harmonic ECRH assisted breakdown has brought down the operating loop voltage to as low as 7 V, while the ICRH based wall conditioning has reduced the impurities like carbon and oxygen to very low levels.

The new projects initiated under the XII<sup>th</sup> five year plan to cater for more advanced technologies are progressing well. An 8-turn single layer solenoid using indigenously developed 30kA cable-in-conduit (CIC) superconductor was constructed and is being tested in the newly set up experimental facility. A new high heat flux test facility using high power electron beam as heat source and large D-shaped vacuum chamber has been set up. This set up is being used to test the material for the divertor and first wall technologies. Successful development of activated carbon sorbents and the experimental systems to study the adsorption properties, Degassing and Out-gassing measurements etc. have put the indigenous development of cryo-pumps in a pedestal. For the large cryogenic systems, small systems are being designed with modularity.

All the R&Ds required for the delivery of Test Blanket Module commitment to ITER have made significant progress at par with other ITER partners. Experiments are also being done to prove the safety worthiness of the Indian design. Irradiation experiments for the blanket mock-up assembly containing Lithium Titanate as breeder material and lead as multiplier have been performed using 14 MeV sealed neutron generator at the Fusion Neutronics Laboratory (FNL). A Prototype Robotic Articulated System for SST-1 In-Vessel Inspection and Maintenance System has been designed and work is in progress for its realization. For testing the Diagnostic Neutral Beam Injection (NBI) for ITER, a test facility is being set up in India, which will later be used for future NBI systems.

While the fundamental plasma experiments at the established set ups like Large Volume Plasma Device (LVPD), Basic Experiments on Toroidal Assembly (BETA) and Non-Neutral Plasma Experiment (SMARTEX-C) etc. are being continued to explore new areas of physics; prelimi-

nary experiments on new machines have also come up. High efficiency plasma torches developed earlier were scaled up to higher powers (up to 30KW) for continuous operation.

With one of the best computational facilities available in the country, the simulation and computational works are getting more and more sophisticated to explore the untouched areas of plasma physics. This venture is also being supported by the broad based fundamental theory expertise available in the institute. The different simulation codes available elsewhere are also being adopted for ADITYA and SST-1 experiments to explain the results obtained from these machines. These results, along with obvious results from other big tokamaks, are being used for the design of larger machine for future Indian Fusion Program through an integrated modelling.

The societal benefits of the technologies developed at FCIPT are inviting kudos from many quarters. The preliminary talks for two technology transfers to the industry from FCIPT had been very successful. Many MoUs were also being signed for many projects. In the meantime, the facilities at FCIPT are being beefed up with advanced material characterization and testing instruments which will be mainly used for material developments for fusion applications.

Most of the deliverable packages to ITER from ITER-India have entered the manufacturing phase along with a strict international quality control and assurance. To keep up the momentum and the quality of the work, regular review meetings are being arranged with relevant people at factory site itself. The building for the workshop necessary for final integration of Cryostat at ITER site has been completed. The R&D, wherever necessary is being done at ITER-India laboratory by developing and testing prototypes for various systems. The review of the projects under the domestic fusion programme (formerly called BRFST) was continued this year.

At the Center of Plasma Physics(CPP), Guwahati, along with many basic experiments, new works have also been started to cater for the major goals of the institute. A segmented plasma torch based divertor simulator system is being developed to study the physics of divertor region of tokamak plasma.

In a broad sense, the progress of the work in all the relevant areas of the institute is both encouraging and satisfying.

Director,  
IPR.

# *ANNUAL REPORT*

**APRIL 1, 2013 TO MARCH 31, 2014**

*Since 1986 the institute has been excelling in plasma physics research with fast growing facilities, trained man power and many fruitful national and international collaborations. Started with small tokamak experiments and basic plasma experiments, the institute has been acquiring expertise in all the relevant scientific and technological requirements for controlled thermonuclear fusion. Through the participation of the country in the International Thermonuclear Experimental Reactor (ITER), the developed technologies are being tested in the international arena. The activities of the Board of Research on Fusion Science and Technology (BRFST) and the Fusion Technology Development Programme under the past and current Five Year Plans are fuelling the required growth. At the same time basic experiments related to immediate plasma technology dissemination to industry through Facilitation Center for Industrial Plasma Technology (FCIPT) forms an integral part of the programme. Now the programme of the Center for Plasma Physics, are also being aligned to the main theme of fusion research*

## **CHAPTERS**

A.SUMMARY OF SCIENTIFIC & TECHNICAL PROGRAMME .....	01
B. ACTIVITIES OF OTHER CAMPUSES .....	37
C. ACADEMIC PROGRAMME .....	51
D.TECHNICAL SERVICES .....	51
E. PUBLICATIONS AND PRESENTATIONS .....	53





## ***CHAPTER A***

# **SUMMARY OF SCIENTIFIC & TECHNOLOGICAL PROGRAMMES**

<b>A.1 Fusion Plasma Experiments .....</b>	<b>02</b>
<b>A.2 Fusion Technology Developments .....</b>	<b>09</b>
<b>A.3 Basic Plasma Experiments .....</b>	<b>24</b>
<b>A.4 Theoretical, Modelling &amp; Computational Plasma Physics .....</b>	<b>31</b>

## A.1 Fusion Plasma Experiments

There are two existing facilities in the institute to do experiments related to fusion plasma, namely Aditya tokamak and Steady-state Superconducting Tokamak-I (SST-I). In this section the status of the device, new developments and details about the experiments done are given.

### A.1.1 Aditya Tokamak

<i>A.1.1 Status of the Device &amp; Experimental Results .....</i>	<i>02</i>
<i>A.1.2 Diagnostics Developments .....</i>	<i>03</i>
<i>A.1.3 Heating Systems .....</i>	<i>04</i>
<i>A.1.2 Steady-state Superconducting Tokamak(SST-1)</i>	
<i>A.1.2.1 Status of the Device .....</i>	<i>05</i>
<i>A.1.2.2 Diagnostics Developments .....</i>	<i>06</i>
<i>A.1.2.3 Heating and Current Drive Systems .....</i>	<i>07</i>

### A.1.1 Aditya Tokamak

#### A.1.1.1 Status of the Device & Experimental Results

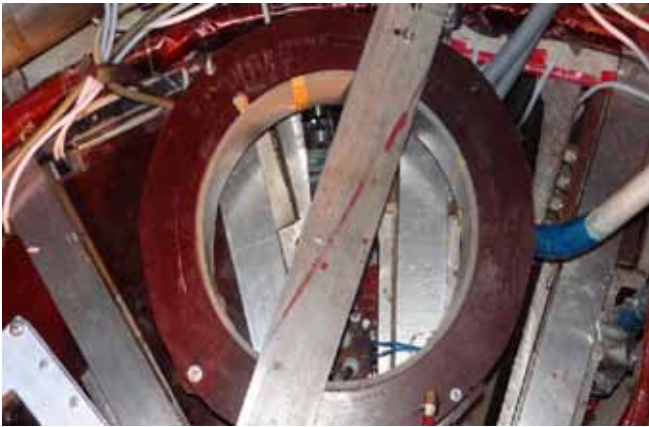
This machine, an air-core, mid-sized ( $R=75$  cm,  $a=25$  cm) ohmically heated circular limiter tokamak, is engaged in carrying out several dedicated experiments on runaway mitigation, disruption control etc. which are of utmost importance for the successful operation of large size tokamaks, such as ITER. The outcomes of these innovative experiments are very encouraging and will play a significant role in future tokamak operations.

**Runaway Mitigation:** Runaway electron generation and mitigation remains challenging topic in the present tokamak research, as these high-energetic electrons can cause severe damage to the vacuum vessel of any tokamak if left uncontrolled. An innovative mechanism has been developed in ADITYA tokamak to mitigate the runaway electrons before they can gain high energies. A localized vertical magnetic field (LVF) perturbation is applied at one toroidal location using two Helmholtz like coils is shown in Figure A.1.1.1, placed at top and bottom of ADITYA tokamak, to extract runaway electrons. The number of turns ( $n$ )  $\sim 50$  turns/coils and the distance from plasma centre to coil centre is approximately 80 cm. The coils were connected to produce local vertical field is in opposite direction to the actual equilibrium field. When LVF pulse applied during ramp-up phase of the plasma current at 30 ms into the discharge, we observed significant reduction in runaway driven plasma current and hard

X-rays. The applied local LVF perturbation acts like an error field for the high energetic runaway electrons and they get lost whereas the much slower thermal plasma electrons remain almost unaffected by this perturbation leading to better discharges in Aditya tokamak. This technique may very well be used to avoid disruption generated runaway electrons to attain high energies in bigger tokamaks.

**Disruptions Mitigation:** Disruptions are rapid events in which large fractions of the plasma thermal energy is lost suddenly and must be avoided for successful operations of bigger tokamaks including ITER. Disruptions, induced by hydrogen gas puffing, are successfully mitigated by two innovative techniques in Aditya tokamak.

(i) By application of voltage to a Mo electrode placed inside the limiter radius of Aditya tokamak and (ii) By launching Ion Cyclotron Resonance Heating (ICRH) pulse of suitable power. These experiments led to better understanding of the disruption control mechanisms and also can be thought of as one of options for disruption control in ITER. In both the techniques, after obtaining reproducible discharges in Aditya tokamak we have injected hydrogen gas in sufficient amount to causes deliberate disruption of plasma current. The hydrogen gas puff excites MHD modes that grow in amplitude, get locked and stop rotating leading to disruption of plasma. However, with the application of positive bias voltage to a Mo electrode placed inside the limiter radius before the gas puff, it has been leading to substantial reduction of the growth of magnetic islands corresponding to  $m/n = 3/1, 2/1$  MHD modes. This in turn avoids mode locking and the sudden dis-



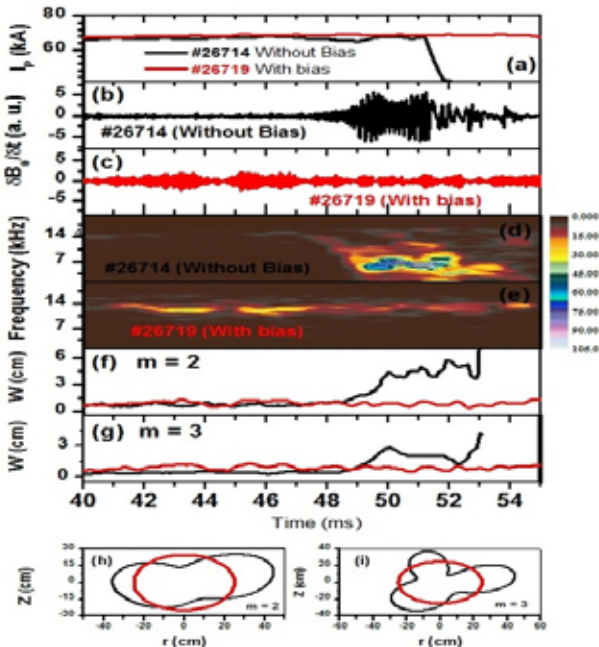
*Figure A.1.1.1. Top and bottom runaway extraction coils*

ruption of plasma current is avoided. The results are shown in Figure A.1.1.2. It was also successfully demonstrated to avoid plasma disruptions by applying an ICRH pulse of frequency 24.8 MHz and power  $\sim 50$  to 70 kW through a fast wave poloidal type antenna sitting outside LCFS as shown in figure A.1.1.3. In this case too a Hydrogen gas puff of sufficient amount has been injected to create disruptions, which are then mitigated by launching an ICRH pulse prior to the gas injection. The results obtained are quite similar to the biasing experiments, as MHD modes did not grow in case of ICRH applications.

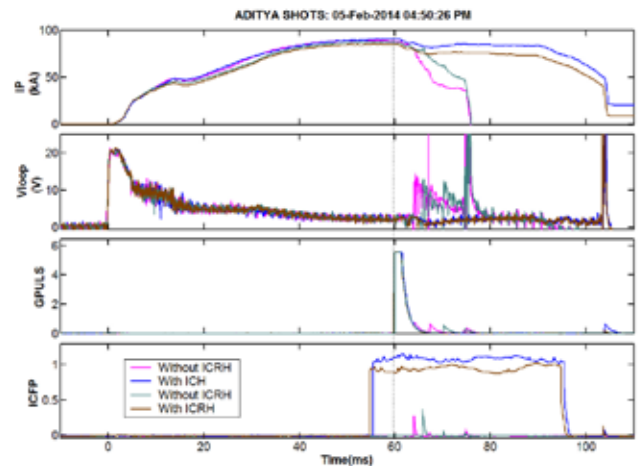
**ITPA Disruption Database:** Analysing thoroughly the huge database of different types of spontaneous and deliberately-triggered disruptions from ADITYA tokamak, a significant contribution has been made to the international disruption database (ITPA). After identification and categorization of over 100 disruptive discharges of Aditya a database is generated as per ITPA suggested format and have been uploaded to ITPA disruption database working group. The IDDB presently includes contributions from nine tokamaks, including both conventional aspect ratio tokamaks and spherical tokamaks. An initial parametric analysis of the available data was presented.

### A.1.1.2 Diagnostics Developments

**Infrared Imaging Video Bolometer:** It utilizes free standing



*Figure A.1.1.2. Disruption avoidance with electrode biasing in Aditya tokamak*



*Figure A.1.1.3 Disruption control with ICRH in Aditya tokamak*

ultra thin large area metal foil, which absorbs radiated power from high temperature magnetically confined plasma through pinhole camera geometry in wide spectral range (SXR to UV). This absorbed power alters the temperature profile on the foil area which is optically (by infrared radiation) imaged and measured by the Infrared Camera seating outside the vacuum vessel through Infrared Transmitting vacuum view port. Using heat diffusion analysis of 2-D temperature profile, total radiated power profile from plasma can be determined. The techniques is being first time utilize for the medium size tokamak, ADITYA.

**Charge Exchange Diagnostics:** This system is installed at ADITYA tokamak (radial port no. 10) and has successfully been operated during the plasma discharges to measure the core ion temperature during the evolution of ohmic plasma. The measurement of core ion temperature is based on the passive mode of charge exchange diagnostics which uses the neutral particle analyzer [NPA] with the electrostatic parallel plate configuration to resolve the different energy components in the neutral beam which comes out of the confined plasma.

**Spectroscopy Diagnostics:** A Photomultiplier Array based diagnostic system has been developed to measure the temporal and spatial profiles of H-alpha, H-beta, and CIII emissions from Aditya tokamak. This diagnostic has a spatial and temporal resolution of 3.0 cm and 10 micro-s, respectively, enabling to study the plasma behaviour during fast changing breakdown and current ramp up phases of the tokamak. The diagnostic consists of lens and optical fiber to view the plasma and transport the light, interference filter for wavelength selection and a modular type detector housing. Experiments were carried out to study the plasma formation in the Aditya tokamak. The study reveals that plasma breakdown occurs nearly at the middle of the high field side of tokamak and this also matches with the magnetic null location estimated through simulation. The optical fiber, interference filter and PMT based H-alpha and impurities emission monitoring, Visible and VUV survey spectroscopy and space resolved multi-track spectroscopy system were in regular operation during various experiments giving valuable information on Aditya tokamak plasma properties, as for example, temporal behaviour of H-alpha signal shows remarkable modification during ICRH experiment. Spatial scanning mirror of NIM system has been converted from its manual to automatic mode operation using servomotor and PLC based system to set the viewing chord in the plasma remotely. This enables to easily change the viewing chord location for the spatial pro-

file measurement of highly ionized impurity emission without accessing the Aditya tokamak.

### A.1.1.3 Heating Systems

**Ion Cyclotron Resonance Heating (ICRH) Experiments:** The system installed on ADITYA have 1 MW RF generator in the frequency range of 20-40 MHz, transmission line with matching system, vacuum interface and fast wave poloidal type antenna with Faraday shield. The heating experiments at second harmonic are carried out using RF pulses of different magnitudes (5 ms-100 ms) at different RF powers (40 kW-200 kW) in plasma duration of 100 ms. The soft X-ray data shows an electron temperature rise from 250 eV to maximum of 500 eV and Neutral Particle Analyser data as well data from Doppler broadening shows the ion temperature rise up to 350 eV.

**Wall Conditioning using ICRH (ICWC):** These experiments are carried out by applying many ICR pulses for 50 ms up to 1.2 seconds and the variations in RGA before and after the application of pulses are recorded to analyse the improvements in vacuum conditions. The ICR plasma is characterised by spectroscopic diagnostics. The experiments are carried out with resonance layer at 0.75 T, without resonance layer at 0.45 T and with the addition of 20% He in hydrogen plasma at 0.45 T. The toroidal magnetic field has a flat top for 1 second and RF pulses of 50-60 kW at 24.8 MHz are introduced during flattop and the gas is fed in continuous mode in the range of  $1 \times 10^{-4}$  to  $3 \times 10^{-4}$  Torr. The relative levels of oxygen and carbon contain impurities have been measured using RGA. All three sets are found to be effective in releasing wall impurities like water & methane. According to the observations, the resonant ICWC is more effective to reduce carbon impurity and non-resonant ICWC is more effective to reduce oxygen impurity from vessel.

**Electron Cyclotron Resonance Heating (ECRH) Experiment:** The gyrotron based ECRH system installed on Aditya having 42 GHz frequency and 500 kW power. The 42GHz system was planned to carry out ECRH assisted plasma breakdown experiments on SST-1 as well as on Aditya. The Gyrotron operates from SST-1 tokamak and transmits power to Aditya tokamak successfully with minimum loss through an ~80 m fibre-optic communication. The Aditya tokamak operates at 0.75T magnetic field and second harmonic ECRH assisted breakdown has been carried out successfully at lower

loop voltage. The ECRH power in second harmonic X-mode is launched in Aditya tokamak and several experiments have been carried out. The normal operating loop voltage of Aditya is  $\sim 22V$ , the ECRH facilitate tokamak to operate at lower loop voltage and save the volt-second consumption during discharge. The Aditya tokamak has been operated successfully at lower loop voltage up to 7V, this lower loop voltage operation in Aditya is a remarkable achievement which could be possible with ECRH assisted breakdown. In Aditya approximately 100-150kW ECRH power is launched around  $\sim 30ms$  prior the loop voltage and successful pre-ionization & breakdown is achieved consistently with pre-ionized density  $\sim 2 - 4 \times 10^{18}m^{-3}$ . The breakdown experiments are carried out over wide range of pressure from  $1 \times 10^{-4}$  torr to  $1 \times 10^{-5}$  torr. The appearance of H\_alpha with ECRH power shows successful pre-ionization and start-up at low loop voltage.

### A.1.2 Steady-state Superconducting Tokamak (SST-1)

#### A.1.2.1 Status of the Device

After the successful conclusion of the ‘engineering validations’ in SST-1 of the various integrated sub-systems, starting April 2011 plasma break down and current ramp-up

experimental initiatives were undertaken in SST-1 (figure A.1.2.1.a ). In the ‘engineering validation phase’; SST-1 had demonstrated that the superconducting Toroidal Field Magnets could be successfully cooled with the available SST-1 helium refrigeration and liquefaction system in a total duration of sixteen days in a controlled manner with allowed thermal strain; the helium leak tightness of the entire 5 K helium circuits including magnets, manifolds and helium communication hydraulics in the cryostat and in the current feeder box; helium leak tightness of the 80 K thermal shields and insurance of temperature uniformity over the entire 130 m<sup>2</sup> LN2 cooled surfaces, Ultra High vacuum compatibility of the assembled vacuum vessel having a total volume of  $\sim 25$  m<sup>3</sup> as well as the synchronization of the signals and events in microseconds time scale in various heterogeneous sub-systems of SST-1. The superconductivity state of the SST-1 TF magnets and the successful charging of the TF magnets up to 1.5 T have been shown in Figure A.1.2.1.b and Figure A.1.2.1.c respectively. Successful break-down of the SST-1 plasma enabled with a 42 GHz, 500 ms Electron Cyclotron source in second harmonic mode and with a power of  $\sim 200$  KW was obtained in May 2013 after which the plasma current ramp-up experiments were initiated providing appropriate field indices and equilibrium fields on the plasma column. Most importantly, the first plasma having a current of  $\sim$

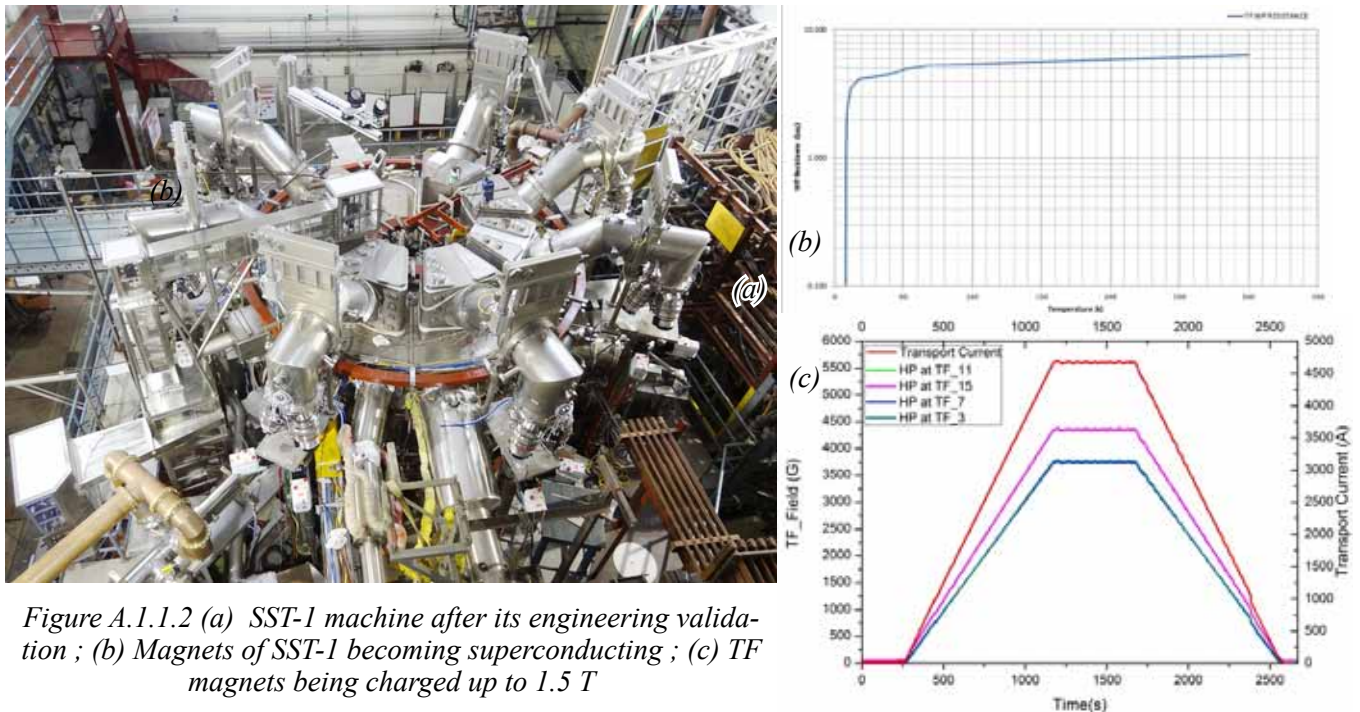


Figure A.1.1.2 (a) SST-1 machine after its engineering validation ; (b) Magnets of SST-1 becoming superconducting ; (c) TF magnets being charged up to 1.5 T

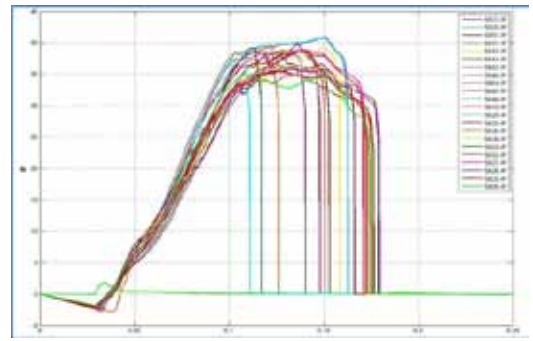
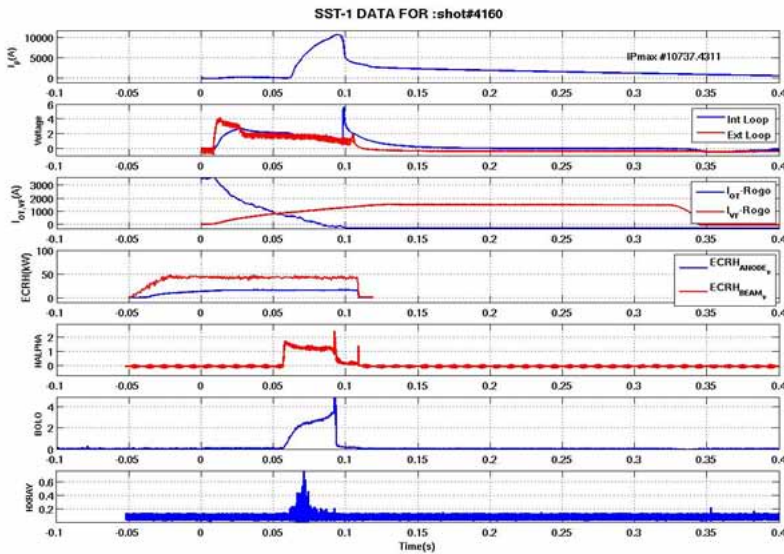


Figure A.1.2.2 (top) First Plasma in SST-1 on June 20, 2013

Figure A.1.2.3 (left) Plasma in SST-1 with a flat-top at 0.75 T

12000 A was obtained on June 20, 2013 during the campaign-IV of SST-1 (figure A.1.2.2). With this unique achievement in SST-1, Indian joined the elite club of countries having successful superconducting Tokamak devices and SST-1 became an experimental device capable of carrying out high aspect ratio plasma experiments. In the campaign-VI, in the second half of 2013-14, SST-1 achieved a maximum plasma current of 51 KA with a field of 0.75 T at the plasma centre (figure A.1.2.3). At subsequent attempts, SST-1 would be operated with a field of 1.5 T at the plasma centre and the pulse length of the plasma would be aimed to stretched beyond 300 ms either by adjusting the vertical equilibrium field with pure Ohmic plasma mode or in assistance with Lower Hybrid

coupling from external sources. SST-1 has also made several unique first-of-its-kind achievements in its engineering and technological capabilities during the report period. SST-1 TF magnets even though are wound with cable-in-conduit (CIC) superconductors have been demonstrated to operate successfully in a cryo-stable manner with Two-phase helium cooling provided by the SST-1 Helium Refrigeration and Liquefaction (HRL) facility (figure A.1.2.4) . These are the only Steady State Tokamak magnets in the world which operates in Two-phase helium. The SST-1 vapor cooled Current Leads have also demonstrated to be operating successfully with cold helium gas instead of liquid helium exploiting the latent heat alone as against latent heat and enthalpy.

**A.1.2.2 Diagnostic Developments**

**Far Infrared Interferometer:** A multiview, multichannel far infrared (FIR) interferometer is being installed on SST-1 tokamak. The radiation source for the vertical and tangential view of FIR interferometer is an optically pumped twin FIR 118.8 mm methanol laser. The FIR beams propagate from (i) laser output couplers to the waveguides; (ii) through waveguides up to the FIR interferometer support structure near SST-1 tokamak; (iii) in free space through optics mounted on the support structure; (iv) through plasma and (v) in free space up to the detectors. The optical components to couple laser beams from laser output coupler to the waveguides and all the optical components on the support structure are enclosed by vacuum enclosures. These enclosures and the waveguides themselves are purged with dry nitrogen. The free space propagation involves steering, focusing and manipulating

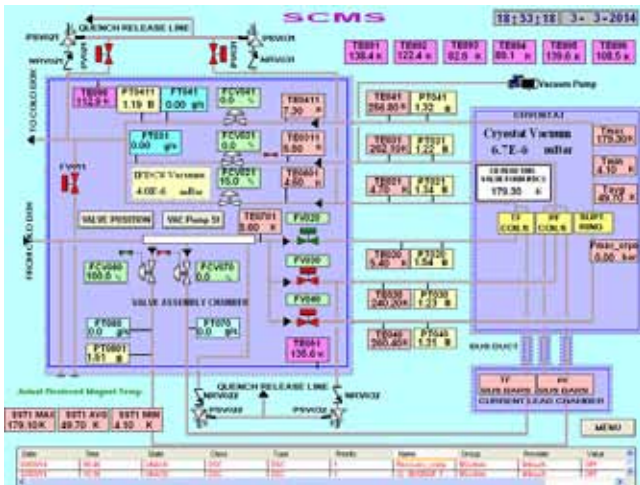


Figure A.1.2.4 The HRL parameters showing the Two-Phase cooling of SST-1 TF operating at 1.5 T

of the beams using around 100 optical components mounted on ~ 7.25 m high support structure. In case of multichannel interferometer, the paths of beams for various channels are matched using plane mirrors. The corner cube retroreflectors have been mounted on the vessel wall for tangential viewing, which reflect the beams back along the same path. After propagation through plasma, the beams are coupled to the Mixers by matching their beam diameter with the mixers' antenna pattern using ellipsoidal mirrors.

**Infrared Thermography (IRT) of Plasma Facing Components:** Infrared Thermography (IRT) of Plasma Facing Components (PFCs, namely Limiter, Diverter etc.) is one of the most essential tools to investigate interaction of plasma with PFCs as it has an advantage of real time monitoring of the surface temperatures remotely with wide field of view (FOV). Limiter Thermography diagnostic system is also upgraded with anti-reflection coated large viewing area IR vacuum view ports at Radial Port-12 of SST-1 tokamak. This will increase Field of View of the system and decrease alignment/installation timings. Cross-calibration of IR-camera temperature with thermocouple embedded in SST-1 limiter was done to estimate reflection and transmission coefficients of IR-Imaging system.

**Infrared Camera for detection of synchrotron radiation emitted by Runaway Electrons:** Conventional runaway diagnostics measures those runaways that are no longer confined (Hard X-Ray monitor). Soft X-ray-array and Fast Electron Bremsstrahlung-array has limitation to detect high

energy REs (Energy > 20 MeV). IR diagnostic technique detects REs when they are still confined inside the plasma and should detect REs with high energy also.

**Charge Exchange (CX) Diagnostics:** This is also deployed at radial port 15 of SST-1, for measuring the core ion temperature of the plasma. At present, the measurement of core ion temperature is based on the passive mode of charge exchange diagnostics which uses the Neutral Particle Analyzer [NPA] with the electrostatic parallel plate configuration to resolve the different energy components in the neutral beam which comes out of the confined plasma. Procurement of another set of ion-detectors and DAQ module for this system is in progress.

**Spectroscopy Diagnostics:** The spectral emissions from H-alpha, H-beta, visible continuum and impurities such, as CII, CIII, OI, OII, OIII, and OV have been regularly monitored during various campaigns of SST-1 tokamak using optical fiber, interference filter and PMT detector based spectroscopic system. Three channels broadband low resolution survey spectrometer have regularly recorded the spectrum in visible wavelength range during the SST-1 plasma operation.

#### A.1.2.3 Heating and Current Drive Systems

##### Electron Cyclotron Resonance Heating System

The 42GHz-500kW ECRH system is used on tokamak SST-1 to carry out ECRH assisted plasma breakdown and start-up experiments at fundamental and second harmonic. The SST1

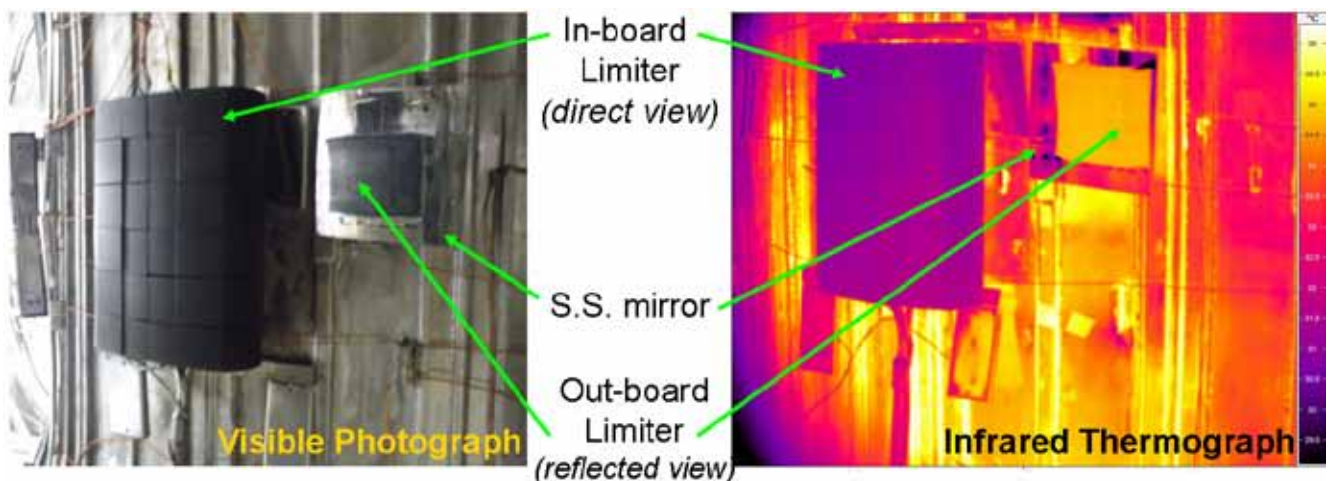


Figure A.1.2.5 Visible photograph (left) shows in-board and out-board limiters (mirror reflection) of the SST-1 from IR-camera view-port. Corresponding IR-thermograph (right) shows the same field of view of the IR-camera.

tokamak is operated at 0.75 & 1.5T magnetic field, various experiments related ECRH assisted plasma breakdown have been carried out. The ECRH experiments are divided into two categories depending on operating toroidal magnetic field:

i) ECRH assisted breakdown at fundamental harmonic: The SST1 is operated to 1.5T operation, ECRH power (~100 to 200kW) in fundamental O-mode is launched from low field side of tokamak. The power is launched around 20ms before the loop voltage. The consistent breakdown assisted with ECRH is achieved in SST1 tokamak, the pre-ionized density in SST1 is  $\sim 4 \times 10^{12}/\text{cc}$ . at operating pressure  $\sim 1 \times 10^{-5}$  mbar.

ii) Second harmonic ECRH assisted breakdown in SST-1: The SST1 tokamak operation at 0.75T magnetic field corresponds to second harmonic for 42GHz ECRH system. The second harmonic ECRH assisted breakdown requires more power as coupling of ECR waves is different at second harmonic. For second harmonic ECRH assisted breakdown experiment on tokamak SST-1, approximately 250 to 300kW ECRH power is launched in X2-mode. The pulse duration for ECRH power is varied from 125ms to 200ms. Since there is delay in second harmonic ECRH assisted breakdown ECRH is launched around 50ms before the loop voltage. The successful second harmonic ECRH assisted breakdown has been achieved in SST-1 at 0.75T operation. The pre-ionized density is  $\sim 4 \times 10^{12}/\text{cc}$ .

**82.6GHz ECRH system for SST-1:** This system is scheduled to connect with SST-1 tokamak to carry out ECRH experiments at 1.5T and 3.0T operation. The layout to connect 82.6GHz system has been finalized and other components like transmission line support, water cooling valves etc. are under procurement. As the launcher for 82.6GHz system is already connected to tokamak SST-1 port (no. 5), the system would be connected to tokamak SST-1 in near future and experiments would be carried out at 1.5T operation (second harmonic).

**RHVPS for Gyrotron testing in pulsed condition:** The 80kV-15A regulated high voltage power supply (RHVPS) dedicated to ECRH is operational with open load test. The RHVPS has been tested stand alone and with ignitron based crowbar system successfully. The integration of 15A RHVPS with Gyrotron system is being planned in the next year.

### Lower Hybrid Current Drive (LHCD) System

**System Integration:** After integrating the in-vessel com-

ponents (grill antenna, vacuum window, In-Vessel Module (IVM), etc.) inside SST-1 machine, it was connected to the high power RF source by means of complex and huge transmission line distribution network. An SS plate (instead of carbon to avoid degassing) was mounted around the grill antenna for protection and to act as a local limiter around grill. Prior to campaign-3, when SST1 machine vessel was maintained in vacuum, the LHCD system was energized for RF conditioning. Several trains of short rf pulses at low power were launched into the machine. Gradually the pulse length was increased to 100ms. Once the LHCD was conditioned at low power, the RF conditioning was repeated by gradually increasing the RF power for short pulses and increasing pulse length in gradual steps. Eventually, the LHCD system was conditioned up to  $\sim 160$  kW. Several diagnostics were installed on LHCD system. The IR camera was installed on the top port (above radial port-4) to image grill antenna. Scintillating (CdTe) detector was mounted to monitor supra-thermal electrons generated during interaction of lower hybrid waves with plasma. Langmuir probes were connected to electronic circuits to measure the edge plasma parameter close to grill antenna. The hard X-ray system drawing is also included in the model. After integrating LHCD system with SST1 machine, the entire LHCD system was QA/QC qualified. The PXI based data acquisition and control (DAC) system for operation of two klystrons simultaneously has been procured and the same has been tested in standalone mode for all the channels.

**Pre-ionization using LHCD System:** Experiments were performed on SST-1 machine by exploring the pre-ionization capability of LHCD system. The LHCD system was operated in a special configuration and experiments were tailored to successfully demonstrate the pre-ionization. The pre-ionization of the plasma with LHCD system was confirmed by observation of H-alpha signal with LHCD power.

**Current Drive Experiments:** The interaction of lower hybrid waves with plasma was also observed. A small drop in loop voltage with injection of LHCD power in SST-1 machine suggesting interaction of LHCD waves with plasma. In the experiment, the toroidal magnetic field was at 1.5 T and machine fill pressure was  $\sim 9.0 \times 10^{-6}$  mbar.

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## A.2 Fusion Technologies Development

Under continuing five year plans, various technologies related to fusion are being developed under the following heads:

A.2.1 Magnet Technology.....	09
A.2.2 Divertor & First Wall Technologies.....	10
A.2.3 Cryo-pump & Pellet Injector .....	12
A.2.4 Test Blanket Module (TBM) .....	14
A.2.5 Large Cryogenic Plants & Cryo-systems (LCPC).....	15
A.2.6 Remote Handling & Robotics Technology.....	17
A.2.7 Negative Ion Neutral Beam System.....	17
A.2.8 Fusion Reactor Materials Development & Characterization.....	19
A.2.9 Fusion Neutronics & its Diagnostics Development.....	20
A.2.10 Fusion Fuel Cycle Development.....	21

### A.2.1 Magnet Technology

Magnet Technologies have made significant progress during the report period. (i) Development of an appropriate ester based high temperature insulation including its successful characterization; (ii) development of prototype radial plates suitable for fusion relevant prototype magnets; (iii) devel-

opment of a 30 KA, 300 V power supply indigenously with the help of Indian industries; (iv) successful fabrication of a 8-turn single layer solenoid using 30000 A indigenously developed cable-in-conduit (CIC) superconductors (Figure A.2.1.1); (v) fabrication and successful characterization of novel intermediate superconductor MgB<sub>2</sub> based race track magnet; (vi) experimental demonstration and validation of



Figure A.2.1.1 Prototype magnet (8-turn single layer) wound with indigenous CIC superconductors of 30kA rating

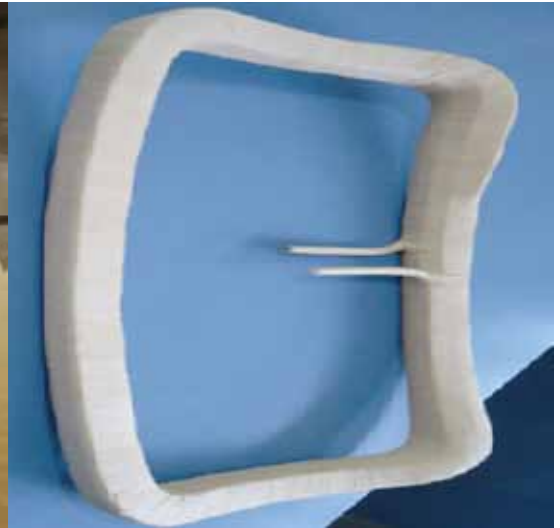


Figure A.2.1.2 A winding prototype of the ELM coil

IGBT and mechanical DCCB based hybrid circuit breakers; (vii) development of special purpose winding machines for Edge Localized Mode (ELM) coils fabrication (Figure A.2.1.2) and (viii) successful technology validations for casing of the ELM coils are some of the milestone achievements. Apart from these, as a part of national initiative, a superconducting Gyrotron cavity magnet appropriate for 42 GHz applications has also been successfully tested. The development of the high temperature insulation has enabled IPR to extend the same for 1:1 ELM coil fabrication of the Joint European Torus (JET) under international collaboration agreements. The radial plates will be used for  $Nb_3Sn$  based prototype TF coils developments. The 30000 A, 300 V power supply shall be used to test fusion relevant prototype magnets in an experimental cryostat which had already been fabricated and validated with 80 K thermal shields. The 8-turn single layer solenoid will be tested in this experimental test facility as a final validation of the development of the indigenous CIC superconductors in a magnet winding pack. Successful experimental validation of the  $MgB_2$  based race track magnet has opened the possibility of using this exciting and novel superconductors in the ELM coils in SST-1 Tokamak at 20-25 K in future apart from its potential usage in wind turbine generators. The hybrid circuit breaker concept experimental validation had also opened exciting possibilities of reliable

and redundant protection of large superconducting magnet with a combination of mechanical circuit breaker and IGBTs. The ELM coil winding is a typical in-out and out-in kind of winding and has been successfully developed for the JET ELM coils. The successful development of the technologies related to the casing fabrications of the same has made IPR a creditable collaborator towards the JET ELM coils. Towards the testing of the 1:1 prototype ELM coils, Magnet Technology Division had also successfully fabricated a 1.5 KA, 250 V power supply. High performance  $Nb_3Al$  superconductor developmental initiatives have also been launched and the first strand of  $Nb_3Al$  are expected soon.

## A.2.2 Divertor & First Wall Technology

### *Development of High Heat Flux Test Facility (HHFTF) :*

High power electron beam source capable of producing cylindrical electron beam of 200kW/45kV (in pulsed as well as steady-state mode of operation) is installed, integrated and tested for its full 200kW power operation. : Large D-shaped vacuum chamber with target-handling facility fabricated, installed & commissioned at IPR. An integrated and interactive graphical tool is developed to simulate a virtual experiment life cycle consist of compute-simulate and measure activities. This toolkit is used to validate the mock up experiments at



*Figure A.2.2.1 D-shaped double walled vacuum chamber & target handling system for testing components whose weight is up to 1 tonne*



Figure A.2.2.2 (a) Curved Tungsten mono-block

high heat flux test facility. A high temperature Cavity Blackbody is installed & commissioned for calibration of non-contact type infra-red thermal sensing equipment such as IR-Pyrometer and IR-Camera. The facility allows calibration in the temperature range of 600 °C to 3000 °C. Procurement of HPHT-WCS is in progress for providing coolant water to the components/ test mock-ups during High Heat Flux tests with pressure 5 to 60 bar, temperature 25 °C to 160 °C and maximum flow rate up to 300 litre/minute.

**Divertor target development:** Tungsten alloy mono-block test mock-ups with straight as well as curved copper-alloy tube (Figure A.2.2.2) developed by NFTDC (Hyderabad) were tested with incident heat flux up to 20MW/m<sup>2</sup> using newly installed High Heat Flux test facility at IPR that uses 200kW electron beam as heat source. Both the test mock-ups could withstand successfully several hundred thermal cycles of incident heat flux up to 20MW/m<sup>2</sup>.

**Copper deposition on Carbon-Fibre-Composite (CFC) material:** Oxygen-Free High thermal Conductivity (OFHC) copper is successfully joined with CFC surface using laser texturing & laser cladding process developed at M/s Magod Laser (Bangalore). Vacuum casting of OFHC copper on titanium clad CFC surface was done using vacuum furnace at IPR.

**Studies on Tungsten Materials Development:** Pure tungsten (W) as well as tungsten alloy (W + 1%La<sub>2</sub>O<sub>3</sub>) materials with fine microstructure has been synthesized by using Direct Sintering Press process. Achieved density of 18.6g/cc and 17.9g/cc respectively indicates that about 96% of theoretical densi-



Figure A.2.2.2 (b) Straight tungsten mono-block

ty could be obtained in these experiments. Thermal Conductivity of these materials measured in temperature range 45 °C to 200 °C is found to be 143-163W/mK for pure tungsten and 144-157W/mK for W+1%La<sub>2</sub>O<sub>3</sub>.

**Irradiation damage studies on tungsten materials using high energy heavy ion beam:** Heavy ion irradiation is taken as a proxy for neutron irradiation to simulate radiation damages in tungsten. Tungsten specimen of dimensions of [8X8X3]mm, is irradiated with gold ions of energy 120MeV at different fluence at IUAC (New Delhi at room temperature. The damage level is estimated from TRIM simulations corresponding to fluence of 1.5X10<sup>14</sup> ions/cm<sup>2</sup> and it is found to be 0.34dpa. The scanning electron micrographs of irradiated specimens show formation of ripples, having period of nearly 100nm. In case of irradiated tungsten specimen, the electrical resistance has increased, which suggests generation of defects/dislocation loops inside tungsten specimen.



Figure A.2.2.3 Curved Tungsten Macro-Brush brazed with CuCrZr substrate

For further confirmation of defect induction inside tungsten lattice, positron annihilation lifetime measurements were carried out at Radiochemistry division of BARC, on pristine and ion beam irradiated tungsten specimens. The variation in positron annihilation lifetime in heavy ion implanted specimens further confirms evolution of vacancy clusters under heavy ion irradiation.

**Brazing Studies and Brazing Experiments:** Studies on fabrication of small-scale (i.e. half size in toroidal and poloidal extent) ITER-like Dome target using Tungsten macro-brush technology are in progress. Fixture design is carried out by performing finite element (thermal & structural) analysis under brazing cycle conditions of a vacuum furnace. Procurement of materials for fabrication is in progress. Joining of Carbon (Graphite) on CuCrZr blocks was successfully developed in coupon level in vacuum brazing using Titanium based filler material such as TiCuNi-70 and TiBraze-375.

**Tungsten Coating Technology Development:** Tungsten coating on stainless steel substrate developed during feasibility study at ARCI (Hyderabad) is used for flaw-detection studies using Ultrasonic Flaw Detector. It is observed that delamination of 40 micron thick coating on SS304 substrate can be detected. MoU is being discussed for further collaborative work with ARCI on the tungsten coating technology development for first wall application.

**Material Studies using Gleeble3800 Thermo-mechanical Simulator System:** Uni-axial compression tests are done on XM 19 (UNS S20910) material. This is one of the structural materials of divertor cassette. XM 19 forging is done to fabricate the various parts of Divertor Cassette. Uni-axial compression tests on XM-19 are done to study the flow behaviour and workability of the material, this will provide primary details for forging process. For these tests, cylindrical specimen of 10mm diameter and 15mm height are used. K-type thermocouple are directly welded on surface of the specimen at mid height. Tests are performed in temperature range of 900 to 1200 °C (in steps of 100 °C) and at constant strain rate of 0.01, 0.1, 1.0, 10.0, 50.00. After the completion of tests, specimens are water quenched using spray nozzles available with the Gleeble 3800 system to freeze its microstructure. As a result of these tests, stress-strain curves at different temperatures and strain rates are generated.

**CFD Analysis on ITER Divertor Vertical targets:** This analysis was carried out using StarCCM+ software, to estimate the maximum temperatures during operation of ITER ma-

chine. The simulation was carried out according to the following load specification document of ITER: Inlet temperature: 100 °C, Inlet Pressure: 42 bar, inlet velocity: 10m/s. The simulation results match well with the parameters specified in the ITER Divertor design. The CAD model was imported into StarCCM+ and meshed with 4 lakh elements. Thermal hydraulic parameters such as the pressure drop, velocity, maximum tile temperature, temperature rise of coolant were estimated.

**Electromagnetic Analysis of ITER Divertor:** This analysis was carried out for major disruption case scenario. The meshed model consisted of all ITER in vessel components along with the vacuum vessel. The disruption case considered in the simulation was 25ms upward and downward case major disruption. The eddy currents for the disruption case was calculated for each time step and the resulting forces due to induced eddy currents were calculated. The electromagnetic forces and moments were calculated to be about 20 MN.

**Numerical Studies on finger mock-up of Helium Cooled Divertor:** Thermal performance of the Helium Cooled divertor concept based on Jet Impinging technique is carried out by providing extended surfaces for enhanced heat transfer. The result showed that, accumulation of extended surfaces increase the thermal performance of the divertor at an acceptable pressure drop. Numerical simulation is carried out using CFD software ANSYS 14. The CFD results for the reference geometry are validated against high heat flux experiments and a good agreement is noticed between the present simulation and reported published results.

### A.2.3 Cryo-pump & Pellet Injector

#### Development of Cryo-Adsorption Cryo-Pump

This project has achieved the following (i) development of hydro formed cryo-panels (patented and technology transferred to industry), (ii) development of activated carbon sorbent, (iii) development of adsorption study system and carrying out studies related to characterization of sorbents for adsorption characteristics at 4K for Helium and hydrogen, (iv) development of experimental set up and studies related to Degassing and Outgassing measurement, (v) development of sorbent coating technology on cryo-panels, (vi) simulation studies related to transmission probability analysis for different geometrical arrangements of baffles, cryo-panels and shields etc. To investigate the pumping speed offered by sorbent coated panels a test facility SSCF (Small Scale

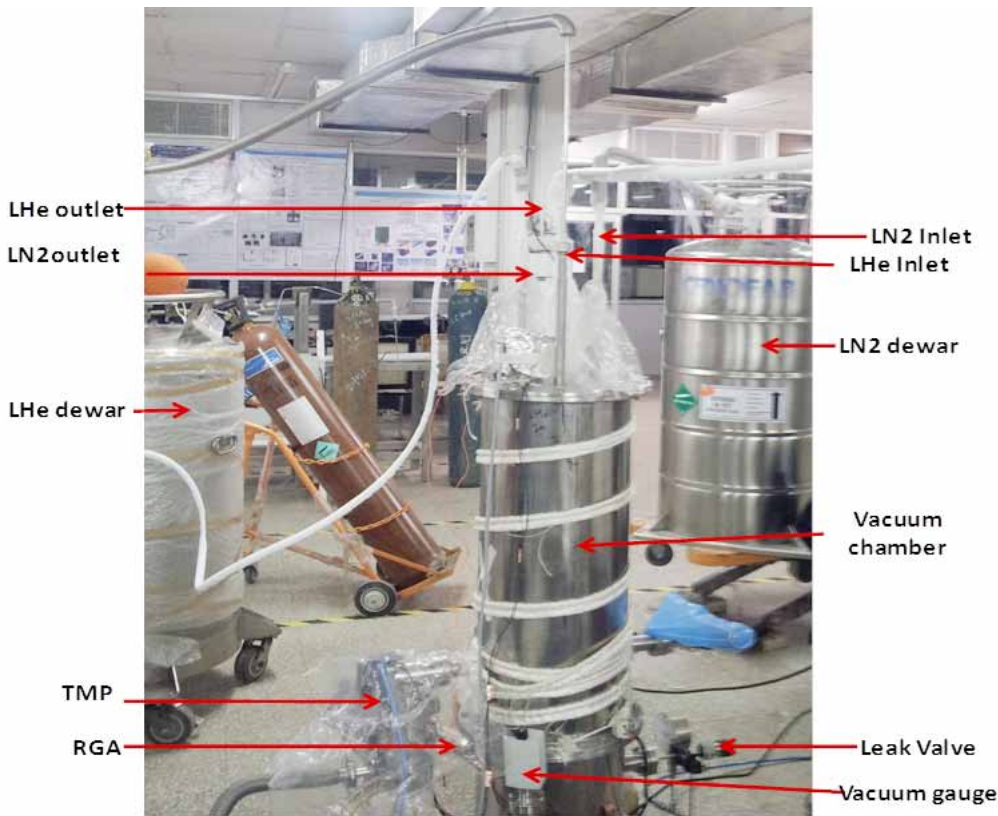


Figure A.2.3.1 Experimental set up as per AVS standards for measuring pumping speed of 500 mm x 100 mm sorbent coated Cryopanel

Cryopump Facility) which can take samples of hydro-formed cryo-panel (a technology developed in India) of size ~500 mm x 100 mm was set up as per international standards comprising a dome mounted with gauges, calibrated leak valve, gas analyser, sorbent adhered to cryo-panel etc. The cryo-panel coated with granular carbon was shielded by chevron baffles. Pumping speed measurements were carried out for gases like Hydrogen, helium and Argon at a constant panel temperature (4.5 K to 10.0 K) in the pressure range of  $10^{-7}$  to  $10^{-4}$  mbar, and pumping speed was found to be in the range of  $2\text{L/s cm}^2$  for a pressure range  $10^{-6}$  to  $10^{-4}$  to  $4\text{ L/s cm}^2$  for pressure range  $10^{-7}$  and below for a pumping surface area of  $\sim 1000\text{ cm}^2$  thus giving an average pumping speed of about  $2\text{-}3\text{ lit/sec cm}^2$ . SSCF used for experimentally obtaining the pumping speed was also modelled in codes like Molflow+ and Movak 3D. The codes used Monte Carlo technique to find transmission probability for given geometric configuration. Using the codes SSCF was modelled and simulation studies performed. Parameters like sticking coefficient, capture coefficients affecting the pumping speed were studied. Experimental results and simulation results obtained for SSCF show good coherence. Experiments were performed for pumping speed evaluation at liquid nitrogen temperature

for gases like argon and nitrogen and at liquid helium temperatures for Hydrogen and Helium.

**Pumping speed of Sorbents at Liquid Helium Temperatures:** Pumping speed measurement for helium gas was performed two times. Average pumping speed over the range of  $1\text{e-}6$  mbar to  $1\text{e-}4$  mbar range is  $\sim 2500\text{ liter/sec}$  ( $2.5\text{ litre/sec.cm}^2$ ). Comparing experimental and simulation value of pumping speed estimate of sticking coefficient of charcoal coated panel at  $4.5\text{K}$  was found. Pumping speed measurement for hydrogen gas was carried out twice and both the results are plotted against pressure. It ranges from  $8000\text{ litre/sec}$  to  $1500\text{ litre/sec}$  with an average over the range of  $1\text{e-}6$  mbar to  $1\text{e-}4$  mbar as  $\sim 2700\text{ liter/sec}$  with pattern of plot remaining same which implicates the repeatability of the experiment. Pumping speed per unit area is  $2.7\text{ litre/sec.cm}^2$ .

**Development of Pellet Injector**

A single barrel pellet injector Single Pellet INjection System (SPINS) capable of injecting a hydrogen pellet is developed at IPR for plasma fuelling studies. This injector is an in-situ pipe gun type injector, where a pellet is injected with high speed by using high pressure propellant gas. At present, this

injector is capable of firing a 3 mm cylindrical pellet at a speed ranging from 800 to 1100 m/s. The pellet delivering capability of this injector in test bench operation is found to be more than 95 %. Pellet formed at cryogenic temperature ( $< 10$  K), it needs either liquid helium based cooling system or a cryocooler. Size of pellet depends on barrel diameter and length of the freezing zone. At present a barrel of internal diameter 3 mm and brazing zone of width 3 mm is used and hence a pellet of equivalent dimension is formed. It takes approximately one minute to form a pellet. After getting the injection trigger, the fast valve is opened for approximately 2 ms duration, and high pressure helium propellant gas rush into the barrel to dislocate and accelerate the pellet to high speed. A pellet injection cycle is completed within five minutes; hence, it is possible to operate the injector in synchronization with a time gap of 3-4 minutes. After a pellet is triggered, the speed of the pellet is measured by light gate diagnostic. Apart from pellet speed measurement; light gate signal can give qualitative information about pellet intactness. Other useful diagnostic for pellet mass and shape measurements are microwave cavity based mass measurement system and direct photographic measurement. Pellet speed is varied by changing the propellant gas pressure. Experimentally obtained pellet speed lies between 70 to 90 % of theoretical predictions.

#### A.2.4 Test Blanket Module (TBM)

India is developing Lead-Lithium Ceramic Breeder (LLCB) Breeding blanket system which has both features of solid breeder and liquid breeder blankets. The overall dimensions of the LLCB TBM are 1.66m (height) x 0.484m (width) x 0.534m (thickness). LLCB blanket consists of Lithium Titanate ( $\text{Li}_2\text{TiO}_3$ ) pebble beds, molten Lead-Lithium (Pb-Li) as coolant & tritium breeder and Reduced Activation Ferritic Martensitic Steel (RAFMS) as structural material. There are two coolants: the Helium coolant for the First Wall (FW) and the external box structure (pressure 8 MPa, Temperature\_inlet/outlet 300–350 °C) and the Pb-Li coolant for ceramic breeder packed beds (T inlet/outlet 300–480 °C). The Pb-Li acts also as additional tritium breeder and as neutron multiplier. To avoid too large MHD-pressure drops, the Pb-Li is isolated from the steel channel walls by means of electrical insulating coatings. The LLCB-TBM (Figure 2.4.1) has the same features of the DEMO LLCB breeding blanket. In particular, the molten Pb-Li eutectic, flows separately around the ceramic pebble bed compartments to extract heat produced in the ceramic and in the Pb-Li itself. Tritium produced in the ceramic breeder zones is extracted by low-pressure helium purge gas. The tritium produced in the Pb-Li circuit is

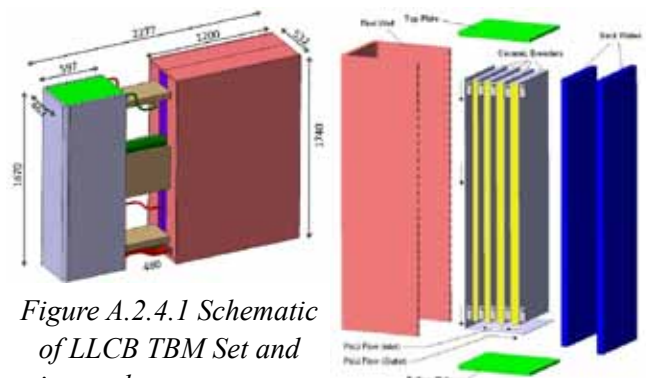


Figure A.2.4.1 Schematic of LLCB TBM Set and internal arrangements

extracted separately by an external detritiation system. The LLCB-TBS includes several ancillary systems, namely the FW helium cooling system, the Pb-Li system, the secondary He-coolant system (for Pb-Li), the tritium removal system (from Pb-Li), the tritium extraction system (i.e., the purge gas system), the coolant purification system and Instrumentation & Control (I&C) system. In order to fulfill the Indian commitment to ITER, the required R&D in breeding blanket technologies has been initiated at IPR with the full support from BARC and IGCAR in terms of enabling technologies development. During this period, the development of new materials and technologies has been started and progressed to a level where India is at par with other ITER partners. The major R&D items which under progress are; Conceptual design of LLCB blanket, Development of Tools for design and analysis, Liquid Metal technologies, Lithium ceramic pebbles development, Lead-Lithium development, Coatings development, Reduced Activation Ferritic Martensitic Steels development, Fabrication technologies development and various diagnostics for TBS. Dedicated man power and budget has been allotted for these R&D programs. The recent progress in the R&D activities are, in LLCB TBM design activity which is focused on the optimization of TBM design with respect to neutronic performance and high-grade heat extraction by keeping the temperature within allowable limits. Neutronic design for LLCB TBS, Shield Blanket Module and various types of blanket concepts are being studied. Engineering design of LLCB TBM and Shield block in terms of thermal hydraulics, thermo-structural analysis and electromagnetic analysis is under progress for optimization of TBM set design. Experimental helium cooling loop of 80 bar operating pressure, 0.4 Kg/s mass flow rate, 400 °C helium temperatures is being constructed in IPR. This loop will be utilized for testing the LLCB TBM First wall mock-up. Lithium titanate pellets has been produced at IPR by solid-state reaction and Solution combustion process. Pebbles production by extrusion and spheroidization is under progress. The chemical



*Figure A.2.4.2 Cold trap testing*

composition is under control. The purity achieved is 99.5 %, the pebbles characteristics meets all the requirements of the LLCB TBM. Packed bed thermal conductivity measurements are being performed to measure effective thermal conductivity of fabricated pebbles. Lead-Lithium technology development involves small scale experiments in lab to test the loop components like pumps, heat exchangers and Recuperator. Cold trap for Lead-Lithium purification is indigenously developed and being tested (Figure A.2.4.2). Lead-Lithium diagnostics development like pressure sensors, flow measurements are under progress. Production of Lead-Lithium in laboratory is being attempted (Figure A.2.4.3). The commercial melts of RAFMS has been delivered to IPR in the form of plates. The 40 mm plates manufacturing is under progress. The IN-RAFMS tubes and pipes and welding electrodes are under production. The fabricability of Indian RAFM steel using EBW, LASER, HIP and TIG welding for ITER-TBM program is under progress. As TBMs are integrated in ITER machine, the TBM systems licensing is also included along with the ITER licensing process. In this regard, Indian team has prepared a detailed LLCB TBS Preliminary Safety Report (RPRS) version 2.0 and submitted to ITER. Safety experiment for Lead-Lithium and water experimental system has been assembled and experiments are in progress.

## A.2.5 Large Cryogenic Plants & Cryo-systems

This programme is to indigenously build Helium Liquefier-cum-Refrigerator (HRL) plant of equivalent cooling capacity about 2 kW at temperature 4.5 K which can be useful for tokamak fusion machines.

**Helium Plant Thermodynamic Cycle Analysis:** The modified claud cycle is considered here for the design of the indigenous helium plant. This configuration has certain ad-



*Figure A.2.4.3 Pb-Li loop for testing diagnostics*

vantage over others: a very cold turbine (Turbine-C) is used, which operates at temperature little higher than the thermodynamic critical temperature (5.2 K) and pressure (2.3 bar) of helium and expands cold high density helium gas from about 13 bar to 4 bar and brings down the helium temperature from ~7.5 to ~6 K. The analysis has been completed with the process as shown in the figure A.2.5.1.

**Plate-fin Heat exchanger design and development:** Heat exchangers are essential components of helium refrigerator and liquefier plant. Here, in the HRL, heat exchanger effectiveness required is pretty high up to ~98% which can be met by only plate-fin heat exchangers (PFHE). Besides complex geometry design and optimization procedures, there are practical problems like flow mal-distribution, axial conduction, inter-stream leakage and limitation of size of vacuum brazing furnace. The PFD has 8 heat exchangers and are categorized as 4 types. Design, analysis and optimization have been done for these 4 different heat exchangers. For all these 4 heat exchangers, procedure verification with the existing plant's heat exchanger parameter, have been done. Figures A.2.5.2 and A.2.5.3 show the different elements of the plate-fin heat exchanger.

**Adsorber bed for helium gas purification:** In the whole helium plant, there are 3 stages of helium gas purifications which use adsorption principle for impurity removal: oil impurity removal in the oil removal system of CORS at room temperature (~300 K), air impurity (N<sub>2</sub>, O<sub>2</sub> and Ar) removal at temperature ~80 K inside the cold box and hydrogen impurity removal at temperature ~20 K inside the cold box of the plant. The expected amount of impure gas in the helium stream for all of these cases could be about 10 to 100 PPM (parts per million) by volume. Design and analysis work have been done for 80 K and 20 K adsorber beds.

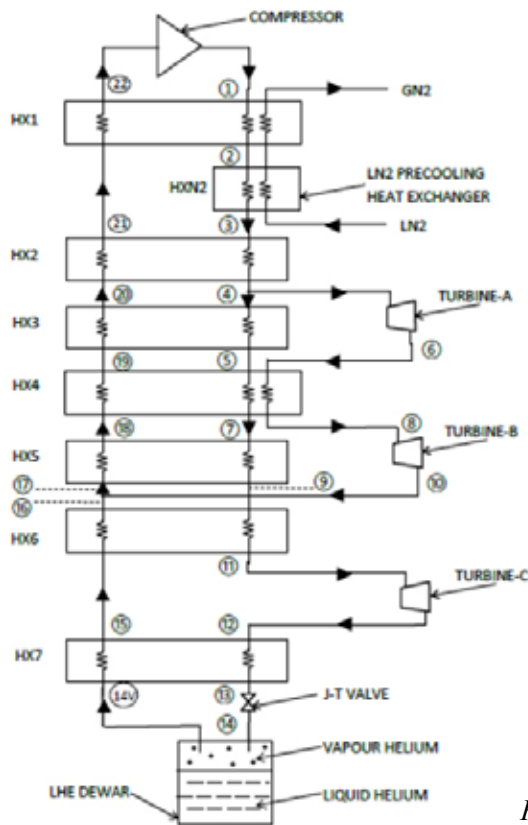


Figure A.2.5.1 Process Flow Diagram

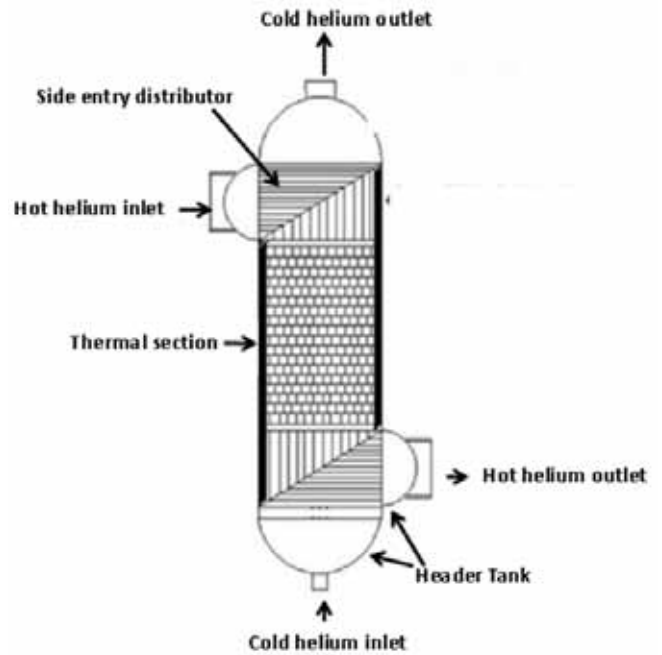


Figure A.2.5.2 Designed heat exchanger HX7 with different elements

**Prototyping and Tests: SS to Al and SS to Cu Friction Welded Joint:** Aluminium plate-fin heat exchangers will need dissimilar metal joints between Aluminium and SS304L pipe for connection with other components of the cold box having SS pipe. Copper thermal shielding cooled by LN2 will need

similar joint between Cu and SS304L piping. The frictional heating (rotating one pipe against another fixed pipe) brings both pipe materials to recrystallization temperature in which material of one side diffuse to other side and make a crystal structure and hence a bonding. After few trials, it is found that Al-SS304L joint has good helium leak tightness in the or-

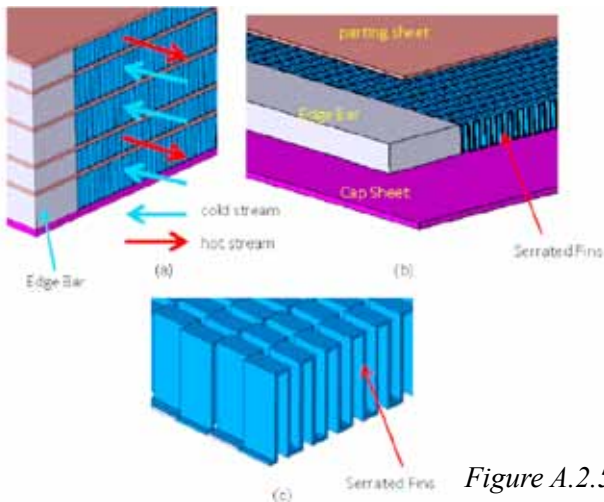


Figure A.2.5.3 Different elements of heat exchanger's main thermal zone

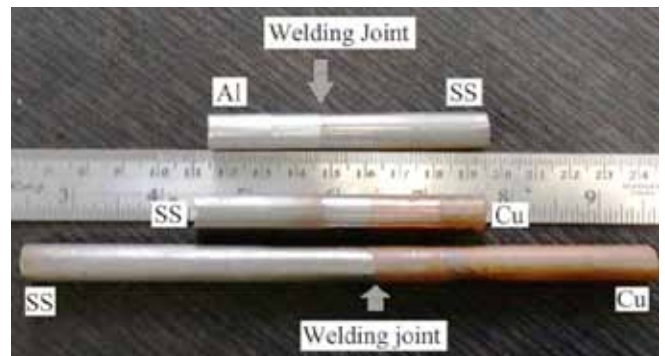


Figure A.2.5.4 Friction welded joint of SS304L to Cu and SS304L to Al pipes

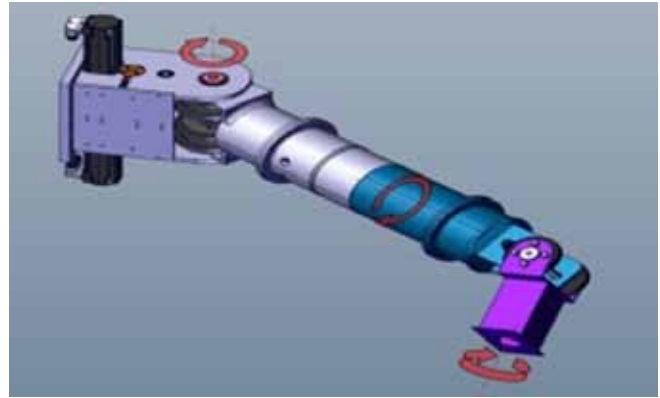
der of  $10^{-9}$  mbar.ltr/s before and after thermally shocked with liquid nitrogen. SS304L-Cu joints were also tested and found to have leak tightness of the order of  $10^{-6}$  mbar.ltr/s before and after thermally shocked in  $LN_2$ . These successful joints were made in-house using milling machine at IPR and shown in figure A.2.5.4.

## A.2.6 Remote Handling & Robotics Technology

The scope of the project is to build a versatile Remote Handling System for Indian fusion devices. This includes the design and development of various Robotics Arms, Deployment systems for the robotic arms, basic and advanced RH compatible tools, and a dedicated Virtual Reality lab for system development, testing, operation and control along with scaled test facilities etc.

**Virtual Reality (VR) Laboratory Development:** Remote operations require an accurate perception of a dynamic environment. The aim is to give the operators the same unrestricted knowledge of the task scene as would be available if they were located in the remote environment. In fact, the Virtual Reality (VR) system can give an overview over the entire scene which is better than being present at the workplace. In addition, different algorithms will be integrated with the VR system like collision avoidance algorithms, path planning algorithms etc. The objective is to develop a Virtual Reality System dedicated for the Remote handling design Simulations and Analysis activities. This VR system will cater the preparation and support of remote handling operations at IPR. It will help to gain experience and expertise in development of system specific RH equipment. The system also aims act as a training facility for engineers to advance in the field of remote handling and robotics for future needs. The fully immersive VR system at IPR is planned to have dual high resolution screens integrated with 6D tracking device and a large number of haptic devices including a 6 DOF force feedback master arm.

**Conceptual Design of Prototype Robotic Articulated System (PRAS 01):** The SST-1 Scale In-Vessel Inspection and Maintenance System (IVIMS) shall allow for in-vessel inspection of plasma-facing surfaces to look for possible damage caused during plasma operations. The system shall also be used for metrology measurements of the plasma chamber and its components. The system is not expected to view in-vessel regions leading off from the main plasma chamber. Prototyping activity, aiming SST-1 In-vessel Inspection and Maintenance System (IVIMS), is being developed as ~1:2 scales of the



*Figure A.2.6.1 Prototype Robotic Articulated System for SST-1 In-Vessel Inspection & Maintenance System.*

actual requirement with 5 Kg payload capacity and 1.5 meter in length that composed three degree of freedom rotary joints that provides postures during the transportation of any tools inside the pre-defined viable area.

**Collaboration with CCFE for conceptual design of RH compatible ELM Coils:** Joint European Torus (JET Tokamak, UK) aims to install a set of 32 ELM control coils to study the ELM mitigation. The conceptual design activities majorly involves design, optimization & analysis of RH compatible supports and support bases, RH compatible electrical leads and connectors for coils, and resolving the interface issues with various diagnostics and in-vessel components inside the machine along with the verification of the vessel integrity for coil loads during operational and disruption scenarios as per the quality standards.

## A2.7 Negative Ion Neutral Beam System

### INTF activities

Indian Test Facility (INTF) is to test the ITER DNB.

(i) INTF Vacuum vessel to house beam source, beamline components is being manufactured after carrying out the complete design of the vacuum vessel in house.

(ii) INTF HV feed-through provides isolation between Vessel and HV Transmission line is designed based on electrostatic and thermo-mechanical optimization. Procurement process for the porcelain ring sub assembly (main insulator assembly) has been initiated.

(iii) INTF Cryopumps consists of 12 cryo-sorption pumping

will handle gas through put inside the ion source and the neutralizer. To meet minimum re-ionization loss inside the vessel, cryopumps will provide total pumping speed of  $\sim 1.8 \times 10^6$  l/s. The size of each cryo-pump is of approx. size 3.2 m (H) x 0.6 m (W) x 0.3 m (D).

(iv) INTF Data Acquisition and Control System (DACS) is designed based on ITER Plant Control Design Handbook (PCDH) guidelines. The interface documents were prepared for the plant systems of INTF. Study for interlock and safety system of INTF is completed. There are around 400 signals in total for the control system. The Data acquisition system of INTF is based on NI pxie. The sensors are optical sensors, thermocouples, current transducers and potentiometers. Since INTF control system is based on CODAC, the hardware procured for it is chosen from the standard PCDH catalogue. Development of prototype for INTF DACS, based on CODAC Core System has been carried out and will be tested in Twin source experiment to gain experience before INTF operation.

(v) INTF Diagnostics: INTF diagnostic system is divided into three categories: (a) Protection diagnostics with active interlocks for safe operation, (b) Monitoring diagnostics to monitor the health of the system and (c) Characterization diagnostics for characterization of the plasma and the beam. Categories (a) and (b) comprise of mainly thermocouples placed on the beam facing surfaces on the BLCs and its cooling circuits, vacuum gauges, electrical signals for HV breakdown inside the components. The designs of these diagnostics are the integral part of the BLC designs. Few monitoring diagnostics in category (c) are designed and some of its hardware is being procured. The engineering design of

beam profile measurement through Infra-red imaging system using carbon-fiber-composite (CFC) plates and IR camera is completed. One IR camera for this diagnostic is indented to start the experimentation. For negative ion density measurement in the beam source, Cavity Ring Down Spectroscopy (CRDS) is designed and corresponding Nd-YAG laser with highly reflecting cavity mirrors are indented, including the detector.

**ROBIN Experiment** : The plasma production and beam extraction experiments (in volume mode / without Cs injection) with extraction area  $\sim 2 \text{ cm}^2$  are carried out in ROBIN. A new diagnostic laser photo-detachment is introduced for negative ion density measurement and preliminary results are obtained. The trigger for Laser system was enabled by the main PLC of ROBIN system. Under volume production mode, negative ion beam extraction experiments are performed and beam parameters and profile are measured using electrical diagnostics and a newly introduced beam interceptor plate with multiple electrically isolated blocks. EPSS (Extraction Power Supply System) 11kV, 35A is hooked up to ROBIN setup and high voltage conditioning experiments (up to 11kV) are performed successfully. Recently beam extraction experiments are performed in ROBIN using EPSS as an extraction power supply and RHVPS (10kV, 400mA) as an acceleration power supply and beam of  $\sim 20 \text{ kV}$  with negative ion current density of  $\sim 10 \text{ mA/cm}^2$  has been extracted.

**Extraction Power supply system (EPSS) for ROBIN**: The 11kV, 35A Extraction Power Supply System (EPSS) has been installed successfully and has cleared all the functional tests and is presently operational and completely integrated with the ROBIN setup including its DAC system, after successful factory acceptance testing for the specified performance .



Figure A.2.7.3.1 Manufacturing of the INTF Vacuum vessel at vendor's site.



**Acceleration power supply system (APSS):** This system (APSS - 35kV, 15A DC) is presently being manufactured at the vendor's site. All the 78 transformers and 70kV isolation have been tested successfully for heat run performance. The system is expected to be completely ready for final factory acceptance testing in the near future. Other electrical systems commissioned are, 2MVA LT power distribution system for the HVPS system of ROBIN has been successfully installed, integrated and commissioned. An inverter system is being procured for providing backup power for the local control & local interface unit of EPSS system.

**Data Acquisition of ROBIN:** Up-gradation of DACS system for 20 kV beam operations in ROBIN has been carried out, in terms of control software programming and hardware modules implementation to orient the available power supplies. The control and data acquisition system is also upgraded to accommodate both the EPSS and APSS power supplies in the system.

**TWIN Source:** TWIN source experiment is the intermediate step between single driver ROBIN and eight driver INTF. TWIN source (TS) has two RF drivers. In this TS program procurement activities related to plasma phase experiments are in progress. TS vacuum vessel purchase order has been placed. Pumping system is indented and quotations are obtained. To house the TS, a mezzanine floor has been erected in INTF lab area in ITER-India building. Procurement activities of electrical distribution panel with cables, PG bias power supply (66V, 333A DC), Filament heating & bias power supplies, PG filter field power supply(10V, 6kA DC) are in the last phase. A standalone control system has been in the last phase of implementation, based on ITER CODAC Core system.

## A.2.8 Fusion Reactor Materials Development & Characterization

### Material Development

**ODS steel development :** The scope of this project is to develop and produce ODS-9Cr RAFM and ODS-14Cr RAFM steel powders and to process these powders by hot iso-static pressing and subsequent hot forming operations like hot rolling to plates, for fusion reactor applications. The RAFM steel powder (70 Kg) has been produced at ARCI (under MoU through IGCAR) using Gas Atomiser with the size distribution of about 50 to 150 micron and keeping the oxygen level well below 100 ppm.

**Composites and Ceramics development:** Development of SiCf/SiC composites through Nano Infiltration and transient eutectic (NITE) technique and CVI technique is being planned for the structural and functional material applications for the fusion reactors. Proton conducting oxide  $\text{LaNbO}_4$  has been prepared with the primary objective of developing hydrogen isotope separation membrane. The samples prepared with different doping with Ti and Ce by Molten Salt synthesis method have been analysed with different analytical techniques such as XRD, SEM, X-ray photoelectron spectroscopy and Impedance Analyser to get the insight into the fundamentals of crystal structure, micro structure and electronic structure in order to obtain the required proton conducting properties.  $\text{MgAl}_2\text{O}_4$  ceramic development activity for IR and RF windows for the Reactors is also in progress with preliminary trials of synthesis with solid state route

### Coating Development

**Tritium barrier coating activity :** The reactive magnetron sputter coating activity for development of  $\text{Er}_2\text{O}_3$  coating on P91 steel as tritium barrier is further extended by completing the procurement of high temperature substrate heating system and integrating it with the existing coating system and testing it. The dip coating (wet method) experiments were also carried out for developing the same coating on flat and tubular SS316 substrates for Hydrogen sensor development activity. Both the above types of coatings were characterized at every step and trials have been done using X-ray diffraction and Scanning electron microscope for the crystallinity, microstructure, thickness and purity.

**Palladium coating:** The pure palladium coating was done on 0.5 mm and 0.25 mm thick pure iron sheets to be used for fabrication of permeation based Hydrogen sensors for Fusion Fuel Cycle division. The coating process was optimized for the parameters to obtain stress-free coating. Subsequently, the deposition rates were evaluated and optimized to precisely control the coating thickness. Two sets of iron sheets with palladium coating on both the sides were prepared with different thickness of 300 and 200 nm. These sheets were, subsequently cut, bent and laser welded to fabricate the sensor and the coating sustained these conditions.

**Material Fabrication :** The materials fabrication R & D comprises of Electron Beam (EB) welding and characterization of AISI SS316L 20mm thick electron beam welded samples for mechanical and structural properties. The welded

samples have shown comparable tensile strength with base metal and the correlation of mechanical properties has been done with the microstructures obtained. Delta ferrite measurements show the significant presence of delta ferrite in the weld zone. Mechanical and Microstructural properties were characterized for the EBW heat treated sample and enhancement in the mechanical properties like Tensile strength and Impact fracture toughness was noticed.

**Material Irradiation and Characterization:** A coordinated research project (CRP) proposal entitled ‘Radiation damage and H/D retention studies on ion-irradiated Tungsten and its alloys - Experiments and Modeling’, submitted by IPR to IAEA has been approved. The activity is being carried out by FRMDC division along with ITER-India and First wall and Divertor Division of IPR. Scientific Investigators of the project Participated in 1st Research coordination meeting (RCM) held at IAEA Headquarters at Vienna during 26 -28 November 2013 and discussed the plan of the proposal. MD, KMC Modelling work for ion irradiated Tungsten has been initiated and coordination for the experimental work of accelerator based high energy ion irradiation and characterization has been planned.

### A.2.9 Fusion Neutronics & its Diagnostics Development

**Neutronics Experiments:** Irradiation experiments for the blanket mock-up assembly containing Lithium Titanate as breeder material and lead as multiplier have been performed using 14 MeV sealed neutron generator at Fusion Neutronics Laboratory (FNL) of IPR. Mock-up assembly was surrounded by 10 cm of thick HDPE. In the first phase of the experiment mock-up was filled with lithium titanate powder and lead this assembly was irradiated for 3 hours. Purpose of this experiment was to study the lead multiplication in the assembly. Neutron flux and spectrum in each zone inside the assembly was investigated with foils activation as detector and SAND-II unfolding code. In second stage lithium titanate powder was replaced with pebbles and mock-up was irradiated for 15 hours. The main goal was to study the tritium production rates inside the assembly. In the breeder mock-up experiment, the TPR was measured with small  $\text{Li}_2\text{CO}_3$  pellets. Tritium accumulates in the pellets during irradiation and is subsequently measured by liquid scintillation counting techniques. Experiment results of these experiments were compared with MCNP calculations.

**Participation in “Neutron Source Calibration” campaign at JET:** The power output of fusion experiments and fusion reactor-like devices is measured in terms of the neutron emission rates which relate directly to the fusion yield rate. This time-resolved fusion neutron yield from the Joint European Torus (JET) is monitored using a set of  $^{235}\text{U}$  fission chambers. The experimental campaign was carried out at JET to calibrate Fission chambers and Activation system in terms of neutrons emission from D-D plasma. The calibration of the neutron detectors was performed by moving a standardized  $^{252}\text{Cf}$  point neutron source inside the vacuum vessel through a large number of positions so as to map out the response to be expected for extended plasma and observing the detector response

### Nuclear Data Generation for Fusion Materials

**Estimation of (n, p) Cross-section for Radio-Nuclide  $^{55}\text{Fe}$  using EMPIRE and TALYS:**  $^{55}\text{Fe}$  is one of the radionuclide ( $t_{1/2} = 2.73$  years) produced in large quantities inside the fusion reactor. Neutron-induced cross-sections for long-lived activation products produced in fusion reactor are very important since they could pose a serious radiation damage, waste disposal and issues related to safety. The excitation function of (n, p) reaction from threshold to 20 MeV and proton emission spectra from  $^{55}\text{Fe}$  target at 14 MeV neutron energy are calculated using optimized input parameters in nuclear reaction modular codes EMPIRE-3.1 and TALYS-1.4. The present work is an important step to measure the cross-section of  $^{55}\text{Fe}(n, p)^{55}\text{Mn}$  reaction by surrogate technique.

**Study of reaction mechanisms in the  $^6\text{Li} + ^{52}\text{Cr}$  system:** The choice of particular reaction is proposed as a surrogate reaction [ $^6\text{Li}(^{52}\text{Cr}, d)^{56}\text{Fe}^*$ ] for the measurement of  $^{55}\text{Fe}(n, p)$  reaction cross-section, which is very important in fusion reactor studies. The present theoretical work is an important step towards the measurement of cross-section of  $^{55}\text{Fe}(n, p)^{55}\text{Mn}$  reaction by surrogate method.

**Relevance of Surrogate Technique in Cross-section determination:** Large numbers of long-lived radionuclides are produced inside the fusion reactor during its operation and may lead to significant long term waste disposal and radiation safety issues. Major Pathways for the production of radionuclides have been calculated by using European Activation System code (EASY) code. The contributions coming from direct, pre-equilibrium and compound nuclear processes are studied.

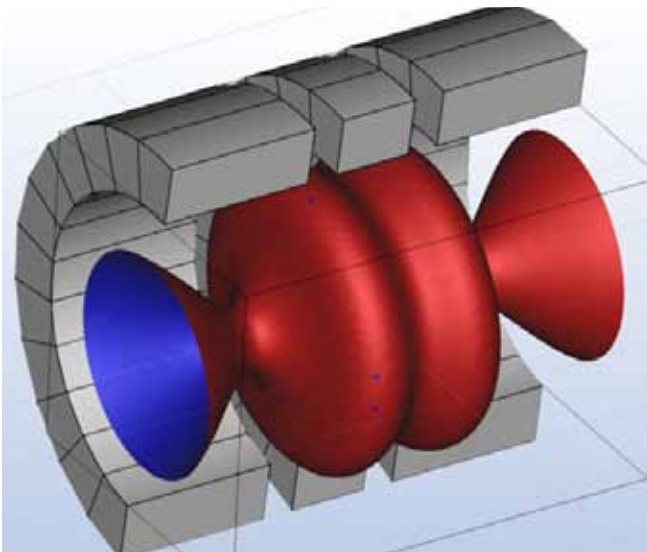


Figure A.2.9.1 ISO surface plot of D Plasma

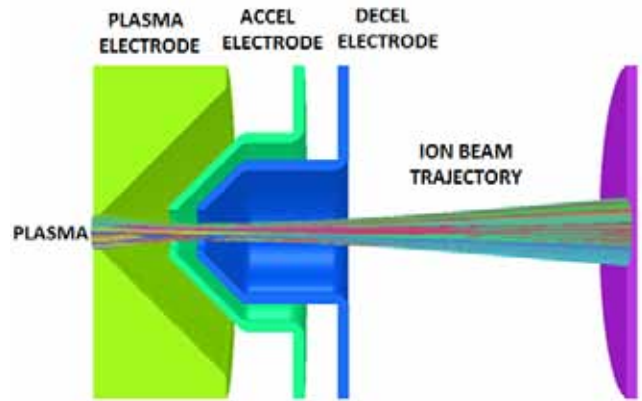


Figure A.2.9.2 High Current Ion Extraction System

**Preparation of Self-Supported metallic thin films of natural chromium:** The preparation of thin film targets for nuclear physics experiment is an essential step in the experiment. Natural Chromium and its different isotopes of very low thickness (< 1 micron) are required as self supporting foils (targets) for advanced nuclear research. Due to its brittle nature it is very challenging to make a thin film of less than 1 micron thickness. In the present work, self supporting thin film of natural chromium, with 99.91% purity, in the range of thickness 300-900 micro-g/cm<sup>2</sup> (< 1 micron) have been prepared by thermal evaporation technique.

**Excitation function of <sup>56</sup>Fe(n, α) <sup>53</sup>Cr reaction from threshold to 20 MeV for fusion applications:** Nuclear data evaluations is required for fusion nuclear technology applications. In this context, the excitation function of <sup>56</sup>Fe(n, α) <sup>53</sup>Cr reaction from threshold to 20 MeV has been calculated using the Hauser-Feshbach statistical model with pre-equilibrium effects by TALYS-1.4 code. The present calculations are compared with existing experimental data as well as with latest available evaluated nuclear libraries ENDF/B-VII, JEFF-3.2 and JENDL-4.0.

**Scattering chamber design for an accelerator based 14 MeV Neutron Generator:** The measurement of double-differential cross-sections (DDX) for fast neutron induced charged particle nuclear reactions on fusion relevant materials are very important for estimating the level of nuclear heating, radiation damage etc. in a fusion reactor environment. Such reactions are induced on bombardment of fast neutrons on the first wall, structural, and blanket components of the reactor thereby leading to formation of gases (helium, hydrogen, deuterium etc.) in the bulk of materials. A general purpose

scattering chamber has been designed at Fusion Neutronics Laboratory (FNL). It will be coupled with particle accelerator based 14 MeV neutron generator at FNL. It has been designed for experiments using silicon surface barrier (SSB) detectors for the on-line detection of charged particles. This facility will be used to perform fundamental nuclear physics experiments (i.e., double differential cross-section determination, alpha – spectrum measurement etc.) at FNL in IPR

### A.2.10. Fusion Fuel-Cycle Development

**Development of laboratory scale hydrogen isotopes removal system (HIRS) for He purge gas:** This system is to validate design concepts for tritium extraction. The complete system consists of atmospheric molecular sieve bed (AMSB)

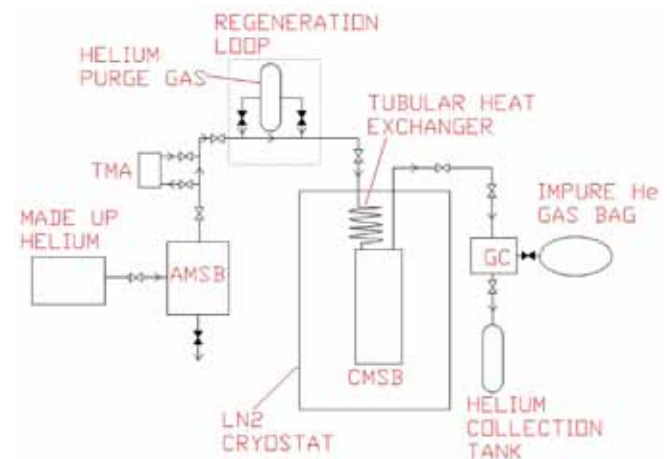


Figure A.2.10.1 Schematic of the experimental set up for HIRS

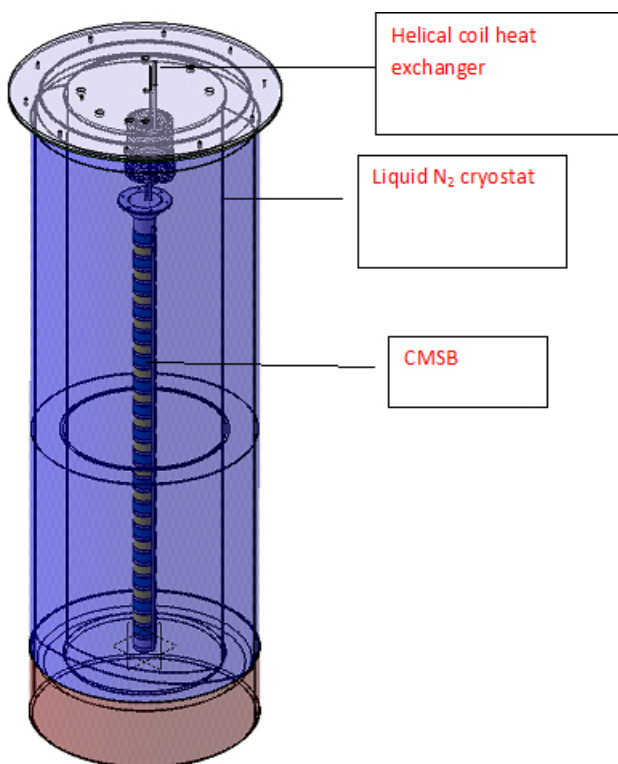


Figure A.2.10.2 3-D drawing of the CMSB system column (for removal of moisture from He purge gas), which would be regenerated using pressure swing adsorption (PSA) and cryo-molecular sieve bed (CMSB) column, which then would be regenerated by heating the bed. A schematic of the experimental set up is shown in Figure A.2.10.1. AMSB was designed and fabricated last year. A humidification system has been designed and fabricated to introduce required amount of

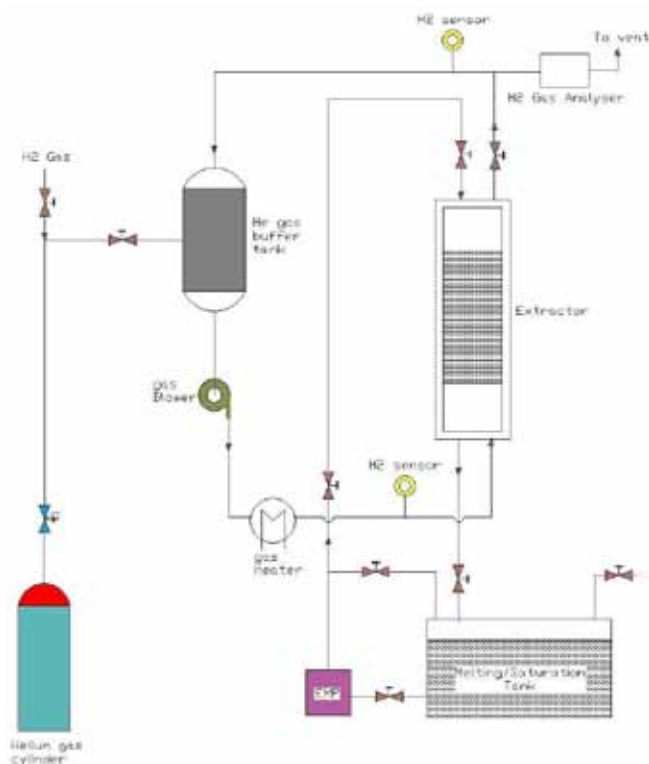


Figure A.2.10.3 Process flow diagram of the set up for hydrogen extraction from liquid PbLi.

humidity in the helium gas. The design of the CMSB is also complete. Theoretical modelling, simulation and design optimisation of CMSB for hydrogen isotopes in He gas is carried out. Most of the essential components, viz., trace moisture analyzer (TMA) system, temperature indicator & controllers, pressure sensors, mass flow controllers, vacuum pump, gauges, associated valves etc. have been procured. They will now be integrated to start experiments with AMSB.

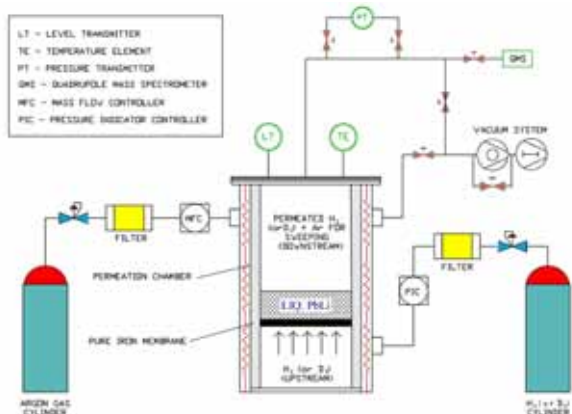


Figure A.2.10.4 Schematic of the set-up for hydrogen solubility experiment

**Development of hydrogen isotope extraction system (HIES) for liquid PbLi:** The process flow diagram (PFD) of the experimental set up as shown in Figure A.2.10.3. Component identification, process design of hydrogen isotope extractor, procurement of most of the required materials/components like Sulzer packing column, SS316L pipes, flanges, PbLi compatible valves, residual gas analysers (RGA) etc. have been completed this year. Procurement of remaining items, like, pressure indicator and controllers (PIC), gas circulators, heaters and other instrumentation would be carried out in future. Fabrication of the set up would be after getting the required components. Experimental set up for determining solubility of hydrogen isotope in liquid PbLi: Solubility of



Figure A.2.10.5 Hydrogen isotope permeation experimental set-up

hydrogen isotope in liquid PbLi is still an area of active research. Values of solubility reported in the literature, differ up to 106. So, need for a reliable experiment to determine solubility of hydrogen isotope in liquid PbLi is well established. An experiment is, therefore, planned to determine hydrogen isotope solubility in pbLi. A schematic of the set-up is shown in Figure A.2.10.4. Hydrogen (or deuterium) gas would be allowed to permeate through PbLi. The permeated flux of hydrogen (or deuterium) gas would be used to determine the value of its solubility in PbLi. Procurements of many of the required components like, capacitance manometers, vacuum pumps, iron foils and RGA have been initiated soon.

**Development of Tritium Permeation Barrier (TPB) coating:**

An experimental setup to study hydrogen isotope permeation to qualify the TPB coating developed has been designed and fabricated (Figure A.2.10.5). After the installation, experiments on permeation of hydrogen/ deuterium gas through flat specimens of Indian Reduced Activation Martensitic Steel (IN-RAFMS) would be started.

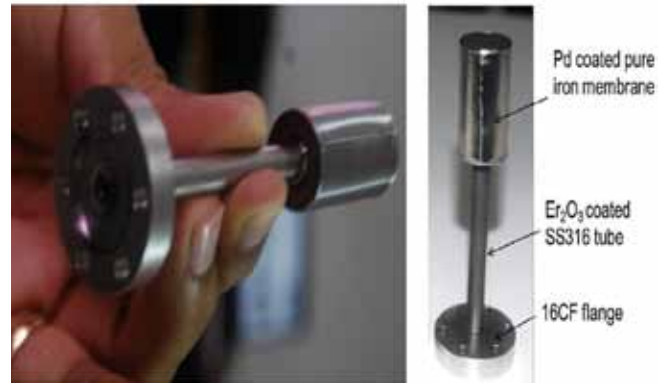


Figure A.2.10.6 Fabricated hydrogen isotope sensor

**Development of hydrogen isotope sensor for PbLi:** A permeation based hydrogen isotope sensor for liquid PbLi is being developed. Fabrication of the sensor has been completed. It is coated with palladium and was fabricated using micro laser welding. This sensor would be first tested for its functionality in hydrogen gas and then hydrogen dissolved in liquid PbLi. Experimental set up for the testing of this sensor in hydrogen gas is being designed and fabrication work is under progress.

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### A.3. Basic Experiments

The institute has a very strong experimental program on fundamental plasma sciences. This exciting programme caters mostly to the requirements of Ph.d. student programme. The current programme has experiments under the following heads:

A.3.1 Large Volume Plasma Device (LVPD) Experiment	24
A.3.2 Basic Experiments in Toroidal Assembly(BETA)	26
A.3.3 Interaction of Low Energy Ion & Neutral Beams with Surfaces	26
A.3.4 System for Microwave Plasma Experiments (SYMPLE)	26
A.3.5 Plasma Wake-Field Acceleration Experiment (PWFA)	27
A.3.6 Experimental Study of Non-linear Plasma Oscillations	28
A.3.7 Experiments on Dusty Plasmas	28
A.3.8 A Linear Helicon Plasma Device With Controllable Magnetic Field Gradient	29
A.3.9 Non-Linear Dynamics In Dc Glow Discharge Plasma	29
A.3.10 Multi-cusp Plasma Experiment	29
A.3.11 Non-Neutral Plasma Experiment (SMARTEX-C)	29
A.3.12 Magnetized Beam Plasma Surface Interaction Experiment	30
A.3.13 Plasma Torch Activities	30

#### A.3.1 Large Volume Plasma Device (LVPD)

In continuation of carrying out investigations on Electron Temperature Gradient (ETG) driven turbulence, the Large Volume Plasma Device (LVPD) has further expanded investigations on the following exciting physics areas, namely, 1) understanding further, the ETG turbulence and its nonlinear properties, 2) the physics of Electron Energy Filter (EEF), 3) unfolding turbulence of near EEF region and lastly 4) tracing the loss path of energetic electrons within LVPD system. We established a mechanism in LVPD by designing EEF, a large variable aspect ratio, rectangular solenoid for excitation of unambiguous ETG turbulence. Using this instrument it has become possible to control cross field diffusion through EEF and thereby control plasma profiles. The presence of this solenoid divides LVPD plasma column into three different plasma regions namely, the source, EEF and target plasmas. The source region covers the region between the filaments and the EEF first wall, the EEF plasma resides between the two walls of EEF solenoid and the target plasma covers the region between the second wall of EEF and the end plate

**Electron Temperature Gradient Driven Turbulence:** The

investigations on plasma turbulence, in the target region, are further expanded. We have seen through observations that the turbulence observed in the core and the edge regions of target plasma offer entirely different features. In order to explore the mode conversion/coupling process in core and edge turbulence, investigations are performed over the entire radial cross-section of the target plasma. Our initial observations indicate that the transition region in the power spectra of the observed turbulence at different radial positions shows a significant shift towards higher frequency for density fluctuations as one move from core to edge region. During this time, initial investigations are carried out on understanding the physics of non-linear structure existing in the background of ETG turbulence.

**Turbulence in the near EEF region:** The activated EEF produces a strong transverse magnetic field of 160G against the axial magnetic field of 6.2G. Almost all plasma parameters exhibit sharp gradients in axial direction across EEF but when EEF is not active, the plasma parameters remain largely unchanged in all the three regions. The physics of EEF can be understood in the following perspective. The EEF selectively stops the energetic electrons of the source region from pass-



Figure A.3.1.1 The newly installed 10kA/20V power supply in LVPD

ing across EEF to target region. It means energetic electrons are suffering very few collisions within strong field of EEF and hence are supposed to be swept to the wall of LVPD all along the EEF axis but to our surprise this is not happening. The target region, on the other hand does not show any presence of energetic electrons hence question arises that where these high energetic electrons are getting lost. The measurements are carried out in the azimuthal plane of the LVPD system by using an array of 32 Langmuir probes mounted

on an axial probe shaft and rotated through 360 degrees in a step of 10 degrees. The energetic electrons are visible in the source and the EEF region. Surprisingly, even after carrying out such an extensive measurements, the loss path of these hot electrons remains an unsolved puzzle. The outcome from these observations has not led us to identify exact path of energetic electrons. No leaking of energetic electrons is taking place to the target region whereas, the loss path as speculated on the basis of magnetic field lines supports the cause that these energetic electrons should have either lost to the device or leaked to the target region beyond the extent of charged area of EEF( 1m charged). We have also initiated steps toward investigating the energetic belt region for plasma turbulence. As reported, in the energetic belt regions of earth's magnetosphere, the high energy electrons excites plasma turbulence. The scenario in LVPD source plasma mimics the similar situation. We initiated investigations in order to find out whether these energetic electrons are dissipating their energy through plasma turbulence as they do in magnetosphere. Initial results have shown that turbulence excited in the belt region is 20 times higher than what is observed in the other region in the source plasma but exact nature and associated free energy source for these turbulence is still unidentified.

**System up gradation:** During last year a major system up gradation activity in LVPD is undertaken towards installa-

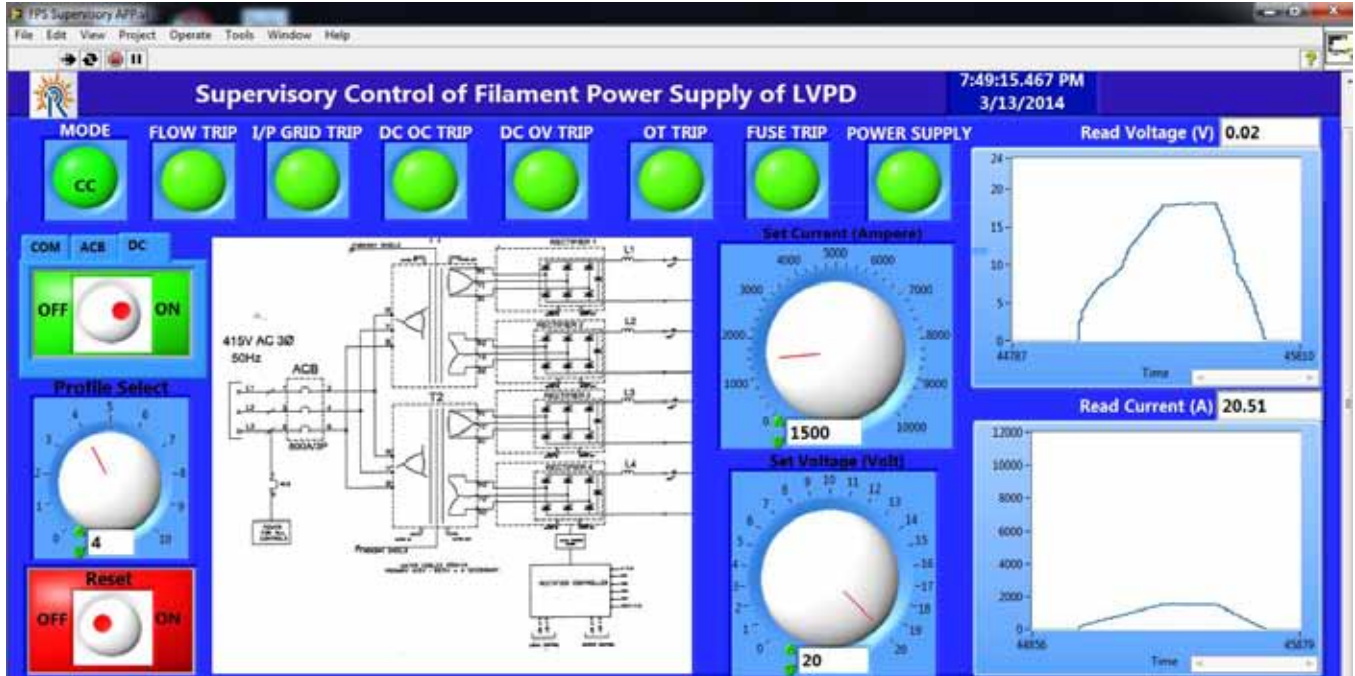


Figure A.3.1.2 The snap shot of a power supply control user interface

tion of high current power supply (10kA/20V) for large area filamentary plasma source [Figure A.2.3.1]. The new power supply has provision of shape control of cathode emission profile. This power supply is computer controlled with a fibre optic link and its output profiles can be programmed in both CV and CC mode. We have developed filament power supply control user interface [Figure A.3.1.2]. We have also undertaken steps to replace the existing data acquisition system of LVPD with a 40 channel PXI based DAS. The SRD( System Requirement Document) is already prepared and reviewed.

### A.3.2 Basic Experiments in Toroidal Assembly (BETA)

#### *Experimental study of generation of fluctuations-driven flow in and mean profile sustenance in BETA - Role of vertical magnetic field:*

During this period, statistical properties of the fluctuating plasma parameters were investigated. A manuscript on the fluctuations and intermittent poloidal transport in toroidal magnetized plasma got accepted for publication during this period. The results indicated the presence of nonlinear behavior in the plasma dynamics. The data analysis was further extended to identify the existence of long-range correlations in the plasma. The observations and new findings in BETA were presented in posters at international / national conferences. In addition to these works, two short-term (3-month) projects were carried out initiating the investigation of fluctuations and intrinsic flow generation with varying toroidal magnetic field strength and topology; radial profiles of mean and fluctuating plasma parameters were obtained. Currently, experiments have been planned for detailed investigation of instability mechanisms with varying toroidal magnetic field strength / topology, and the measurements will be conducted soon. A systematic experimental campaign was carried and is presently ongoing to investigate the effect of vertical magnetical field. This has resulted in the following:

1. A study of transition of flow from coherent to turbulent regime with variation in toroidal magnetic field strength and the role of vertical field on fluctuations and intrinsic flows. Both these work will be continued to the next year.

### A.3.3 Interaction Of Low Energy Ion & Neutral Beams With Surfaces

Additional cooling channels were incorporated in the new electromagnet which was earlier designed and got fabricated in a local company. We also replaced circular copper wires by rectangular copper strips of the same cross-section. With

this slight modification we were able to have same number of turns of copper coils while adding extra cooling channels without changing the overall dimensions of the electromagnet. We have run the new electromagnet in its final form, i.e. after adding the extra cooling channels for final test which is to obtain ten times more ion current / plasma density compared to earlier (old) electromagnet continuously without any time restriction. It has passed the crucial test and did it much better. Even with 40A coil current we achieved ion current / plasma density twenty times more compared to results obtained with the old electromagnet. The electromagnet has been run with 40A coil current without interruption for long hours (more than six hours) without any significant increase in its temperature. Thus we have achieved all our objectives when we decided to replace the old electromagnet by a radically new design of an electromagnet so that ion / neutral flux can be increased by at least a factor of ten without increasing the electrical power consumption of the magnet. We have done better than that, i.e. we succeeded in increasing ion (hence neutral) flux by a factor of twenty while decreasing the electrical power consumption. Plasma density measurement with langmuir probe also confirmed this observation. The maximum density calculated was  $2.2 \times 10^{13} \text{ cm}^{-3}$  which is twenty times  $1.1 \times 10^{12} \text{ cm}^{-3}$  measured when the old electromagnet was used. With the increase in ion flux by a factor of twenty we now expect the neutral flux has also increased by the same factor. Hence this increase in signal to noise ratio will make it easier for us to detect and diagnose the neutral beam. We have now logically moved to the next step, i.e. to develop and setup the neutral beam diagnostics sub-system to be added to the existing system. We have also decided to replace all existing oil based pumps by completely dry pumps. This will get rid of unwanted (hydro-carbon) impurities from detection mechanism which otherwise makes it very difficult to quantitatively calculate neutral beam flux with certainty. Some of the pumps have already arrived and the rest are in the process of being procured.

### A.3.4 System For Microwave Plasma Experiments (Symple)

SYMPLE aims at investigation of interaction between plasma and high power microwave (HPM). While on one side, efforts are on to develop HPMs of a few hundreds of Mega Watt power, to study relativistic effects of wave-plasma interaction, investigations using moderate (~ a few Mega Watts) power HPMS, that are commercially available are now initi-

ated, as “Phase-1” part of the project, to address issues related to wave trapping in plasma. Figure A.3.4.1. shows a schematic diagram of this Phase-1 system. Towards the development of this system, the work carried out during last year include, procurement of a Magnetron based HPM, design of a pulse modulator to drive the Magnetron, designing a plasma system along with its pulser, developing a scheme for coupling the power and procedures towards the component procurement, designing a mode converter, to orient the microwave electric field along the direction of plasma density gradient etc. Expanding the experiments on characterization of the SYMPLE plasma, optical emission spectroscopy (OES) studies have been carried out to cross check the Langmuir probe results. The optical setup employed is based on collimating lens, optical fiber and Ar spectra were acquired by changing fill pressure and operating voltage. At present, work is in progress to find out Te using steady state coronal model from the recorded spectra. A yet another task undertaken is related to developing high frequency (~1-5 GHz) diagnostics for SYMPLE. The diagnostics requirements here include measurement of wave magnetic field in air / vacuum as well as the plasma response by picking up magnetic fluctuations generated in the plasma. In this respect, the major focus last year has been on developing miniature magnetic probes in-house. Considerable database exists for studies at relatively low frequencies (up to a few Mega Hertz), on the design of miniature magnetic probes using special winding and shielding to extract noise free information. The requirements in SYMPLE is more stringent demanding still smaller probes, which at the same time should give detectable signals at a few Gega Hertz frequency. We have carried out a pcb (printed circuit board) based design, fabrication and performance test of miniature magnetic probes, that respond such high frequencies.

### A.3.5 Plasma Wake-Field Acceleration Experiment (PWFA)

Interferometry based diagnostic methods for lithium vapor density measurement have been initiated and extensively worked upon as part of the continuing characterization studies of the heat pipe oven and perfecting the related techniques. Though the preliminary studies with He-Ne laser based interferometry were successful in the formation of clear interferogram the instability of the fringe pattern observed required to be addressed to proceed with the actual experiment. The studies conducted presented wide practical knowledge base in interferometry and also led to the conclusion that the vibration isolation optical tables needed to be rearranged and the distribution of experimental systems had to be reconfigured to remove the instability. This has been effected and the fringe pattern found to be stable enough to proceed with white light as well as CO<sub>2</sub> laser interferometry techniques. A new heat pipe oven system, designed and fabricated as per the conclusions derived from the earlier experimental and theoretical studies, has replaced the first system. In this new new system, while the length of the heater section and so the heat pipe oven length is maintained at 400 mm, each of the two water sinks have been repositioned further 10 cm away from the center of the heat pipe system symmetrically. Each of the sinks also has one thermocouple sensor incorporated inside which allow correct temperature feed back to the heater power supply. A new buffer gas feeding arrangement allows accurate pressure adjustments and presents further improvement in maintaining the purity of gas and two newly integrated pneumatically operated gate valves have further add to the safety of the system at emergencies. The SS mesh pipe of heat pipe has been spot welded on a single line along its length to reduce deformation in long run as has been observed earlier. Studies on this new system would facili-

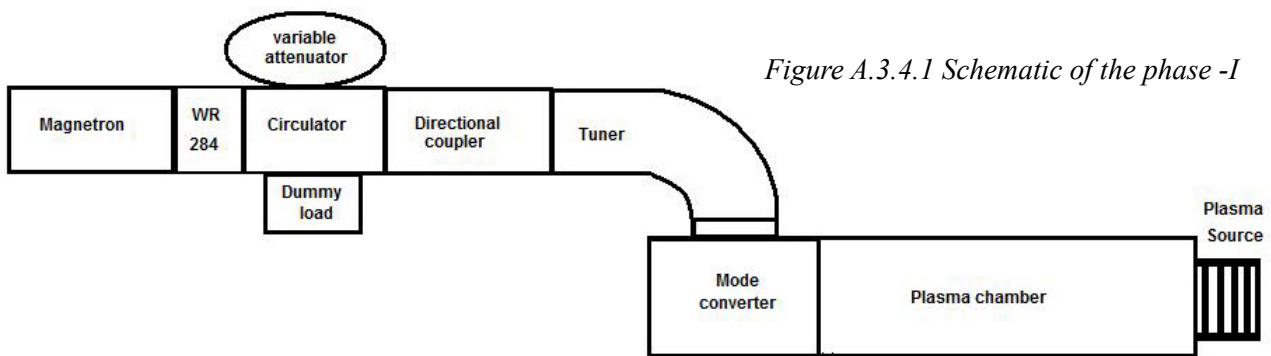


Figure A.3.4.1 Schematic of the phase -I

tate the next important step of the PWFA project of building the indented 1000 mm plasma source as per the plan. Results of the detailed characterization experiments which have been conducted on the new system verify distinct improvement over heat pipe oven temperature profile and confirm the lithium neutral vapor as well as plasma density. Axial probe measurement of vapour temperature established flat temperature profile nearly 30 cm at the actual experiment pressure at 0.3 m bar of helium buffer gas pressure. Already established diagnostic methods based on the absorption of excimer laser power by the lithium vapor as well as study by emission and absorption spectroscopy at 610 nm and 670 nm respectively by spectroscopy have been redone on the new system and earlier results were reconfirmed. The Mach-Zander white light interferometry using Hook's method for lithium vapour density has been conducted and the interferograms observed found to be of very low resolution and so unreliable. The reason has been traced to the limitation of the spectrometer in use. This particular method require an imaging spectrometer to count the shift in fringe pattern. Availability of such a spectrometer is being looked into to conclude this experiment. The FEM studies are being continued on the heat pipe oven process now with emphasize on the dynamical effects of the whole process. These studies also aim at finalization of the designing aspects of the one meter plasma source. The beam shaping optical configurations for excimer laser have been identified and the most suited beam profile has now been chosen for plasma experiments. Purchase orders have been placed for specific optical components, custom formulated specifically and fabricated indigenously by a Bangalore based manufacturer, for the CO<sub>2</sub> laser interferometry technique for plasma density measurement. The process involves 45 degree maximum reflection of 193 nm excimer laser and no loss liner transmission of 10.6 micro-meter CO<sub>2</sub> laser into the system by the same optics. Multi-wavelength dichroic optics with reflectance  $\geq 96\%$  @ 193nm and Transmittance  $\geq 95\%$  @ 10.6 micro-m have also been identified and purchase enquiry generated. Procurement and acceptance tests for various optical and opto-mechanical components and tools were carried out and these include commissioning 30 Watts CW and pulsed CO<sub>2</sub> laser, 20 mW He-Ne laser and CO<sub>2</sub> Laser beam profiler. Control for CO<sub>2</sub> Laser source has been upgraded enabling precise remote control over its parameters with PC based operation. Preliminary conceptual design of the Linac was completed after discussions with experts from RRCAT and IUAC. It was decided that the Linac system should be built on a turn-key basis so that the responsibility

of delivering the parameters of the Linac would rest with the vendor. The preliminary design for the Linac building has been completed and the detailed design changes will be made in consultation with the architect. Request for land has been approved by CDC, IPR.

### A.3.6 Experimental Study Of Non-Linear Plasma Oscillations

An experimental device to study non linear plasma oscillations and a host of other nonlinear waves and instabilities has been installed which has been designed and fabricated in house. This has been developed in two stages. After successful completion of the proof of principle experiments in the first stage, the device has been upgraded and made operational. The upgraded system is 3.34 m in length. The axial magnetic field in the main chamber has been varied from 100 Gauss to 1.2 kilo Gauss using a set of fourteen water cooled electromagnets. The base pressure of the system is  $1.3 \times 10^{-6}$  mbar, the operating pressure ranges from  $1.5 \times 10^{-5}$  mbar to  $1 \times 10^{-3}$  mbar. The lowest operating pressure of this device is among the lowest in its class if not the lowest, thus producing a collision-less plasma enabling one to explore a host of collision less phenomena experimentally. Initial experiments have shown that the plasma temperature in the system can be varied from 1 to 8.5 eV, the density can be varied from  $10^{10}$  to  $10^{11}$  cm<sup>-3</sup>. The plasma produced in the device is very quiet a quiescence of  $2.5 \times 10^{-3}$  has been achieved experimentally; such a low ambient noise will enable one to excite and study the propagation characteristics of low amplitude waves experimentally. Our initial experiments indicate that the design of the device have been a success.

### A.3.7 Experiments On Dusty Plasma

Vortices occur in a wide range of natural phenomena in nature, like tornadoes, smoke rings etc. Such kind of vortices can also be generated in Laboratory complex (dusty) plasma experiments in various scenarios. For example vortices can be induced by radiation pressure or by introduction of magnetic field in a discharge. We have experimentally generated vortices in a parallel plate DC glow discharge without the presence of any external magnetic field or radiation pressure. The properties of these vortices are being studied experimentally and cause of their formation is being explored. Our current investigation suggest that the reason behind the formation of such structures is the presence of shear in the ion wind

coming towards the cathode surface and repelling sheath electric field on the surface of cathode. The shear in the ion drag force acts as a torque on the dust particle cloud resulting in the formation of rotating dust structures. The evolution of these vortices with discharge parameters are being studied experimentally.

### **A.3.8 A Linear Helicon Plasma Device With Controllable Magnetic Field Gradient**

Experiments have been carrying out, developing an inductively coupled radio frequency (RF) plasma source. Principle is to introduce an RF current to a coil/antenna, where the changing magnetic field associated with the coil/antenna current induces an electromagnetic field in the similar way of transformer action. Depending on the coupling mechanism of the RF fields to the plasma, the discharge has been classified into three modes. Electrostatic coupling of RF power with the plasma is called as E-mode and electromagnetic coupling of RF power with the plasma is named as H-mode. In presence of external static magnetic field, these electromagnetic disturbances can propagate at low frequencies (compare to electron plasma frequency) and charge particles can absorb energy from these waves, called W-mode. A special class of such waves are known as helicon waves. Helicon waves are the low frequency bounded waves, which distinguish them from the unbounded wide band whistler's wave observed in space. A half wave right helicon antenna has been used to launch a type of propagating disturbance called a helicon wave which propagates away from the antenna into the bulk plasma, where the wave energy is absorbed by electrons. Experiments have been performed to identify the phenomena of left polarized wave absorption near electron cyclotron resonance frequency in helicon antenna produced plasma. Observation of multiple density peaks at low magnetic field (30 and 50 Gauss) explains the resonance angle propagation of the helicon wave. Experiments have been carrying out to study the dynamics of nonlinear potential structures in the expanding helicon antenna produce RF plasma. External axial magnetic field configuration has been playing important role for the formation of these potential structures.

### **A.3.9 Non-Linear Dynamics In Dc Glow Discharge Plasma**

An experimental system has been developed to study the non-linear dynamics in dc glow discharge plasma. Experimental

set up consists of cylindrical borosilicate glass tube diameter of 15.5cm and 120 cm in length for the vacuum chamber, electrodes, pumping station and power supply. Discharge has been ignited by applying dc voltage between two metal electrodes and discharge current has been measured using a current sensing resistance with necessary instrumentation. It has been observed that discharge current, pressure and electrode separations are the most important parameters for controlling the non-linearity of the dc glow discharge plasma. Array of photodiodes and current probe are the primary diagnostics to study the non-linear dynamics in this plasma. Photodiode is used for measurement of fluctuations in light emitted from plasma while current probe is used to measure the fluctuations over the dc discharge current

### **A.3.10 Multi-Cusp Plasma Experiment**

The prototype magnet has been tested to the final design and the order for the remaining magnets have been completed. In the meantime, to keep the cooling options for magnets in consideration, provisions have been incorporate and it was estimated a cooling water of 80 litres per minute with an inlet pressure of 4 bar will be needed. The provisions needed in the vacuum chamber to integrate the magnets have been redesigned and are ready for integration. The plan to hold the heating filaments of the cathode ionizer needed a revamp due to the inability of special spot-welding requirements. Now instead of spot welding, holding with appropriate screws are being explored. The purchase order for the delivery pipes of the cesium oven has been done and is expected to be delivered in the first quarter of the next year. The floating power supply for the filament heating has been installed and tested. Also before letting Cesium vapour into the chamber, a set of argon glow discharge plasma is being produced to reduce the oxygen content inside the chamber, as oxygen is detrimental for cesium vapour and filament operations. The design for the self cleaning Langmuir probe has been completed and is being fabricated.

### **A.3.11 Non-Neutral Plasma Experiment (SMARTEX-C)**

The High Current DC Power Supply (5000A/100V/1.2s) has been delivered in IPR after preliminary testing at factory site at the limited power levels available out there. Further testing in IPR is underway. Some of the results have been shown below whereby the output current and ripples have been measured by two current transformers of different characteristics

in order to assure the validity of the measurements. The older 28 – turns Toroidal field coils have been removed. A thicker coil with 14 – turns has been wound in order to allow high current from High Current DC Power Supply. The design of a third coil to be fabricated from Copper rods has been prepared to allow even higher currents ~ 5kA. The UHV system has been upgraded by integrating the cryopump, a multi-way cross and a gate-valve. A Helicoflex® has replaced old aluminium wire-seal between collar and the top flange. The overall effects of these modifications resulted an ultimate base vacuum of  $2 \times 10^{-9}$  mbar. A dual Micro Channel Plate followed by multi-anodes has been identified and termed as electric mode of imaging diagnostics to be implemented in SMARTEX – CU. A Prototyping will be done before procurement and implementation of the actual imaging diagnostics

### A.3.12 Magnetized Beam Plasma Surface Interaction Experiment

Presence of conducting boundaries in inhomogeneous magnetized plasmas can greatly modify the potential structure by inducing wall currents through the electrode. Amongst the important plasma parameters, the electron temperature and density gradient in the plasma can be governed by long range electric field through launched through the conducting boundaries. The combined effect leads to instabilities that drive anomalous transport of charge particles across the magnetized plasma column. The above phenomenon applies commonly to radio-frequency antennas and the diverters or limiters in fusion devices. Therefore systematic investigation in to the properties of magnetized sheaths is of utmost importance in magnetized plasmas because the boundary condition at the end-plates can globally disturb the plasma equilibrium. The APPEL-Device provides a unique opportunity for investigating such phenomenon in the laboratory. A prototype of the set-up is currently working and is devoted towards investigating the role of external boundary plates on the equilibrium properties of the magnetized plasma column. In the last year, we have refined and automated our principal diagnostic systems. An automated Langmuir Probe station is developed in conjunction with an automated linear probe-feed through drive. In conjunction a cost-effective microcontroller based tunable microwave source is developed through M.Tech project students. The in-house developments of these techniques has greatly benefitted by reducing the cost of these equipments and provided valuable training and skills for the

project students. In conjunction a number of M.Sc-physics internship students from Indian School of Mines have devotedly contributed to physics experiments last summer. The result was presented in the 66th Gaseous Electronics Conference, New Jersey. International visitors from the University of Liverpool, U.K and Dublin City University, Ireland visited our laboratory. A proposal of scientific collaboration in the areas of magnetized sheath physics associated with radio-frequency discharges is under discussion. In conjunction MBPSI-division shall be collaborating on the Indo-Taiwan project funded by DST-India on experimental and simulation study of radio-frequency sheaths.

### A.3.13 Plasma Torch Activities

High efficiency plasma torches developed earlier were scaled up to higher powers (up to 30kW) for continuous operation. With the high power source and heat exchanger in place, exhaustive experimentation was carried out to formulate scaling laws that have paved way for increasing the power further. Such plasma torches find use in a variety of industrial applications ranging from spraying and cutting to aero-thermal testing of materials. Computational models of the plasma torch were used to explore the role of fluid dynamics in the high electro-thermal efficiency of these torches. On the other hand, several classes and configurations of torches were designed, developed and operated for benchmarking and fine tuning the model. This model will help greatly in reducing the torch design cycle times. Efforts are underway for improving the model by including temporal and non-equilibrium dynamics. An important milestone was achieved with the design and development of a miniature enthalpy probe entirely using in-house facilities and techniques. This diagnostic is an important tool for finding the temperature and flow profiles of the plasma plume.

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## A.4. Theoretical, modeling and Computational Plasma Physics

Plasma physics requires a very intense computational capability for its modelling and simulation program. The institute has developed a versatile computational facility in many years. At present work is being done in the the following heads:

A.4.1 Non-Linear Plasma Studies & simulation	.....	31
A.4.2 Laser Plasma Studies	.....	31
A.4.3 Dusty &/or Complex Plasma Studies	.....	32
A.4.4 Fusion Plasma Studies	.....	33
A.4.5 Global Gyro-kinetic Studies	.....	34
A.4.6 Non-neutral Plasma Studies	.....	35
A.4.7 Molecular Dynamics (MD) Simulations	.....	35
A.4.8 Modelling and Demo Studies	.....	36

### A.4.1 Non-Linear Plasma Studies & Simulation

**Phase-mixing of electrostatic modes in a cold magnetized electron- positron plasma :** In a fluid description, we study space-time evolution of electrostatic oscillations in a cold magnetized electron-positron plasma. Nonlinear results up to third order, obtained by employing a simple perturbation technique, indicate phase-mixing and thus breaking of excited oscillations, and provide an expression for the phase-mixing time. It is shown that an increase in the strength of ambient magnetic field results in an increase in the phase-mixing time. The results of our investigation will be of relevance to astrophysical environments as well as laboratory experiments.

**Study of Transient Electric Field in a Capacitively Coupled Discharge Using Particle-in-cell Simulation:** The analytical prediction of the presence of transient region comprised of finite electric field between the bulk plasma and sheath edge in an radio frequency capacitively coupled plasma (RF-CCP) discharges was reported early. We have used the semi-infinite particle-in-cell (PIC) simulation technique to validate the theoretical prediction for the existence of transient electric field in the linear regime. It is shown that the PIC simulation results are in good agreement with the results predicted by analytical model; the linear theory overestimates the transient electric field as one moves from linear

to weakly nonlinear regime. The effect of applied RF current density and electron temperature on evolution of transition field and phase mixing regime has been explored.

### A.4.2. Laser-Plasma Studies

**Effect of polarization and focusing on laser pulse driven auto-Resonant particle acceleration:** The effect of laser polarization and focusing is theoretically studied on the final energy gain of a particle in the Auto-resonant acceleration scheme using a finite duration laser pulse with Gaussian shaped temporal envelope. The exact expressions for dynamical variables viz. position, momentum, and energy are obtained by analytically solving the relativistic equation of motion describing particle dynamics in the combined field of an elliptically polarized finite duration pulse and homogeneous static axial magnetic field. From the solutions, it is shown that for a given set of laser parameters viz. intensity and pulse length along with static magnetic field, the energy gain by a positively charged particle is maximum for a right circularly polarized laser pulse. Further, a new scheme is proposed for particle acceleration by subjecting it to the combined field of a focused finite duration laser pulse and static axial magnetic field. In this scheme, the particle is initially accelerated by the focused laser field, which drives the non-resonant particle to second stage of acceleration by cyclotron Auto-resonance. The new scheme is found to be efficient over two individual

schemes, i.e., auto-resonant acceleration and direct acceleration by focused laser field, as significant particle acceleration can be achieved at one order lesser values of static axial magnetic field and laser intensity.

**Stabilization of beam-weibel instability by equilibrium density ripples:** We present an approach to achieve suppression/complete stabilization of the transverse electromagnetic beam Weibel instability in counter streaming electron beams by modifying the background plasma with an equilibrium density ripple, shorter than the skin depth; this weakening is more pronounced when thermal effects are included. On the basis of a linear two stream fluid model, it is shown that the growth rate of transverse electromagnetic instabilities can be reduced to zero value provided certain threshold values for ripple parameters are exceeded. We point out the relevance of the work to recent experimental investigations on sustained (long length) collimation of fast electron beams and integral beam transport for laser induced fast ignition schemes, where beam divergence is suppressed with the assistance of carbon nano-tubes.

**Ultra-short hard x-rays from laser irradiated bio-plasmas (with TIFR):** Earlier TIFR group demonstrated that laser irradiated biological target consisting of a few micron-layer of microbe (E. Coli) can lead to bright hard x-ray emissions (up to 300 keV) at a moderate laser intensity. Further experiments done by the same group showed that if E.coli are doped with AgCl nano-particles x-ray emission can be enhanced further by 100 fold compared to the case with only E.coli. We have reproduced experimental results by electromagnetic particle-in-cell simulations, with different parts of the target (slab, bacteria and nano-particles) having different densities to mimic the experimental scenario.

**Anomalous collisional absorption of light waves in underdense plasma:** Collisional absorption occurs when laser photon energy is transferred to the plasma mainly via the electron-ion collisions. The simplest classical model of collision frequency incorporates a factor known as Coulomb logarithm which is conventionally assumed to be independent of the electron-ponderomotive velocity. According to this conventional model, the frequency and the corresponding fractional laser absorption remain almost constant up to a critical value of the peak intensity of the laser pulse, and then decrease when peak intensity is increased beyond critical value (irrespective of temperature of the plasma). We propose that

when a strong laser field is applied the Coulomb logarithm should depend on the total velocity, not the thermal velocity only. Below some temperature  $<10\text{-}15\text{-eV}$ , with a total-velocity (thermal velocity plus the ponderomotive velocity) dependent Coulomb logarithm, it is found that frequency and absorption grow hand in hand up to a maximum value around the critical value followed by the conventional decrease when peak intensity is greater than the critical value. Such a non-conventional anomalous variation of fractional absorption versus the laser intensity was observed in some earlier experiments, but no explanation has been given so far. In this work we consider modified Coulomb logarithm, which seems to explain those experimental observations. With increasing temperature (e.g. at 30 eV) and density, the anomalous behavior is found to disappear even with the modified Coulomb logarithm, and the variation of frequency and absorption with intensity approach to the conventional scenario.

### A 4.3 Dusty &/or Complex Plasma Studies

**Study of vapor-liquid phase transition phenomena in dusty plasmas:** The phenomenon of phase transition in a dusty plasma has attracted some attention in the past. By using molecular dynamic simulations the existence of a liquid to solid (LS) transition in a dusty plasma system was demonstrated where the dust particles interact through a Yukawa potential. However the question of the existence of a vapor-liquid (VL) transition in such a system remains unanswered and relatively unexplored so far. We have investigated this problem by performing extensive molecular dynamics (MD) simulations over a large range of parameters to look for such a transition. Our results indicate that the VL transition does not have a critical curve in the pressure versus volume diagram for a large range of the Yukawa screening parameter  $\kappa$  and the Coulomb coupling parameter  $\Gamma$ . Thus the VL phase transition is found to be a continuous transition in the dusty plasma model of Farouki and Hamaguchi. We further provide an approximate analytic explanation of this finding by means of a simple model.

**Studies of complex dust dynamics in dusty plasmas:** A system of heavily charged small dust particles suspended in a plasma, easily sustainable in simple laboratory experiments often exhibits properties analogous to multiple phases of matter, ranging from a weak or strongly coupled fluid that can support collective wave propagation, to a crystalline or amorphous solid, or even a visco-elastic material. In the re-

cent studies motivated by experimental observations in dusty plasmas, formation of self-organized hollow toroidal dust flow patterns are analyzed and an orbit instability of cluster forming dust particles is explored driven by the sheared flux of the streaming ions that results in the self-organized dust flow. The mechanism behind the dust structures is relevant to various fundamental physical processes in nature following the dynamics of autonomous systems of large number of interacting elements.

**Generalized Hydrodynamics and Molecular Dynamic simulation of Dusty Plasma:** Dusty plasma is typically collection of electrons, ions and highly charged and massive micron sized dust particles. The ensemble of dust particles with high dust charge can easily be found in all three states of matter due to strong coupling between dust particles. In our previous studies, we have used GH description of dusty plasmas to describe various nonlinear phenomena like Kelvin-Helmholtz (KH) Instability, singular coherent structures etc. This year, we have used the GH model to study the nature of elastic turbulence in dusty plasmas and made further studies to find its similarities with polymers and other visco-elastic fluids. We have also used the particle model to study dusty plasmas assuming them to interact with each other through Yukawa potential. Molecular Dynamics (MD) simulations have been carried out to study KH instability, shear wave propagation, vortex evolution etc. Some understanding has been developed about the correct representation of dusty plasma by comparing few collective phenomena using GH model and MD approach.

**Debris charging:** The increasing number of debris in ionosphere has posed serious problem to future spacecraft/satellite programs. These moving debris get charged due to ionosphere plasma may interact through strong electrostatic force with other space objects. We have carried out Particle-in-cell simulations to study the charging of space debris in ionosphere using SPIS open source electrostatic PIC code.

**Study of Kolmogorov Flow In Strongly Coupled 2D Fluids using Generalized Hydrodynamic Model:** To investigate a special class of shear flow, namely Kolmogorov flow, its stability and transitional behaviour in strongly coupled dusty plasma using viscoelastic and hydrodynamic fluids, a Pseudo-spectral code which solves the fully nonlinear equations is developed. This correctness of the calculation is verified by benchmarking against Eigen value problem. Several

interesting features are obtained. [1] Transition of laminar flow to turbulent flow from the critical value of Reynolds number. [2] Growth rates come from pseudo spectral code are very close to Eigen value solver. [3] Nature of growth rate below critical value of Reynolds number is obtained different in nature in viscoelastic fluid from conventional fluid.

#### A.4.4 Fusion Plasma Studies

**2-Dimensional predictive computer simulations of Scrape-off Layer plasma transport for Phase-1 operations of Tokamak SST-1:** Computational analysis of coupled plasma and neutral transport in the Scrape-Off Layer (SOL) region of the Steady-State Superconducting Tokamak (SST-1) is done using SOLPS for Phase-I of double-null divertor plasma operations. The device is to have a diverted plasma in a magneto-hydrodynamic (MHD) plasma equilibrium with D shape, variable elongation, and finite triangularity. An optimum set of plasma parameters is explored computationally for the first phase operations with the central objective of achieving an effective control over particle and power exhaust. While the transport of plasma species is treated using a fluid model for multiple plasma species in the code B2.5, a full kinetic description is provided by the EIRENE code for the neutral particle transport in a realistic geometry of the tokamak. Cases with external means of control for the plasma operations, like an active gas puffing, are analyzed for finding regimes where an effective control of plasma operations can be exercised by controlling the SOL plasma conditions over a range of heating powers. Our computational characterization of the SOL plasma with variable input power and a lower hybrid current drive (LHCD), for the desired separatrix density, indicates that there will be access to high recycling operations producing reduction in the temperature and the peak heat flux at the divertor targets. This indicates that a control of the core plasma density and temperature would be achievable. A power balance analysis done using the kinetic neutral transport code EIRENE, indicates about 60-75 % of the total power diverted to the targets, providing quantitative estimates for the relative power loading of the targets and the rest of the plasma facing components.

**Electron Temperature Gradient Mode:** We have predicted that the apart from various known sources (ohmic heating, bootstrap current, radio frequency heating etc.) contributing to plasma current drive in tokamaks, the another source may also be present due to sharp gradients in tokamak pedestal

region namely Electron Temperature Gradient (ETG) mode. We have presented a formalism to predict and calculate the contribution of ETG turbulence driven current drive in tokamak current.

#### **Study of Tearing Modes with equilibrium shear flows:**

Work on proper theoretical understanding of recent experimental observations of DIII-D, ASDEX etc has been conducted which show strong influence of plasma rotation on excitation and evolution of NTMs. This work is part of ITPA MHD Topical Group joint activity. Recent DIII-D experiments show the asymmetry in NTM threshold for co and counter toroidal flow which remain an unresolved issue. Using Culham Transporter of Ions and Electrons (CUTIE) code which is a two fluid initial value nonlinear global code. Initial CUTIE results suggest that two-fluid effects generally behave like poloidal MHD flows and tend to stabilize in the absence of axial flows. When axial flow is present, two-fluid effects are destabilizing relative to single-fluid theory for negative flow shear. They stabilize for positive axial flow shear. So two fluid effects may break symmetry as shown in the experiment.

#### **Study of Edge Localized Modes with Resonant Magnetic Perturbations :**

Work on understanding the dynamics of resonant magnetic perturbations (RMPs) and control of ELMs is underway. This work is supposed to be useful for JET RMP calculation. Using CUTIE code, a  $n=2$  static external magnetic perturbations is applied at wall for all  $m$  values as  $m=4$   $n=1$  perturbations have no effect on ELMs. Such RMPs looks effective to mitigate ELMs. Observations of repetitive ELMs which is otherwise very rare in numerical simulations, quite helpful to understand how RMPs can modify ELMs frequency and amplitude. Pellets and toroidal rotations also have strong effect on ELMs.

**Edge-Peeling Ballooning Modes in Tokamaks :** Three dimensional (3D) edge localized mode in the presence of peeling ballooning instability (ELM-PB) in tokamak plasma geometry had been studied using BOUT++ code. Linear growth rate and its eigen modes had been studied and compared with ELITE results. Hyper-resistivity induced chaotic magnetic field was found in the nonlinearly saturated phase. The ELM-PB had been stabilized in the presence of resonance magnetic field perturbation (RMP) and flows. Influence of an externally heating source had been studied to simulate ELM-PB crash rates. Some results in the linear phase and also at

the start of the nonlinear phase has been presented in a forum. The source increased mean pressure and generated few eigen modes in the inner regions of the tokamak plasmas. In the presence of the flows these modes stayed at longer duration of time. With source and flows the ELM width and ELM energy loss were found in lower magnitudes in compared to the case of without flows (with source).

#### **Hydrodynamic Transport Coefficients and Glass formation in a strongly coupled plasma:**

Investigation on atomistic origin of the hydrodynamic transport coefficients in a model strongly coupled dusty plasma liquid using Molecular Dynamics simulation is underway. Similarly a study of shear localization in glass forming Yukawa systems and glass transition studies is being investigated. Work on 3D-Percolating Plastic Failure as a Mechanism for Shear Softening in Amorphous Solids has been written up and is under review.

### **A.4.5 Global Gyro-kinetic Studies**

#### **Gyrokinetic simulations of Micro-tearing Mode in large aspect ratio Tokamaks:**

Gyrokinetic calculations for large aspect ratio tokamaks revealed the existence of unstable micro-tearing modes, which were previously thought to be stable in purely collision-less, high temperature plasmas. Starting from a finding of the instability at low  $n$  values, extensive studies revealed the highest linear growth rate at high- $n$  values of  $n=23$ . The free energy coming from the electron temperature, and the even parity of the A-parallel identify the mode as micro-tearing mode. The typical length scales of the MTM magnetic vector potential to the electrostatic potential fluctuations are sub-ion-larmor radius, with significant contribution from the electron larmor radius scales and could only be resolved with a large number of radial grid points and poloidal harmonics. Porting to the newly commissioned Udbhav HPC Cluster at IPR and Utkarsh HPC via the DAE Grid enabled these high resolution gyro-kinetic simulations of the micro-tearing instability with computational requirement of about 1TB of RAM and 40 CPU cores per run. Taking into account fully gyro-kinetic highly passing ions and electrons, the global 2-D structures of the collision-less mode with full radius coupling of the poloidal modes were obtained. The Electron magnetic drift resonance of the passing electron population is shown to be the main collision-less destabilizing mechanism. The mode grows monotonically with the plasma beta and is strongly electromagnetic as observed from the ratio of fluctuation strengths of magnetic vector potential

to the electrostatic potential. Scans at different plasma beta values show an inverse relationship between the temperature gradient length scale and plasma beta leading to a stability diagram, and implying that the mode might exist at moderate to strong temperature gradients for finite beta plasmas in large aspect ratio tokamaks. Real frequency shows a clear and strong dependence on the plasma beta and eta and increases with them. This is in contrast to a nearly constant value found from local-flux tube calculations by others. Linear growth rates from n-scan and beta scan show that if trapped electrons are neglected, MTMs are more unstable than the Kinetic Ballooning mode.

#### A.4.6 Non-Neutral Plasma Studies

##### Studies in Pure Electron and Pure Ion Plasmas:

A suite of 1D, 2D and 3D Particle-In-Cell codes have been developed to address physics of non-neutral plasmas. Following improvements were made in April 2013: a) the code was OPEN-MP parallelized over particles. b) Later the Poisson solver was parallelized over nodes. c) It was realized that in order to fully bench mark the code, the boundary walls of 2D cross section had to be made circular, as most benchmarking-standard publications were based on this geometry. So without changing the Cartesian X-Y geometry of the code to r-theta, the code was made manoeuvrable to switch between rectangular and circular boundaries with different aspect ratios. d) The fact that the same code could now be applied to cylindrical geometry as well as toroidal geometry with circular as well as rectangular c.s. , and the fact that it had a full dynamics version as well as a Guiding centre motion approximated versions, opened up some new avenues of research which are being pursued at present. e) The code was bench marked using several standard analytical results in cylindrical geometry. During all the stages of the above mentioned period relevant papers and other resources on the physics was studied and useful theories were documented. Following interesting benchmark studies were performed: a). Studies and simulations on vortex dynamics of 2D euler fluids using electron plasmas with attention to spatial landau damping, quasimodes, vortex merging, vortex crystals etc. b). Studies and simulation on 2D electron plasma close to the brillouin limit (break away from the fluid analogy) with attention to anomalous growths of diocotron modes of various profiles in this limit. Using this powerful tool, a new physics problem of effect of finite inertia at high Brillouin limit was investigated which resulted in inertia driven radial oscillations and nonlinear relaxation.

#### A.4.7 Molecular Dynamics (MD) Simulations

**Strongly coupled plasmas under gravitational field - a Molecular Dynamics study:** Using 2D Molecular Dynamics (MD) simulation, the equilibrium and dynamical properties of a gravitationally equilibrated Yukawa liquid are investigated. It is observed that due to asymmetry introduced in one direction by gravity, several interesting features arise. For example, for a given value of coupling parameter  $\Gamma$ , screening parameter  $\kappa$ , and according to a chosen value of gravitational force  $g$  (say in y-direction), the system is seen to exhibit super-, sub- or normal diffusion. Interestingly, x-averaged density profiles, unlike a barotropic fluid, acquires sharp, free surface with scale free linear y-dependence. As can be expected for a system with macroscopic gradients, self-diffusion calculated from Green-Kubo's formalism does not agree with that obtained from Einstein-Smoluchowski diffusion. A 2D angular-radial pair correlation function  $g(r, \theta)$  clearly indicates asymmetric features induced by gravity. It is observed that due to compression in y-direction, though in liquid state for all values of gravity considered, the transverse mode is found to predominant as compared to the longitudinal mode, leading to a novel Anisotropic Solid-like Yukawa liquid.

**Molecular Dynamics study of Pair-Ion Plasmas - Phase Transition and Transport in SuperCritical Regime:** The equilibrium properties and phase transition of strongly coupled pair-ion plasmas with soft core have been investigated. Extensive Molecular Dynamics (MD) simulations are performed on such plasmas at different temperatures to analyze the phase stability. To understand the physics of such system, diagnostics techniques such as pair-correlation function, self-diffusion coefficient, velocity autocorrelation function, pressure tensor autocorrelation function and heat flux correlation function have also been investigated. This study shows interesting phase co-existence between liquid-like and vapor-like phase. This and the corresponding critical properties are calculated directly from MD simulation and the results indicate clearly the existence of a critical point. Temperature quench molecular dynamics method was also calculated to locate vapor-liquid phase coexistence points in pair-ion plasmas, where by equilibrating a single phase under NVT conditions and then quenching the system into a two-phase region, it spontaneously separates into two coexisting phases

#### A.4.8. Modelling and Demo Studies

**Modeling activities related to ADITYA and SST-1:** The divertor equilibrium for ADITYA-upgrade has been constructed with additional coils kept at the inboard side. These coils are up-down symmetric and have to carry about 150 kA for producing divertor configuration. There are two more coils at the outboard side which will be useful to make plasma bigger in radius. A study has been carried out to see the flexibility of these configurations to finalize the requirements of these coils. The SST-1 tokamak is now operational and produces routinely plasma with current of 40-50 kA. As it is envisaged, the next step in the SST-1 operation is to produce divertor plasma. One of the advanced divertor concept is X-divertor, which is not yet proven experimentally. An attempt is made to construct X-divertor equilibrium for SST-1 without altering the existing divertor targets of SST-1 standard divertor. This has shown the need of additional coil for which one can use the active feedback coil of SST-1. The following Fig. shows one such configuration for SST-1. The performance of 2nd harmonic ICRH scenarios is studied with TORIC code. The simulation for a typical Aditya shot shows that the power coupled to ions is about 35% and the remaining is coupled to electrons through fast wave damping. A study on fast wave absorption scenarios in ion cyclotron frequency range in L-mode plasma of SST-1 has been carried out. In this study, various minority species and plasma ion species are considered. It is found that the helium plasma with minority hydrogen ions of 2 % has shown good coupling of RF wave and this SST-1 scenario will be relevant for ITER helium discharge which is mainly aimed to achieve H-mode operation in ITER.

**Fusion reactor design activity:** The 0-d reactor physics design code SPECTRA has been enhanced with the inclusion of self-consistent estimation of helium concentration in the steady state operation, synchrotron radiation and possible two impurities and their impact on the power balance. This has reproduced most of the published results and this has been used to participate in the IAEA benchmarking session of reactor design tools. In this activity, there are about other 6 ITER partner codes are also compared. For this, a well-defined reactor case is taken and is found all the codes are within the range. There few specific choices like current drive efficiency, impurity choices, divertor choices, detailed

modeling of magnets, etc. brings the difference between these codes. The comparison of geometrical parameters and plasma parameters for a typical DEMO reactor is shown here. The poloidal profile or shape of Toroidal Field (TF) coil is crucial to decide the size of the reactor and is obtained by using bending moment free scenario of TF coil. This has been applied to ITER like magnets and validated. This method is used to obtain the shape of medium sized reactor like SST-2. This is fed to CAD modeling and then analysed for The Graphical User Interface (GUI) has been made to integrate these design tools so that it can be run seamlessly. The preliminary GUI is capable of coupling 0-d reactor physics code, TF shape code and limited capability in modifying the input file for neutronic calculations.

**HPC cluster “Udbhav” :** The HPC cluster of 5.2 Tflops named Udbhav has been procured and commissioned. It is operational from Dec. 2013 and given the access to user from Feb. 2014. This has nine nodes and each node contains 32 core. The RAM per core is 8 Gb and each node can provide about 256 Gb RAM. The total number of cores in Udbhav is about 320 out of which users can access about 288 cores. The choice of processor is such that it can give 4 floating point operations in one cycle and makes it efficient for computational purpose. There are about 20 users of IPR theory group presently using and they have already exploited Udbhav’s full capability. The Udbhav is up by 99.79 % time with a smaller

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# CHAPTER B

## ACTIVITIES ON OTHER CAMPUSES.

The following are activities done on other campuses and other heads, even though the work done are all under the mandate of the Institute. There are three other campuses at present as following :

B.1. Facilitation Center for Industrial Plasma Technology (FCIPT) Activities .....	38
B.2. ITER-India .....	40
B.3. Center of Plasma Physics(CPP-IPR), Guwahati .....	46

## B.1 Facilitation Center for Industrial Plasma Technologies (FCIPT) Activities

### Plasma Surface Engineering

**Design & Development of Prototype Plasma Treatment System and Process Optimisation to Modify the Surface of Polyester & Nylon Fabric to improve its Adhesion with Polyurethane (PU) & Polyvinyl Chloride (PVC) Coatings/Lamination:** Technical textiles are one of the fastest growing sectors of the global textile industry. In India too, it is an emerging area with great potential for growth. Coating and lamination are twin technologies that can completely transform the appearance, properties and performance of technical textiles. In order to improve the adhesion between textile substrate and deposited coating or laminate layer, plasma treatment is an environment friendly and economical alternative. In the present project, a prototype plasma reactor was developed for fabric treatment and installed at MANTRA, Surat in August 2013 (Figure B.1.1). After plasma treatment on polyester, adhesion with PVC coating was increased up to 30-40%.

**Development and demonstration of prototype plasma carburizing system:** Case hardening by carburising is an old art that has recently experienced a growth sprint in new equipment designs and processes. Plasma carburising represents a new technology and is being accepted in the heat treating industry. Plasma carburising differs from conventional gas carburising process as it is carried out in a vacuum chamber at sub atmospheric pressure. The atmosphere is methane gas. The carbon source is ionised and accelerated to the work pieces due to an electrical potential between the work piece and the surroundings. This is manifested as a glow discharge around the work piece. The glow is very uniform, creating a very uniform carbon profile over the entire surface of the work piece. Plasma carburising is slightly done at a higher temperature than gas carburising process. The work piece has less distortion than conventional carburising process. Because, plasma carburising is not limited by the gases ability to supply carbon to surfaces, it saturates the surface with carbon very quickly. As a result, plasma carburising process could attain the same carbon gradient in about 15 minutes. In FCIPT, we have developed a prototype plasma carburising system as shown in Figure B.1.2. Plasma carburising was carried out at 950-1050 °C. We were able to get a hardness of 750 HV in AISI 8620 steel after plasma carburising for 10 minutes.

**High Density DBD plasma system development for polyethylene, textile, merino wool etc. treatment:** High density DBD plasma can perform fast surface modifications in order to match the In-line speed requirements in textile industries. This surface modification basically reduces the amount of hazardous chemical required in the industries and hence, high density DBD plasma technology may help in providing environment friendly solution for hazardous chemical processes in textile industries. FCIPT, IPR has successfully developed a new DBD plasma system that generates plasma in air for treatment of various materials. The treatments of polyethylene, textile, and merino wool have shown significant improvement in functionality with reduction in treatment time.

**Growth of silver nanoparticles on free standing GaSb nanodots project work completed under DAE-BMBF bilateral project :** FCIPT/IPR has completed Indo-German (DAE-BMBF) bilateral project between FCIPT, Institute for Plasma Research and Ion Beam and Material Research, HZDR, Germany. Under this project a process to grow hexagonally ordered silver nanoparticles in a two-step approach was developed: at first hexagonally patterned nanodots (ND) were formed on the surface of the substrate by plasma ion irradiation, and subsequently, physical vapor deposition (PVD) silver growth at grazing incidence was performed on such patterned substrate. A fairly homogeneous hexagonal ordering of nanodots of around 30 nm length is obtained for sample (a), where further deposition of silver nanoparticles was performed. In right image in figure 1 shows the growth of silver NPs on non-ordered and dot-ordered substrate, respectively. Randomly distributed NPs are formed when grown on normal nonpatterned GaSb substrate, while ordered NPs are formed when grown on NDs. In the reflection measurements of these samples, we have observed two LSPR peaks corresponding to the ordered NPs. The two plasmon resonance peaks appear to be arising due to the NP ordering, as in this case not only the dipole resonance of the single NP, but also a higher-order resonance is excited. Such kind of highly ordered nanoparticles are in demand for sensing technology and for plasmonic solar cell to trap the light and increase solar cell efficiency.

**Iron oxide nanoparticles under Indo-Italy Bilateral Cooperation funded by DST, India:** Iron-oxide nanoparticles have been synthesized by high temperature arc plasma route with different plasma currents and characterized for their structure, morphology and local atomic order. Two samples made under 32 A and 65 A plasma current were studied in detail. Both the particle shape and size distribution are different for



*Figure B.1.1 Plasma reactor for textile treatment developed by FCIPT, IPR and functioning at MANTRA, Surat.*

the samples analysed. The crystallinity of the samples were analysed by powder X-ray diffraction. The XRD analyses clearly indicate high crystalline phases while the “d” values point out the presence of both  $Fe_3O_4$  and  $\gamma-Fe_2O_3$ . There are no major differences between the two spectra except for the

presence of  $Fe_2O_3$  (hematite), which appears better in the 65 A sample. This contribution points out the possibility of a multicomponent product formation at higher energies. Fe K-edge x-ray absorption spectra done at Elettra Sincrotrone, Italy reveal distinct local structure of the samples grown with different plasma currents. It is found that the local disorder is higher for the higher plasma current (65 A) grown samples even though the average particle-size is larger. The results provide useful information to control structural and morphological properties of nanoparticles grown by high temperature plasma synthesis process.



*Figure B.1.2 Plasma Carburising system developed in FCIPT*

**Space plasma & spacecraft solar array interaction study SPIX-II:** In the year 2010, ISAC, ISRO has awarded a project on” Space plasma & spacecraft solar array interaction study SPIX-II”. The objective of this project is to develop an indigenous experimental test facility to simulate LEO and GEO like space conditions in the laboratory. It has been observed that at elevated bus voltage, under the influence of plasma and energetic electrons, arc initiates at the surface of satellite solar panel. The aim of this activity is to understand the arc initiation and categorization behaviour. This facility has been commissioned successfully and accepted by ISRO of-

ficials. For different types of solar panel configurations, various experiments have been conducted and obtained results well match with the results observed at NASA, JAXA and ESA laboratories. This facility is now in operation and series of experiments are planned with different types of satellite solar panels.

### Plasma Pyrolysis

#### ***Design and Development of 15kg/hr plasma pyrolysis / gasification system to dispose solvent mixture and solid waste:***

FCIPT has received this project from CSIR- Central Salt & Marine Chemicals Research Institute (CSMCRI) in May 2013. The value of the project is Rs.45.00Lacs. FCIPT has designed 15 kg/hr plasma pyrolysis system which generates usable combustible gases by disposing solvent mixture waste (liquid) and solid waste that are generated in CSMCRI lab. The system is in the final stage of fabrication. This system will be delivered to CSIR-CSMCRI by May 2014.

#### ***Recovery of Phosphorus from Phosphoric Acid using a Plasma Pyrolysis system:***

FCIPT received this project from M/s Excel Industries Ltd., Mumbai. The objective of the project was to see the possibility of recovering Phosphorus from Phosphoric acid using plasma pyrolysis process. The elemental yellow Phosphorous has been recovered from Phosphoric Acid in plasma pyrolytic environment. The process was optimized and 70% yield of yellow Phosphorous was achieved. FCIPT has successfully completed this project.

***Technology Transfer:*** For the commercial exploitation of indigenously developed Pulsed power instrumentation for plasma nitriding source, a technology transfer agreement has been signed with M/S Auto Controls Mumbai.

## B.2. ITER-India

In the past one year ITER-India made significant progress in the ITER project. During this period, the ITER-India project has entered into the manufacturing for few packages. The details of the activities completed under different packages/heads are given below.

### B.2.1 In-Wall Shielding (IWS)

IWS blocks shall be placed between outer and inner shells of Vacuum Vessel (VV) to stop escaping the neutrons and to reduce the toroidal magnetic field ripple. These shield structures are made of SS 304B4, SS 304B7, SS 430 and SS 316L

(N)-IG and Fasteners (Bolts, Nuts, Spacers, Washers etc.) are made from XM-19 and Inconel-625. The manufacturing of IWS blocks is in progress at Avsarala Technologies while all the material procured from Industeel (France) and Carpenter (USA) has been received at manufacturer's site. Process qualification of material XM-19 for fasteners has been completed and bulk production of these materials has started. Water jet Cutting of PS1 for all Vessel Sectors (except VS 7 and 8) (Approx. 4176 plates) has been completed out of which machining of 319 Plates (PS1 of VS5 and VS6) has been completed. Water Jet cutting of Support Rib of PS1 for all Vessel Sector has been completed out of which machining and inspection of PS1 of all Vessel Sectors except VS 7, 8 and 9 is completed. Water Jet cutting of 144 Upper Brackets has been completed. Water Jet cutting and machining of lower welded brackets of PS1 VS6 and VS5 are also completed and so is its dimensional inspection. Out of about 1600 Manufacturing Drawings of IWS Blocks, 168 drawings of blocks, 158 drawings of IWS Support ribs are approved by IO while 693 drawings of IWS block, 148 drawings of Support Ribs and Manufacturing Assembly drawings for Bracket-Rib assembly of PS1 for all Vessel Sectors have been submitted to ITER Organization, France (IO). Process Qualification for Welding of lower bracket to Support Rib is going on. Feasibility study of using Ultrasonic time of flight method for bolt pre-loading measurement and its verification has been performed. Outgassing rate measurement of Free Issue Material (FIM) samples of has been carried out. To evaluate the effect of corrosion on Outgassing Rate three samples of different IWS materials have been corroded by immersing them in water for a particular time period. Outgassing Rate of these samples has to be measured. Typical out gassing rates observed for IWS materials is  $3.27 \times 10^{-8} \text{ Pa}\cdot\text{m}^3\cdot\text{s}^{-1}\cdot\text{m}^{-2}$ . After categorization of 853 IWS blocks of the regular vessel sector, 50 blocks were selected from 55 categories and detailed assembly schemes and tools/fixtures are developed for these 50 blocks. Nesting Plans of PS1 Support Ribs, PS1 plates for all Vessel Sectors, lower bracket of VS6 and VS5, PS2 Support Ribs for VS6 and VS1 have been approved by ITER Organization, France.

### B.2.2 Cryostat & VVPSS

Cryostat is a reinforced, single walled structure with overall diameter & height ~29 m. Fabrication activities for Cryostat Base Section started henceforth and are in progress at Larsen & Toubro (L&T) Heavy Engineering, Hazira. Construction of Cryostat Temporary Workshop at ITER site in full swing and is nearing completion. The construction of the Cryostat



*Figure B.2.1 Cryostat Base Section Mockup*

Workshop (110 metres long, 44 metres wide and 27 metres high) is nearing completion at ITER site, Cadarache, France. The 54 modules of Cryostat manufactured in India will be brought to the ITER site, which will be fabricated further in this workshop into 4 main sections for assembly in the Tokamak pit. A gantry crane of capacity 200 tonnes (inset) has also been installed in this workshop.

### **B.2.3 Cooling Water system**

Cooling water system is needed to take away heat from the

various components/systems and reject this in to the atmosphere. The Contract for Detailed Design, Engineering, Procurement and Supply of ITER Component Cooling Water System (CCWS), Chilled Water System (CHWS) and Heat Rejection System (HRS) has been awarded to M/s L&T Construction Infrastructure, Chennai. According to the priority at ITER site, the Final Design of Lot-1 Piping has been completed and was followed by the Manufacturing Readiness Review of the Lot-1 piping. Final Design of Lot-2 & Lot-3 piping and the systems has been started. The first lot of piping is expected to be delivered to ITER site by September 2014.

### **B.2.4 Cryodistribution & Cryolines**

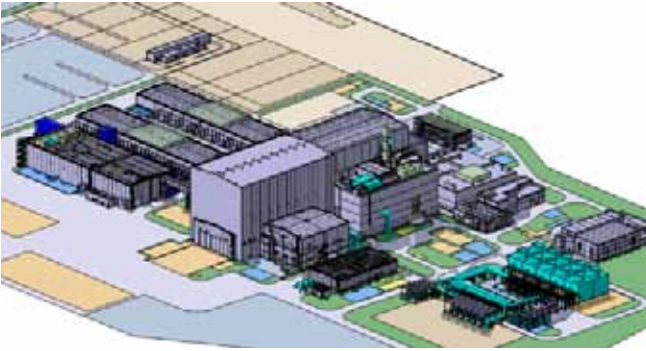
The cryogenics is needed to transport cold power to different components to support and sustain the plasma fusion and to maintain specific systems on working temperature. The cryogenic system also minimizes the heat losses from the superconducting magnets and help to sustain the large current in them. Manufacturers have been finalized for Cold Circulators and Test Auxiliary Cold Box. Mechanical installation of Prototype Cryoline (PTCL) Test Infrastructure at ITER-India lab completed and commissioning is in progress.

### **B.2.5 Ion Cyclotron Heating & Current Drive Sources**

ITER plasma will be heated with 20MW input power using ICRF sources. Under this package IN-DA is committed to deliver 1 Prototype and 8 complete ICRF units each of having



*Figure B.2.2 Cryostat Workshop at ITER site, Cadarache, France and crane installed inside*



*Figure B.2.3 Layout of Cooling Water System at Site*

2.5 MW capability. Due to very stringent source specifications, an R&D program has been initiated using two different kinds of high power vacuum tubes i.e. using Diacrode and Tetrode tubes, to identify the best technology for ITER application. During this reporting period, manufacturing of tubes and major section of cavities related to driver and final stage amplifiers completed. Assembly, installation and stage wise testing initiated at M/s Thales Electronics Devices, France & M/s Continental Electronics Corporation, USA, as a part of Factory Acceptance Test (FAT). Manufacturing and FAT of 15 kW solid state, wideband and continuous wave pre-driver amplifier completed successfully. Manufacturing, Factory Acceptance Test and Site Acceptance Test of 1.7 MW Dummy Load completed. Manufacturing & Factory Acceptance Test of 3MW Dummy Load is also completed. Integrated testing of Local Control Unit (LCU) at ITER-India Test Facility has been completed. To obtain ITER grade perform-

ance, a full-fledged test facility is being developed at ITER-India Test Facility.

### B.2.6 Electron Cyclotron Heating (ECH) system

The EC H&CD system will be used for plasma heating and current drive applications including plasma start up. In this context, the Indian Domestic Agency (ITER-India) has a procurement package (EC Gyrotron Source Package) whose main scope is to supply a set of two high power state of the art Gyrotron sources (170 GHz/1MW/3600s) including their auxiliary systems. The execution approach includes procurement of high power gyrotron tubes on functional specification basis and establishment of complete integrated performance. A Gyrotron Test Facility (IIGTF) with prototype auxiliary systems is being developed to establish the integrated Gyrotron system performance. Component testing has been done to establish a Wire burn test set up around the indigenously developed 75kV Ignitron based Crowbar switch. The three series ignitron crowbar successfully diverts the fault current in < 10 micro seconds and limits the fault energy deposition in the Gyrotron tube. A prototype filament power supply 30V/50A (AC) with customized requirements has been developed and tested. As a part of the prototype developments for the Local Control Unit of the Gyrotron system, an Engineering design task has been completed. An Industrial grade fiber optic based signal conditioning unit (SCU) based on in-house design has been developed. IR thermography setup has been established at IIGTF as a part of Gyrotron RF beam diagnostic, being a non-contact technique it shall be utilized



*Figure B.2.4 Prototype Cryoline (PTCL) Test Infrastructure at ITER-India lab*



Figure B.2.5 ITER-India ICRF test facility: Cooling Water layout

in high power Gyrotron RF beam mode purity analysis. Acceptance tests completed on a 3 TR water chiller with pressure of 7 bar, flow rate of 110 LPM for the helium compressor of Super conducting magnets of Gyrotron tube.

**B.2.7 Diagnostic Neutral Beam (DNB)**

The Diagnostic Neutral Beam (DNB) (3 S On/20 S Off with 5 Hz modulation) in ITER is mandated to provide 100 kV, ~18-20 Amp Hydrogen beam to support the Charge Exchange Recombination Spectroscopy (CXRS) for the measurement

of Helium ash in the ITER machine. Manufacturing of DNB Beam Source and SPIDER Beam Dump is in progress at PVA Tepla, Germany. Fabrication of Vacuum Vessel for DNB test facility has also commenced at Vacuum Techniques, Bangalore. R&D activities like Prototype Ceramic Ring for DNB High Voltage Bushing (HVB) and EB welded Heat Transfer Elements modules for calorimeter have been carried out.

**B.2.8 Power Supply Group**

The Group is responsible for design, development and supply of power supplies for the Diagnostic Neutral Beam (DNB), the Ion-Cyclotron (IC) and the Start-up Electron Cyclotron (EC) System of ITER. A high voltage power supply for SPIDER acceleration grid (AGPS) is to be supplied at Neutral Beam Test Facility (NBTF); RFX, Padova-Italy. Additionally the group is to support R&D for DNB, EC and IC systems at ITER-India lab which includes development of prototype power supplies. Contract for manufacturing of SPIDER AGPS and DNB AGPS is awarded to M/s Electronics Corporation of India Limited (ECIL), Hyderabad. Final design review (FDR) for AGPS was held at ITER-India; detail design was presented by ECIL team and reviewed by reviewers from RFX Padova, Fusion for Energy (F4E) Barcelona, Culham Centre for Fusion Energy, CRPP EPFL Lausanne, IO and IPR. The design is approved; manufacturing of major components like transformer and SPS modules has started following formal closure of Manufacturing Readiness Review. Mul-

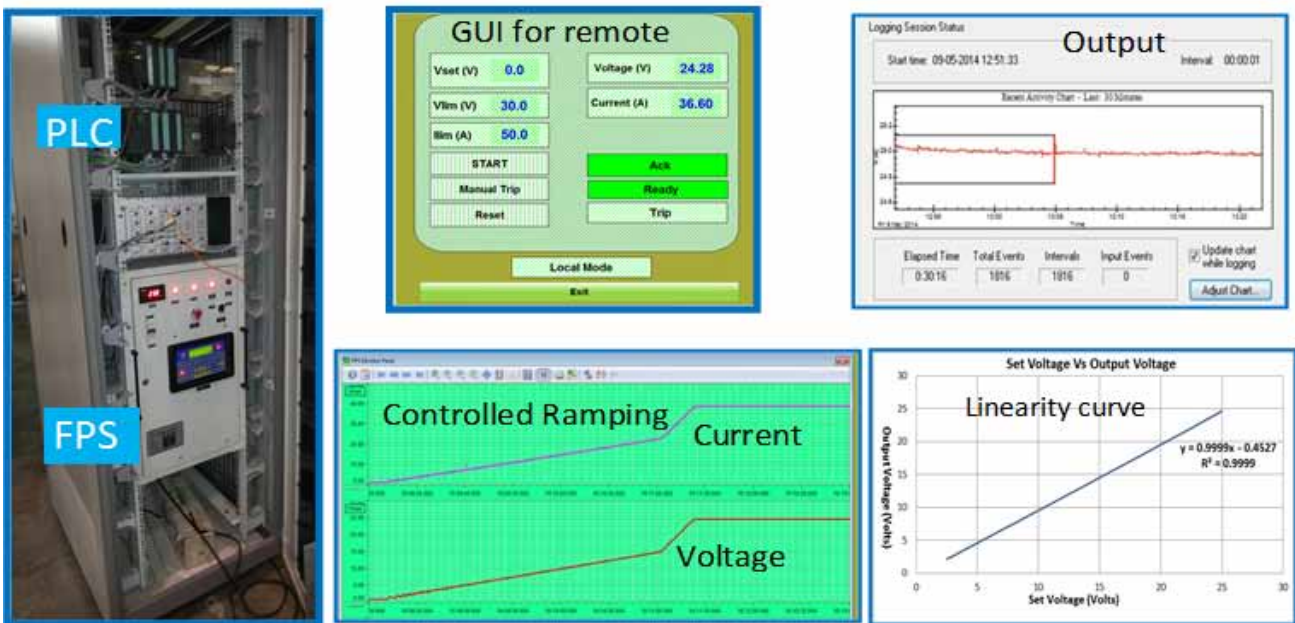


Figure B.2.6 Filament power supply for Gyrotron cathode heater



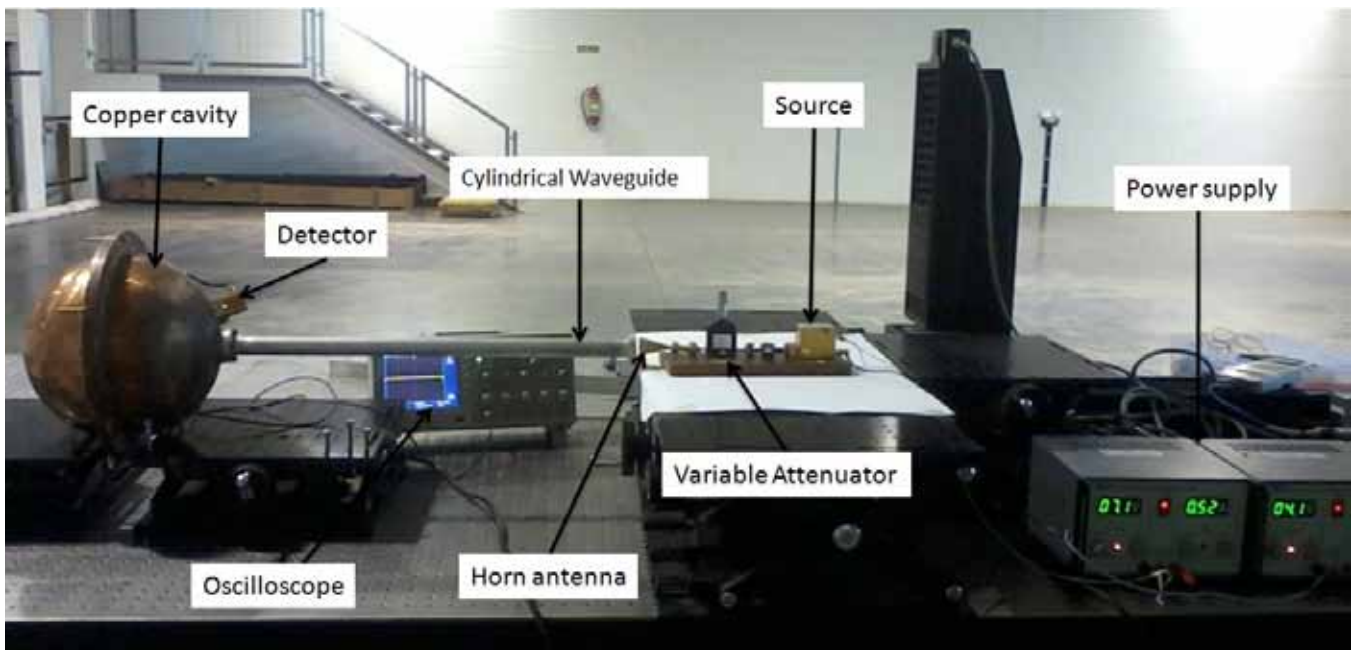
*Figure B.2.7 Prototype Ceramic Ring DNB HVB*

tisecondary Transformer for EC Main High Voltage Power Supply (ECMHVPS) is received at ITER-India lab, as a part of domestic programme. IC HVPS prototype components arrived at ITER-India lab, site acceptance of individual components and pre-commissioning test are performed. Integration work is completed; functional test of power supply is to be initiated.

### B.2.9 ITER-India Diagnostics

Signing of Procurement Arrangement (PA) of diagnostics

package continued and two more systems (1) Electron Cyclotron Emission (ECE) diagnostic system & (2) Upper Port # 09 (UP#09) have been signed for ITER, following successful completion of the document specifying the functional specifications and the technical scope of the package. Preparation of Quality Assurance documents i.e. Quality Plan, Procurement description, & Risk plan for two X-Ray Crystal Spectroscopy (XRCS) diagnostics systems, ECE diagnostics system & UP#09 were completed successfully. After completing design requirements assessment for the X-ray spectrometer's major components, the 3-D CATIA model is under preparation for the survey sight-tube incorporating remote handling flange at the port-plug connection and vacuum components. Preliminary design of the bellows was made to compensate relative movements of the port-plug and thermal expansions. Design of supports for the neutron shield and sight-tube was also made. Layout of the Type-2 vacuum pump and its connections to the system was prepared and first order pump down calculation were completed. Detailing of Service Vacuum System (SVS) connections has also progressed. Neutronics analysis using ATILLA code was carried out. Shadow ray-tracing analysis was completed to study effect of tilt of side crystals on the image or spectral resolution. In order to prepare for prototype experiments, the design work on realizing broadband and fixed anode x-ray sources progressed. Procurement activities are in progress for an x-ray characterization system comprising of a miniature x-ray tube and



*Figure B.2.8 Experimental arrangement to measure performance of the sniffer for ECE package*



silicon drift detector. A code has been written to design filament and fixed anode source providing inputs to the hardware procurement. AERB's mandatory training on safety aspects of ionizing radiation was successfully completed. An assessment of x-ray radiation hazard in the ITER-India lab due to XRCS activities was made.

For ECE, preliminary design of connection box, layout for transmission line & hot body calibration source has been completed and the design of transmission line, vacuum joints and Support arrangements is in progress. Contracts have been awarded for the procurement of Fourier Transform Spectrometer (FTS) & fabrication of silicon carbide contour plate, to be used for prototype experiments for ECE diagnostics system. NOTEC code developed by FOM Institute Netherlands has been used to study the impact of non-thermal electrons in temperature measurements using ECE. Simulation studies for sniffer (detector) design and estimation of waveguide attenuation has been completed. An ECRH stray radiation measurement sniffer was developed and tested for their required parameters as shown in the figure B.2.8.

I & C requirements for ECE diagnostics have been assessed and preliminary reports prepared. Detail designing of UP#09 is progressing well towards the Preliminary Design Review. External interfaces are identified for the verification of Configuration Management Model (CMM). Preliminary analysis model for assessment of diagnostics shielding module and upper port plug is prepared and preliminary structural analysis is completed. Preliminary Structural analysis of Interspace Support Structure (ISS) for the assessment of deflection is completed. Model preparation for Neutronics analysis is in progress. A proposal for common manufacturing of Interspace Support Structure (ISS) and Port Cell Support Structure (PCSS) has been worked out and discussed with ITER Organization.

#### **B.2.10 Activities of the Fusion Physics, Information Technology and IO-DA coordination group**

Modelling of disruption mitigation and shutdown of ITER plasmas with repetitive pellet injection with runaway current suppression using the TSC code is ongoing. Establishment of Local Area Network for ITER-India lab has started. Leased line connection (34Mbps) between ITER-India office in Gandhinagar and ITER-India lab at IPR has been established and being used. SAP implementation across ITER-India and IPR is nearing completion. All transactions for Material Management as well as Finance (payroll etc.) are being executed

in SAP since the past one year. The Internet Bandwidth of ITER-India as also bandwidth of leased line connection to ITER-France was increased to 45 Mbps and 80 Mbps respectively during this period. The IT group has initiated the process of implementing ISO 27001 and ISO 20000 training, implementation and certification process with the help of a professional company

#### **B.2.11 Activities common to all packages and project office**

Package review meetings were conducted, budget estimates were prepared and payments were tracked. Regular schedule updates were made and reported at International organization. Ultrasonic Testing procedure qualification for In-Wall shielding blocks completed. EOT cranes are successfully installed & commissioned at ITER-India lab. Ensured compliance to Quality Management System through various documents (Quality plan, Manufacturing & Inspection Plans, Procedures etc.) reviews. Adhering to modern international project management practices and also developing awareness on Intellectual Property Management (IP) through in-house training and pre-screening of publications for IP. ITER-India hosted the ITER IP Contact Persons meeting in December 2013. Extended public awareness activities on fusion by participating in public exhibitions at Indian Institute of Technology, Gandhinagar and Gujarat Science City, Ahmedabad as well as international public communication events like Monaco-ITER International Fusion Energy Days (December 2013) and World Energy Congress (Korea, September 2013). ITER-IO conducted Quality Audit of ITER-India during 25th Sept to 01 October 2013. This audit had covered seven PA and one ITER-India's Contractor.

#### **B.2.12 Activities of Design Office**

96 DETs (Design Exchange Tasks) were executed between IO and DA and associated Technical support. 3 Design collaboration implementation forms (DCIFs) have been signed with IO (ECRF, UPP09 and ECPS). Design activities in Synchronous mode using ENOVIA for Cryostat, CWS, DNB, DNBPS, ICHVPS, IWS and Diagnostics. Fifteen high end workstations (HZ820) installed. Procurement of AMC for ANSYS, CATIA, 3DVIA, STAD-Pro, AUTO-CAD licenses have been procured and installed. Seven more workstations added in ITER Collaborative Network between IO and INDA for CAD DB access (through ENOVIA). Design and Drawing evaluation of many systems and ANALYSIS support in the domain of Static, Seismic and thermal. Technical co-or-

dination and Configuration management support to ITER and our vendors on behalf of ITER-India. Training to ITER-India Staff: on Equipment and System (Piping Module) ANSYS CFD Introduction, ANSYS and HYPERMESH. ENOVIA Certification Training for 14 ITER-India and Vendor's staff completed.

### B.3. Centre of Plasma Physics, Guwahati

#### B.3.1 Theoretical and Simulation Works

**Neutronics analysis of the 1D Indian DEMO:** A preliminary neutronics analysis was carried out for Indian DEMO with a 1D MCNP model with radial build-up. The initial materials chosen are lead-lithium cooled ceramic breeder (LLCB) for breeding blanket, water cooled SS for both shield blanket and vacuum vessel. The calculation model was a toroidal cylindrical geometry including the blanket, the shield, the vacuum vessel and the TF coil on both sides of the plasma, and the center solenoid (CS) coil. All the materials are considered as homogeneous mixtures for this preliminary analysis. The tritium breeding ratios for inboard and outboard breeding blanket were found to be 0.361 and 1.008 respectively with a total ratio of 1.369.

**MD simulation of 1D, 2D and 3D structure formation in vertically aligned dust chains:** In this work, using Molecular Dynamic techniques, we have studied the self-assembly and structure formation in reduced ( $D < 3$ ) dimensions by charged dusts levitating within a glass box immersed in plasma.

**Potential formation in a Collisionless Plasma produced in an Open Magnetic Field in presence of Volume Negative Ion source:** The electric potential near a wall for a multi-species plasma with volume produced negative ions in presence of axially varying magnetic field is studied following an analytical-numerical approach. A constant negative ion source is assumed throughout the plasma volume, along with finite temperature positive ions and Boltzmann electrons. The particles are assumed to be guided by an open magnetic field that has its maximum at the centre, and field strength decreasing monotonically towards the walls.

**Effect of ion-neutral collision on the sheath formation in presence of dust:** The sheath formation is studied in presence of dust in a collisional environment. In common laboratory plasma the dust acquires negative charges because of high thermal velocity of the electrons. The usual dust charging theory dealing with the issue is that of the Orbit Motion Limited (OML) theory. However, the theory does not find its

application when the ion neutral collisions are significantly present. An alternate theory exists in literature for collisional dust charging. Collision is modelled by constant mean free path model. The sheath is considered jointly with the bulk of the plasma and a smooth transition from the bulk to the sheath is obtained. The various plasma profiles such as the electrostatic force on the grain, the ion drag force along with the dust density and velocity are shown to vary spatially with increasing ion neutral collision.

**Erosion due to ion sputtering in absence of Debye Sheath at Divertor plates - PIC simulation:** A 2D-3V Particle-in-Cell code with Monte Carlo Collision and a Plasma Surface Interaction Code written in Matlab is used to study the effect of grazing angle ( $\alpha$ ) on solid surface (divertor) erosion due to ion sputtering in magnetic fusion devices, where  $\alpha$  is the angle between the magnetic field and the surface tangent. The ion distribution in front of an absorbing wall is computed using a kinetic model. Important factors like ion energy and impact angle for wall erosion and sputtering are highlighted. The dependence of these two parameters on grazing angle is investigated in detail. A comparison is done in Erosion due to ion sputtering in presence and absence of Debye Sheath.

#### B.3.2 Experimental Works

**CPP-IPR Magnetized Plasma Experiment for Plasma Surface Interaction (CIMPLE-PSI):** A supersonic plasma jet assisted experimental reactor configuration was developed with a BRNS sponsored project. Using an almost similar vacuum expanded linear plasma jet configuration as in the nano-reactor, we have developed a High Heat Flux (HHF, 10 MW/m<sup>2</sup>) system in this laboratory, which may be used for material testing under high heat load conditions or synthesis of materials in an extremely dense plasma. Another major activity of this laboratory is the ongoing development of a common facility in the form of an independent linear magnetized plasma device, which will reproduce the extreme plasma and heat flux parameters foreseen in the Divertor region of ITER like modern Tokamak machines. Apart from using this system to explore the physics and chemistry behind a host of plasma surface interaction issues of current interest to the plasma fusion community, this will also be utilized as a test-bed for direct validation of new materials/components under extreme fusion plasma like environment. Currently, the above mentioned HHF system has been very efficiently used as the forerunner of CIMPLE-PSI system. The segmented plasma torch is being optimized in that system only and plasma diagnostics systems are integrated there. We had reported previously the successful development of this HHF



*Figure B.3.1 The High Heat Flux system*

system at CPP-IPR and production of a well collimated beam of argon plasma even without a magnetic field. This plasma jet configuration, which was measured to deposit more than  $10 \text{ MW/m}^2$  heat flux on a 2 cm diameter calorimeter surface, should be ideal for high heat flux testing of Tokamak grade materials. However, the beam gets diffused if produced with hydrogen alone, which justifies introducing an axial magnetic field of maximum 0.4 Tesla in our new complete Diverter Simulator system. We have also observed that the plasma beam still retains its collimated structure while produced with the following gas mixture: argon 20 lpm and hydrogen 10 lpm, which was seen to deposit maximum heat flux on the calorimeter as well.

**Studies on synthesis of nanostructured tungsten materials:** Tungsten, because of its very high melting temperature, low sputtering yield and negligible tritium retention, is considered to be the best material for certain plasma fusion applications. Plasma enhanced chemical vapor deposition or plasma spray techniques are being investigated to produce tungsten coatings on appropriate base materials like graphite, copper, stainless steel and their combination, which may be eventually used inside a Tokamak machine as plasma facing materials. Yet another new direction of investigation is using nanostructured tungsten materials, in either nanoparticle or nanocoating form. We have synthesized fine crystalline nanoparticles of tungsten by injecting particles of ammonium paratungstate (APT) with the powder feeder into the reactant injection section.

**Extraction of Negative Hydrogen Ions Produced by Caesium (Cs) Coated Dust:** A new experimental set up is designed for dusty plasma laboratory under XII<sup>th</sup> Five Year Plan. The prime technical objective of the proposed project is to develop extraction mechanism of the negative hydrogen ions produced by surface produced Cs-coated tungsten-dust particles in the dusty plasma device of CPP-IPR. The experimental set-up consists of extraction chamber, vacuum system, dust dropper, Cs oven etc. It also consists of designing and fabrication of the Plasma Grid, Extraction Grid and the Acceleration Grid and their positioning and support inside the plasma chamber. Langmuir probe, Laser Photo Detachment and OES will be used as diagnostic tools to study the properties of plasma with H<sup>-</sup> ions. Calorimeter will be used to measure the extracted negative ion beam current. Faraday cup and electrometer will be used to study the dust charging mechanism.

**Ion-ion plasma experiments in a Helicon source:** Helicon sources are popular due to its high ionization capability. However, the radio-frequency energy absorption mechanism in such sources is still debatable. Considering the electron mass in wave dispersion theory, it has been proposed that the efficiency of the absorption mechanism is due to Trivelpiece-Gould (electron cyclotron – TG Mode) modes which is quasi-electrostatic and is rapidly absorbed as they propagate inward from the radial boundary. The role of electrons in energy absorption mechanism in helicon sources can be further deeply studied, if the fraction of electrons can be varied without affecting the positive ion density. In this regard, elec-



*Figure B.3.2 Tungsten samples are being exposed to Helium plasma*

tronegative gases (F, Cl, Br, I, O<sub>2</sub>, SF<sub>6</sub> etc.) can be used in the plasma, which can control the electron population density by their electron affinity property. Electronegative gases can even produce positive ion – negative ion (ion – ion) plasma with very small fraction of electrons.

**Study on surface processes in a negative ion source and measurement of negative ion parameters:** Surface processes enhances the population of vibrationally excited hydrogen molecules resulting in improved yield of negative hydrogen ions by the process of dissociative attachment. Also, it is known that plasma uniformity near the magnetic filter should be kept as low as possible for good ion beam optics. Surface processes, through an enhanced production of negative ions, will also have an effect on the plasma uniformity near the magnetic filter. Here we are trying to investigate this important aspect of the influence of surface processes on plasma conditions near the magnetic filter.

**Development of a quasi-stationary type coaxial plasma gun with a GW/m<sup>2</sup> level power density to simulate plasma material interaction of fusion reactor:** We are going to build a 200 kJ (further extendable to 600 kJ) pulse power system to drive a coaxial plasma gun. The pulse power system comprises of several sub systems, components and parts like gas injection valve and its power supply, ignitron and its triggering system, dummy load, dump resistors, pulse shaping resistors, decoupling switch etc. To test these items prior to use in the main pulsed power system, the components and subsystem have to be tested and checked for their performance. Therefore, we are trying to build a small-pulsed power system of 2-6 kJ with variable

voltage 20 kV to test the ignitron, current monitor, and other components such as triggering system, dummy load, dump resistors, pulse shaping resistors, decoupling switch etc. in pulse mode. The applied voltage in the 200 kJ PPS will be of 15 kV. Therefore the resting circuit should be operated with voltage greater than that voltage i.e. around 18-20 kV. To build this small PPS, we need a capacitor of rating 10 micro-Farad, 20 kV. With parallel combination of 2-3 numbers of such capacitors we can have PPS of energy 4-6 kJ with voltage 20 kV. This will help us to test the voltage withstand test of different components and additionally we will be able to do the initial operational test of the components/parts before putting the items into the circuit of the main pulse power system.

**Development of Neutron Source Based on Inertial Electrostatic Confinement Fusion Scheme and its Application in Damage Study of Fusion Materials:** We are trying to fabricate a cylindrical and a spherical IECF device for generation of neutrons that will operate both in continuous and pulsed mode. The cylindrical IECF device will act as a linear neutron source which will emit neutrons anisotropically whereas the spherical device will provide isotropic neutron emission. Continuous operation of the device will facilitate to expose neutrons continuously onto the materials and components to be tested. On the contrary, by operating the IECF device in pulsed mode we expect to produce higher neutron flux. IECF chamber will have multiple ports for evacuation, viewing windows, high voltage feed-through, gas inlets, different diagnostics coupling etc. as shown in the figures below. Top port will be used as an access port for high voltage feed-through and one side port will be dedicated for coupling to the evacuation system. A residual gas analyzer will be used to monitor the quality of the vacuum and to detect minute traces of impurities in the chamber. Anode and cathode grids of both geometries (spherical and cylindrical) of SS with varying dimensions and transparency will be employed. High voltage DC vacuum feed-through will be used to provide the necessary potential to the cathode using high voltage DC power supply which enables us for continuous mode of operation. Glow discharge plasma of fuel gases will be initially created by the filament discharge by keeping four filaments in between chamber wall and anode. The deuterons produced by the glow discharge will be accelerated towards the transparent anode and cathode grid due to the high electrostatic field in between both the grids and, subsequently, those ions fuse to produce neutrons.

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Figure B.3.3 Newly system for negative ion extraction system

## **C. Academic Programme**

C.1 Doctorate Programme	.....50
C.2 Summer School Programme	.....50

## **D. Technical Services**

D.1 Computer Services	.....50
D.2 Library Services	.....51

## **E. Publications and Presentations**

E.1 Journal Articles	.....52
E.2 Internal Research and Technical Reports	.....65
E.3 Conference Presentations	.....71
E.4 Invited Talk Delivered by IPR Staff	.....90
E.5 Talks Delivered by Distinguished Visitors at IPR.....	93
E.6 Colloquia Presented at IPR	.....95
E.7 Scientific Meetings Hosted by IPR	.....95
E.8 MoUs Signed	.....96

## C. ACADEMIC PROGRAMMES

### C.1 DOCTORATE PROGRAMME

In the Ph.D. programme conducted by the institute thirty nine (39) research scholars have been enrolled at present. Out of them, fourteen (14) are working in theoretical and simulation projects while fourteen (14) are engaged in experimental projects. Eleven (11) new students have joined this programme during the year and are going through the course work. After successful completion of this course work, they will be enrolled for their Ph.D. works. Presently sixteen (16) Post-Doctoral Fellows are engaged in their research work.

#### Ph.D. Thesis Submitted (during April 2013 - March 2014)

Radiation Pressure Acceleration of Ions in Bulk Targets by Ultra-Intense Laser Pulses  
Ujjwal Sinha  
Homi Bhabha National Institute, 2013

Momentum Transport: Intrinsic Rotation and Zonal Flows in Microturbulence in Tokamaks  
Rameswar Singh  
Homi Bhabha National Institute, 2013

Laser Driven Acceleration of Charged Particles in Vacuum  
Vikram Sagar  
Homi Bhabha National Institute, 2013

Study of Shear Driven Electron Magnetohydrodynamic (EMHD) Instabilities in Plasmas  
Gurudatt Gaur  
Homi Bhabha National Institute, 2013

Generalized Hydrodynamic Description of Dusty Plasmas  
Sanat Kumar Tiwari  
Homi Bhabha National Institute, 2013

Study of Wave Propagation and Potential Structures in an Expanding Helicon Plasma  
Kshitish Kumar Barada  
Homi Bhabha National Institute, 2013

Observation and Theory of Electron Temperature Gradient Turbulence in Laboratory Plasma  
Sushil Kumar Singh

Homi Bhabha National Institute, 2013

Studies of Plasma Flows in Scrape-Off Layer Plasma of Aditya Tokamak  
Deepak Sangwan  
Homi Bhabha National Institute, 2013

### C.2 SUMMER SCHOOL PROGRAMME

Forty nine (49) students participated in this programme, which aimed at providing an opportunity to (26) students from M.Sc. Physics and (23) students from Engineering discipline which include Mechanical, Electronics and instrumentation, Electrical, Chemical and Metallurgy, to interact actively with scientists of the institute and learn about Plasma Physics and related areas through a project and series of lectures.

Besides the above-mentioned training programme, project works are being routinely offered in Computer, Electronics, Mechanical and Electrical Engineering for regular students as a part of their academic requirements

## D. TECHNICAL SERVICES

### D.1 Computer Services

During the period the following have been the achievements:

- Internet bandwidth upgraded to 100 Mbps over OFC ring and internet service provider changed to BSNL. FCIPT and IPR-Labs at Gandhinagar were also upgraded to 10 Mbps over OFC.
- New fireproof safe cabinet installed @ FCIPT under Phase-I of IPR's Disaster Recovery Plan. Users can store static backups of their data at this facility.
- New state-of-the-art A/V systems installed at Committee Rooms, Board Room & VC setup (Director's Office) at New building
- Core Internet Servers at IPR have been upgraded to HP Blade Chassis with 8 blades.
- 10Mbps OFC internet bandwidth procurement initiated for CPP-IPR Guwahati Campus
- Guest House is made Wi-Fi Zone with ticketing system for guests. This is phase-1 of the IPR Wi-Fi project.
- Feasibility study of the upcoming industry standard "Data Center" carried out.

- IPR's IT Security Policy has been drafted and pending approval.
- Installation of Gateway Firewall (UTM -Unified Threat Management) is underway.
- Installation of 10 TB SAN (Storage Area Network) is underway. This will provide centralized storage as well as backup.
- Installation of new Cisco Routers that can be remotely monitored for FCIPT & IPR-LAB Gateway is underway.
- New IBM HPC (5.2 TF) has been successfully installed at Computer Center and users are extensively working on this facility.
- Eight new state-of-the-art Video Conferencing Systems were installed at CPP-IPR, FCIPT & IPR. This will facilitate better communication between the various campuses of IPR.
- Audit of the existing network of IPR is currently underway. Details and recommendations of this audit will be used to upgrade the 17 year old network of IPR.
- As per DAE guidelines, the IT asset/inventory information for IPR/FCIPT was collected using a web based software specially developed for this purpose by the center using PHP and MySQL. This software enables easy access to the IT inventory database and also for report generation.
- CAT6A networking has been implemented in the additional offices building.
- Email quota was increased for IPR users.
- In the last 1 year, 10 graduate and post-graduate students carried out their academic projects at the center.
- Live video streaming and archival system was developed and implemented.
- System for network threats and vulnerability scanning and analysis was developed and implemented.
- System for network monitoring and analysis system was developed and implemented.
- New IPR e-office system with document repository systems for the following were implemented; (a) Abstract Submission & approval (b) Official Document Uploads (c) Project Management Group
- Other modules for E-office that were developed by CC include ; (a) Academic project management (b) Guest House and Hostel management
- Conference abstract management system was developed on Indico platform and was successfully implemented for the Plasma-2013 as well as PSSI-PSC-2014 conferences. This system provides a complete solution to conference abstract / paper management.

## D.2 Library Services

The institute library as in the past continued to serve its users community. It subscribes to major databases such as SCOPUS, SCIENCE DIRECT, Archives of Journal of Plasma Physics, AIP, APS Journals and PROLA. During this year library has undertaken digitization process of scanning all old IPR newsletter (Waves and Fourth State) issues available in library and made full text access of these newsletter available through library webpage. About 286 books, 60 internal research reports, 33 technical reports, 56 research reports received from other research institutes, 142 reprints, 28 pamphlets and 42 software's were added in to the library collection and subscribed to 105 periodicals. Total 18 E-books and 9 theses were added to the collection. Library orientation was given to newly joined members, SSP Students, and Research Scholars. A talk was presented for the benefit of library users on a topic "IPR Pustakalay Aapke Desktop Par" (IPR Library Services: On Your Desktop) on 25th April 2013 at IPR in a two days hindi seminar on Scientific and Administrative Topics. Smoke detectors and fire alarming systems were installed in library area. 77.44% of the requests made by IPRites were satisfied through Inter Library Loan (ILL) service. IPR Library provided documents to other institutes against ILL queries and 89% of the total need were satisfied. Total 47168 photocopies supplied to users. The library homepage acts like a window, through which it is possible to access the digital content subscribed by IPR as well as open access content. It also provides access to the institutional repository consisting of journal articles published by the IPR authors from year 1986 to present using Dspace an open source repository software. More than 1506 articles by IPR authors are now part of the repository. IPR theses from year 1982 onwards (75) are now available full text for IPR users. The library also added news alert service through website for users. Total 43 News items were displayed as an Alert Service in the field of Plasma Physics and Fusion Technology. IPR Library helped in activities of Official Language Implementation Committee (OLIC) programmes. All library staff actively participated in professional meetings and institutional activities. Library provided internship training programme to 3 MLISc students (1 student from Hemchandracharya North Gujarat University, Patan and 2 students from Central University of Gujarat (CUG), Gandhinagar

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## E. Publications and Presentations

### E.1 Journal Articles

- Effect of Isothermal Heat Treatment on Microstructure and Mechanical Properties of Reduced Activation Ferritic Martensitic Steel  
K.S. CHANDRAVATHI, C.S. SASMAL, K. LAHA, P. PARAMESWARAN, M. NANDAGOPAL, V.D. VIJAYANAND, M.D. MATHEW, T. JAYAKUMAR, E. RAJENDRA KUMAR  
Journal of Nuclear Materials, 435, 128-136, 2013
- Electron Heating in a Multi-Dipole Plasma by Electrostatic Plugging  
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- Comparison of Low and Atmospheric Pressure Air Plasma Treatment of Polyethylene  
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PREDHIMAN KAW  
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M. RAGHUNATHAN and R. GANESH

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P.K. CHATTOPADHYAY, KSHITISH K. BARADA, J.  
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D.V. MODI and C.N. GUPTA

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H. Vaghela, B. Sarkar, R. Bhattacharya, H. Kapoor, M. Chali-  
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R. Bhattacharya, B. Sarkar, H. Vaghela, and N. Shah

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S. AGRAWAL, R. RANE, and S. MUKHERJEE

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PRATIBHA GUPTA

Vigyaan, Edited by Suresh Kumar Jindal and Phuldeep Ku-  
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GAINCARLI

IPR/RR-589/2013      APRIL 2013

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RAJIV GOSWAMI

IPR/RR-590/2013      APRIL 2013

Experimental study of the nature of liquid metal flow under  
uniform transverse magnetic field, in a channel which consist  
of sharp 90° bends

- ANITA PATEL, R. BHATTACHARYAY, E. RAJENDRA KUMAR, P.K. SWAIN, P. SATYAMURTHY, S. IVANOV, A. SHISHKO  
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- Fluctuations and intermittent poloidal transport in a simple toroidal plasma  
T.S. GOUD, R. GANESH, Y.C. SAXENA and D. RAJU  
IPR/RR-592/2013      APRIL 2013
- Curved small tungsten (W) macro-brush test mock-up fabrication using vacuum brazing for divertor target element  
K.P. SINGH, S.S. KHIRWADKAR, ATUL PRAJAPATI, M.S. KHAN, SUNIL BELSARE, ALPESH PATEL, KEDAR BHOPE, PRAKASH MOKARIA, NIKUNJ PATEL  
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DEEPTI SHARMA, R. SRINIVASAN and M. KUNDU  
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HITESH KUMAR B. PANDYA, MAX AUSTIN, R.F. ELLIS  
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RANA PRATAP YADAV, SUNIL KUMAR and S.V. KULKARNI  
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Ujjwal sinha  
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PARESH PATEL, C. B. SUMOD, D. P. THAKKAR, L.N. GUPTA, V. B. PATEL, L. K. BANSAL, K. QURESHI, V. VADHER and U.K. BARUAH  
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RAMESWAR SINGH, R. SINGH, P. KAW and P.H. DIAMOND  
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DEVENDRA SHARMA, RATNESHWAR JHA, YUHE FENG, and FRANCESCO SARDEI  
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DEEPAK SANGWAN, RATNESHWAR JHA, JANA BRO-TANKOVA, and M.V.GOPALKRISHNA  
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S. K. SINGH, RAMESWAR SINGH, L. M. AWASTHI, R. SINGH and P. K. KAW  
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VISHNU CHAUDHARI, KIRAN PATEL, AMIT SRIVASTAVA, JINTO THOMAS and AJAI KUMAR  
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- Plasma response to electron energy filter in LVPD  
A. K. SANYASI, L. M. AWASTHI, S. K. MATTOO, P. K. SRIVASTAVA, S. K. SINGH, R. SINGH and P. K. KAW  
IPR/RR-607/2013 JULY 2013
- Suppression of rayleigh taylor instability in strongly coupled plasmas  
AMITA DAS and PREDHIMAN KAW  
IPR/RR-608/2013 JULY 2013
- An analysis of junction discontinuity effects in the multi-element coupled lines and its diminution at designing stage  
RANA PRATAP YADAV, SUNIL KUMAR and S.V. KULKARANI  
IPR/RR-609/2013 JULY 2013
- Predictive 2-d SOL plasma transport modeling of phase-i operations of tokamaks SST-1 using SOLPS5  
M. HIMABINDU, ANIL TYAGI, DEVENDRA SHARMA, SHISHIR P. DESHPANDE, and XAVIER BONNIN  
IPR/RR-610/2013 AUGUST 2013
- Second harmonic ion cyclotron resonance heating scenarios of aditya tokamak plasma  
ASIM KUMAR CHATTOPADHYAY, S. V. KULKARNI, R. SRINIVASAN, and ADITYA TEAM  
IPR/RR-611/2013 AUGUST 2013
- Gas and solid phase reaction study in CH<sub>4</sub>/N<sub>2</sub> dielectric barrier discharge plasma  
ABHIJIT MAJUMDAR, SANDHAN CHANDRA DAS, BASUDEV GHOSH, SUBROTO MUKHERJEE and RAIN-ER HIPPLER  
IPR/RR-612/2013 AUGUST 2013
- Feasibility of ECE measurements using hilbert-transform spectral analysis  
YURIY DIVIN, and HITESH KUMAR B. PANDYA  
IPR/RR-613/2013 SEPTEMBER 2013
- Commissioning and test of radiation transport tool attila with dmp in cpp-ipr neutron cluster  
C. DANANI, A. BORTHAKUR, N. TALUKDAR and B. J. SAIKIA  
IPR/RR-614/2013 SEPTEMBER 2013
- Collisional absorption of laser light in under-dense plasma: the role of coulomb logarithm  
M. KUNDU  
IPR/RR-615/2013 SEPTEMBER 2013
- Experimental investigation & thermal analysis of heat-pipe oven  
MILIND A. PATEL, KRUNAL PATEL, MOHANDAS K.K., RAVI A. V. KUMAR  
IPR/RR-616/2013 SEPTEMBER 2013
- Mechanical, electrical evaluation and test results of composite insulation materials at cryogenic temperature  
RAJIV SHARMA, V. L. TANNA, S. FALNIKAR and S. PRADHAN  
IPR/RR-617/2013 SEPTEMBER 2013
- Amplitude mediated chimera states  
GAUTAM C SETHIA, ABHIJIT SEN, and GEORGE L. JOHNSTON  
IPR/RR-618/2013 OCTOBER 2013
- Excitation function of the <sup>55</sup>Fe(n,p)<sup>55</sup>Mn reaction from threshold to 20 meV  
BHAWNA PANDEY, P.M. PRAJAPATI, S. JAKHAR, C.V.S. RAO, T.K. BASU, B.K. NAYAK, A. SAXENA, and S.V. SURYANARAYANA  
IPR/RR-619/2013 OCTOBER 2013
- Plasma assisted microwave sintering of tungsten in multi-mode microwave applicator  
CHARU LATA DUBE, YASHASHRI PATIL, SHAILESH KANPARA, S.S. KHIRWADKAR, SUBHASH C. KASHYAP  
IPR/RR-620/2013 OCTOBER 2013
- Momentum transport in the vicinity of q<sub>min</sub> in reverse shear tokamaks due to its turbulence  
RAMESWAR SINGH, R SINGH, HOGUN JHANG, P H DIAMOND  
IPR/RR-621/2013 OCTOBER 2013
- Towards long-time confinement in SMARTEX-C  
LAVKESH LACHHVANI and SAMBARAN PAHARI  
IPR/RR-622/2013 OCTOBER 2013
- Deformation of single crystal iron at very high strain rates: a molecular dynamics study  
S. RAWAT and P.M. RAOLE  
IPR/RR-623/2013 NOVEMBER 2013
- Disruption avoidance using biased electrode in aditya tokamak  
PRAVESH DHYANI, J. GHOSH, P. K. CHATTOPADHYAY,

- R.L. TANNA, D. RAJU, S. JOISA, A.K. CHATTOPADHYAYA, DEBJYOTI BASU, N. RAMAIYA, S. KUMAR, K. SATHYANARAYANA, S.B. BHATT, P.K. ATREY, C.N. GUPTA, C.V.S. RAO, R. JHA, Y.C. SAXENA, and R.N. PAL  
IPR/RR-624/2013      NOVEMBER 2013
- Experimental and finite element analysis of distortion for thin plate welding  
M. ZUBER, V. CHAUDHARI, S.K. ALBERT, S.B. PATIL, V.K. SURI  
IPR/RR-625/2013      NOVEMBER 2013
- Observation of self-organized dynamic toroidal structures in dusty plasma  
MANJIT KAUR, DEVENDRA SHARMA, P. K. CHATTOPADHYAY, J. GHOSH, and Y. C. SAXENA  
IPR/RR-626/2013      DECEMBER 2013
- Numerical studies on helium cooled divertor finger mock up with sectorial extended surfaces  
SANDEEP RIMZA, KAMALAKANTA SATPATHY, SAMIR KHIRWADKAR, KARUPANNA VELUSAMY  
IPR/RR-627/2013      DECEMBER 2013
- Chimera states: the existence criteria revisited  
GAUTAM C SETHIA and ABHIJIT SEN  
IPR/RR-628/2013      DECEMBER 2013
- Inertia driven radial breathing and nonlinear relaxation in cylindrically confined pure electron plasma  
M.SENGUPTA and R.GANESH  
IPR/RR-629/2013      DECEMBER 2013
- Experimental and finite element analysis of temperature distribution during gta welding for modified 9CR-1MO steel  
M.ZUBER, S.K.ALBERT, M.VASUDEVAN, V.CHAUDHRI, V.K.SURI  
IPR/RR-630/2014      JANUARY 2014
- Design and development of ultra-wideband 3db hybrid coupler for ICRF heating in tokamak  
RANA PRATAP YADAV, SUNIL KUMAR and S.V. KULKARNI  
IPR/RR-631/2014      JANUARY 2014
- Ultra slow em wave propagation characteristics of metamaterial loaded helical guide  
D.K. SHARMA and S.K. PATHAK  
IPR/RR-632/2014      JANUARY 2014
- Effect of polarization and focusing on laser pulse driven auto-resonant particle acceleration  
VIKRAM SAGAR, SUDIP SENGUPTA and PREDHIMAN KAW  
IPR/RR-633/2014      JANUARY 2014
- Plasma parameter characterisation of cylindrical magnetron discharge operating in argon-nitrogen gas  
R.RANE, S.MUKHERJEE  
IPR/RR-634/2014      JANUARY 2014
- Properties of gravitationally equilibrated yukawa systems - a molecular dynamics study  
HARISH CHARAN, RAJARAMAN GANESH, and ASHWIN J.  
IPR/RR-635/2014      JANUARY 2014
- Transient evolution of electron energy distribution function of solitary electron holes in laboratory plasmas  
MANGILAL CHOUDHARY, S. KAR and S. MUKHERJEE  
IPR/RR-636/2014      JANUARY 2014
- Global gyrokinetic stability of collisionless microtearing modes in large aspect ratio tokamaks  
ADITYA K SWAMY, R. GANESH, J. CHOWDHURY, S. BRUNNER, J. VACLAVIK, and L. VILLARD  
IPR/RR-637/2014      JANUARY 2014
- Fast wave absorption scenarios in ion cyclotron frequency range in l-mode plasma of SST-1  
ASIM KUMAR CHATTOPADHYAY and R. SRINIVASAN  
IPR/RR-638/2014      FEBRUARY 2014
- Investigation of surrogate method for  $^{55}\text{Fe}(n,p)^{55}\text{Mn}$  reaction cross-section measurement  
BHAWNA PANDEY, P.M. PRAJAPATI, S. JAKHAR, C.V.S. RAO, T. K. BASU, B.K. NAYAK, A. SAXENA, S.V. SURYANARAYANA  
IPR/RR-639/2014      FEBRUARY 2014
- R & d on high temperature ester based insulation  
PRIYANKA BRAHMBHATT, NITISH KUMAR, SUBRATA PRADHAN  
IPR/RR-640/2014      FEBRUARY 2014
- A set up for biased electrode experiment in aditya tokamak  
PRAVESH DHYANI, JOYDEEP GHOSH, SATHYANARAYANA, PRAVEENLAL V E, PRAMILA, MINSHA SHAH, R.L. TANNA, PINTU KUMAR, C. CHAVDA, N.C.



PATEL, V. PANCHAL, C.N. GUPTA, K.A. JADEJA, S.B. BHATT, S. KUMAR, D. RAJU, P.K. ATREY, S. JOISA, P.K. CHATTOPADHYAY, Y. C. SAXENA and ADITYA TEAM  
IPR/RR-641/2014 FEBRUARY 2014

On use of an oblique view electron cyclotron emission(ECE) detector in iter for getting a better radial resolution and signature of the presence of non-thermal electron populations  
P.V. SUBHASH, YASHIKA GHAI, AMIT K. SINGH, A. MEHARAJ BEGUM, and P. VASU  
IPR/RR-642/2014 FEBRUARY 2014

Effect of a small fraction of non-thermal electrons on temperature measurement using electron cyclotron emission diagnostics for iter-scenario-2: a computational parametric study  
P.V. SUBHASH, NIKITA CHHETRI, TRUPTI SHARMA, A. MEHARAJ BEGUM, HITESH KUMAR B. PANDYA, and P. VASU  
IPR/RR-643/2014 FEBRUARY 2014

Turbulence in two dimensional visco-elastic medium  
SANANT KUMAR TIWARI, VIKRAM SINGH DHARODI, AMITA DAS, BHAVESH G. PATEL and PREDHIMAN KAW  
IPR/RR-644/2014 MARCH 2014

Prediction of residual stress and distortion in autogenous gas tungsten arc welding of modified 9CR-1MO steel plates  
M. ZUBAIRUDDIN, S. K. ALBERT, S. MAHADEVAN, M. VASUDEVAN, V. CHAUDHARI and V. K. SURI  
IPR/RR-645/2014 MARCH 2014

Neutron transport equation and introduction to ATTILA software  
DEEPAK AGGARWAL, H L SWAMI, A K SHAW, B J SAIKIA, C DANANI  
IPR/RR-646/2014 MARCH 2014

High heat flux performance of tungsten monoblock type test mock-ups using indian high heat flux test facility  
YASHASHRI PATIL, S S KHIRWADKAR, S M BELSARE, RAJAMANNAR SWAMY, M S KHAN, S TRIPATHI, K BHOPE, D. KRISHNAN, P MOKARIA, N PATEL, I ANT-WALA, K GALODIYA, M MEHTA, T PATEL  
IPR/RR-647/2014 MARCH 2014

Theoretical study of head-on collision of dust acoustic solitary waves in a strongly coupled complex plasma  
S. JAISWAL, P. BANDYOPADHYAY and A. SEN  
IPR/RR-648/2014 MARCH 2014

## E 2. 2 Technical Reports

Resin Cast Multisecondary Transformer's Multiwinding Coil Cast Development

L.N.GUPTA, PARESH.J.PATEL, N.P.SINGH, VIBHU TRIPATHI, VISHNU PATEL, DIPAL THAKKAR, SUMOD C.B, L.K.BANSAL, KARISHMA QURESHI, VIJAY VADHER and U.K BARUAH  
IPR/TR-245/2013 (APRIL 2013)

Benchmarking using Star CCM+ CFD Tool  
K. SATPATHY and S.S. KHIRWADKAR  
IPR/TR-246/2013 (MAY 2013)

Thermal-hydraulics of Water Cooled PFC for SST-1 Tokamak  
PARITOSH CHAUDHURI, P. SANTRA, GATTURAMESH, RAVI PRAKASH, S. KHIRWADKAR, D. CHENNA REDDY and Y. C. SAXENA  
IPR/TR-247/2013 (JULY 2013)

Ultrasonic Evaluation Report of Cu-W Monoblock Divertor Assembly  
KEDAR BHOPE, MAYUR MEHTA, M.S KHAN, S.S. KHIRWADKAR  
IPR/TR-248/2013 (JULY 2013)

Scientometric Study of Department of Atomic Energy Institutes: A Picture from Scopus  
S. SHRAVAN KUMAR  
IPR/TR-249/2013 (JULY 2013)

Tesla Based Pulse Generator for Electrical Breakdown study of Liquid Dielectrics  
G. VEDA PRAKASH, R. KUMAR, J. PATEL, SAURABH. K, and A. SHYAM  
IPR/TR-250/2013 (AUGUST 2013)

Design of Compact Electron Cyclotron Resonance (ECR) Ion source  
SUDHIRSINH VALA, D BUTTON and M HOTCHKIS  
IPR/TR-251/2013 (AUGUST 2013)

VIRCATOR - A High Power Microwave Source  
PRIYAVANDA J. RATHOD, RAJESH KUMAR, V.P. ANITHA, ANURAG SHYAM and Y.C. SAXENA  
IPR/TR-252/2013 (AUGUST 2013)

- Ignitron Trigger Generator for SYMPLE  
PRIYAVANDA J. RATHOD, V.P. ANITHA, and Y.C. SAXENA  
IPR/TR-253/2013 (AUGUST 2013)
- Design Development and Testing of Pulse Forming Network for Plasma Source of SYMPLE  
PRIYAVANDA J. RATHOD, V.P. ANITHA, Z.H. SHOLAPURWALA and Y.C. SAXENA  
IPR/TR-254/2013 (AUGUST 2013)
- Design and Testing of a PFN for SYMPLE  
PRIYAVANDA J. RATHOD, V.P. ANITHA, Z.H. SHOLAPURWALA and Y.C. SAXENA  
IPR/TR-255/2013 (SEPTEMBER 2013)
- Neutron Flux Measurement of an Accelerator based 14-MeV Neutron Generator  
SUDHIRSINH VALA, MITUL ABHANGI, RAJNIKANT MAKWANA, CVS RAO, and T.K. BASU  
IPR/TR-256/2013 (SEPTEMBER 2013)
- Plasma Torch Stabilization with IGBT based Power Supply through Embedded Control System Design  
C. PATIL, V. JAIN, B. K. PATEL, A. VISANI, and V. CHAUHAN  
IPR/TR-257/2013 (SEPTEMBER 2013)
- Development of Large Scale Atmospheric Pressure Plasma System for Angora Wool Treatment  
R. RANE, A. VAID, C. PATIL, S. MUKHERJEE, and S. NEMA  
IPR/TR-258/2013 (OCTOBER 2013)
- RELAP5/MOD4.0 MODIFICATION for IN-LLCB TBS Safety Analysis and Preliminary Validation of the Code for Steady State Lead Lithium Eutectic Applications  
K. TONY SANDEEP, VILAS C CHAUDHARI, R. BHATTACHARYAY, A. PATEL, and E. RAJENDRA KUMAR  
IPR/TR-259/2013 (OCTOBER 2013)
- Determination of Air Activation for the Proposed Neutron Generator Laboratory  
RAJNIKANT MAKWANA, SUDHIRSINH VALA, C. V. S. RAO, and T. K. BASU  
IPR/TR-260/2013 (OCTOBER 2013)
- Langmuir Probe Diagnostic Electronic for SYMPLE (System for Microwave Plasma Experiments)  
PRAMILA, JIGNESH PATEL, R. RAJPAL, R. JHA, ANITHA V.P., & ELECTRONICS GROUP  
IPR/TR-261/2013 (NOVEMBER 2013)
- Efficiency Calibration of the High Purity Germanium Detector  
RAJNIKANT MAKWANA, M. ABHANGI, S. MARKO, S. POPOVICHEV, B. SYME, S. CONROY  
IPR/TR-262/2013 (NOVEMBER 2013)
- Failure Analysis Report of Ceramic Material Used as Insulation of RC Coil In SST-1  
P SANTRA, S JAYSWAL, T PAREKH, P BISWAS, P CHAUHAN, H PATEL & S PRADHAN  
IPR/TR-263/2013 (NOVEMBER 2013)
- Integrated Testing of Microwave Interferometer Systems in SST-1  
PRAMILA, R. RAJPAL, R. JHA, C.J. HANSALIA, S.K. PATHAK, P.K. ATREY, U. KUMAR, V. GYANCHANDANI, A. SINHA  
IPR/TR-264/2013 (DECEMBER 2013)
- Performance of Main Vacuum Pumping System of SST-1 Tokamak  
ZIAUDDIN KHAN, FIROZKHAN PATHAN, SIJU GEORGE, KALPESH DHANANI, YUVAKIRAN PARAVASTU, PRATIBHA SEMWAL and SUBRATA PRADHAN  
IPR/TR-265/2013 (DECEMBER 2013)
- Modeling and Simulation Studies of Ion Extraction System for ECR Ion Source  
SUDHIRSINH VALA, D BUTTON and M HOTCHKIS  
IPR/TR-266/2013 (DECEMBER 2013)
- MDSplus Integration with ICRH SST1 DAC Software  
RAMESH JOSHI, MANOJ SINGH, H M JADAV, S V KULKARNI and ICRH GROUP  
IPR/TR-267/2013 (DECEMBER 2013)
- Studies on Development of Ultrasonic Inspection Technique for Cu-W Monoblock Divertor Assembly  
KEDAR BHOPE, MAYUR MEHTA, M.S KHAN and S.S. KHIRWADKAR  
IPR/TR-268/2013 (DECEMBER 2013)
- Compatibility Study of Plasma Grown Alumina Coating with Pb-17Li under Static Conditions  
N. I. JAMNAPARA, A. SARADA SREE, E. RAJENDRA KUMAR, S. MUKHERJEE and A. S. KHANNA  
IPR/TR-269/2013 (DECEMBER 2013)
- A Sheet Code in Matlab to Demonstrate Nonlinear Oscillations in Unmagnetized and Magnetized Plasma



SOMESWAR DUTTA, SUDIP SENGUPTA, R. SRINIVASAN

IPR/TR-270/2013 (DECEMBER 2013)

Characterization and Calibration of 8-Channel E-Band Heterodyne Radiometer System for SST-1 Tokamak

S. VARSHA, DHARMENDRA KUMAR, S. PRAVEENA, and S.K. PATHAK

IPR/TR-271/2014 (JANUARY 2014)

Design and Analysis of Cooling Scheme for SST-1 Plasma Facing Components

YUVAKIRAN PARAVASTU, ZIAUDDIN KHAN and SUBRATA PRADHAN

IPR/TR-272/2014 (JANUARY 2014)

Design, Analysis, Fabrication, Testing & Commissioning of D-shape Vacuum Chamber for High Heat Flux Test Facility

RAJAMANNAR SWAMY, M.S. KHAN, SAMIR KHIRWADKAR, SUNIL BELSARE, SUDHIR TRIPATHI, DEEPU KRISHNAN, PRAKASH MOUKARIA, NIKUNJ PATEL, TUSHAR PATEL

IPR/TR-273/2014 (JANUARY 2014)

Technical Report on Design, Fabrication, Installation of Radial Control Coil

SNEHAL JAYSWAL, PROSENJIT SANTRA, PRADEEP CHAUHAN, PRABAL BISWAS, HITESH PATEL, TEJAS PAREKH, SUBRATA PRADHAN

IPR/TR-274/2014 (FEBRUARY 2014)

Development of Prototype Hybrid DC Circuit Breaker for Superconducting Magnets Quench Protection

SWATI ROY, DEVEN KANABAR, CHIRAGSINH DODIYA and SUBRATA PRADHAN

IPR/TR-275/2014 (FEBRUARY 2014)

IGBT based Pulsed Power Supply for PVD Applications

NARESH VAGHELA

IPR/TR-276/2014 (FEBRUARY 2014)

Scattering Chamber Design for an Accelerator based 14 MeV Neutron Generator at IPR

P. M. PRAJAPATI, BHAWNA PANDEY, SHRICHAND JAKHAR, SURESH KUMAR, B. K. NAYAK, A. SAXENA, S. V. SURYANARAYANA, N. C. GUPTA, SUDHIRSINH VALA, C. V. S. RAO, T. K. BASU

IPR/TR-277/2014 (MARCH 2014)

### E.3 Conference Presentations

*Joint Meeting of ITPA MHD, Disruptions & Control and Energetic Particle Physics Topical Groups, Culham Centre for Fusion Energy, Culham Science Centre, Abingdon, UK, 22-25 April 2013*

Runway current control following Disruptions using VS3 circuit in ITER

I. Bandyopadhyay

*14th International Conference on Plasma-Facing Materials and Components for Fusion Applications, Julich, Germany, 13-17 May 2013*

Evaluation of Tungsten Alloys for Plasma Facing Component Applications

Shailesh Kanpara

*Asian Metallurgy Summit Conference, Mumbai, India, 23-24 May 2013*

Heat Treatment using Plasma based technologies

J. Alphonsa, J. Ghanshyam Jhala, Subroto Mukherjee

*24th ITPA Diagnostics TG Meeting, San Diego, USA, 4-7 June 2013*

Progress on conceptual design of the 55.EE Hard X-Ray Monitor for ITER (Hydrogen Phase)

Santosh P. Pandya, Jayesh Raval, Narendra Kadamdhad, Govindarajan Jagannathan, Robin Barnsley, George Vayakis and Michael Walsh

*IEEE 25th Symposium on Fusion Engineering (SOFE 2013), San Francisco, 10-14 June 2013*

Manufacturing of ITER Vacuum Vessel In-Wall Shielding

H.A. Pathak, J.R. Raval, G.S. Phull, R. Laad, X. Wang, K. Ioki, P.V.S. Suresh

Negative Hydrogen Ion Density and Extraction Current Measurements in RF based Negative Ion Source, ROBIN, IPR

Gourab Bansal, K. Pandya, J. Soni, A. Gahlaut, H. Tyagi, K.G. Parmar, R. Pandey, M. Vuppugalla, B. Prajapati, H. Mistery, A. Chakraborty, M. Bandyopadhyay, R. K. Yadav

Design of Beam Dump for SPIDER facility

C Rotti, M Nagaraju, H Patel, A. Chakraborty, M Dalla Palma, P Zaccaria, P Sonato, D Boilson

Optimization of Functionally graded materials for PFC's by finite element methods

D S Krishnan, S. Kanpara, S.S. Khirwadkar, Y. Patil

**46th Annual Fermilab Users Meeting, Fermilab, USA, 12-13 June 2013**

Beam Instrumentation for High Pressure cavity experiment at Fermilab MuCool test Area

M. R. Jana, M. Chung, B. Freemire, P. Hanlet, M. Leonova, A. Moretti, T. Schwarz, A. Tollestrup, Y. Torun and K. Yonehara

**MAP 2013 Collaboration Meeting (MAP13), Fermilab, USA, 19-22 June 2013**

Measurement of 400 MeV Proton Beam Intensity and Transmission through Collimator of HPRF Cavity at Fermilab MuCool Test Area

M. R. Jana, M. Chung, B. Freemire, P. Hanlet, M. Leonova, A. Moretti, T. Schwarz, A. Tollestrup, Y. Torun and K. Yonehara

**4th School on Hands-On Research in Complex Systems, ICTP, Italy, 1-12 July 2013**

Shear Flow Instability in Dusty Plasmas: Fluid and Particle Approach

Sanat Kr Tiwari, Amita Das, Bhavesh G. Patel, Predhiman Kaw

**ITER-Neutronics meeting and Nuclear Working Group Meeting at F4E, Barcelona, Spain, 09-13 July 2013**

Neutronics Activities at ITER-India

P.V. Subhash, S. Jakhar, Russell Feder, Sajal Thomas, Sapna Mishra, Deepak Agarwal and CVS. Rao

**38th International Conference on Vacuum Ultraviolet and X-ray Physics (VUVX-2013), Hefei, China, 12-19 July 2013**

XAFS characterization of iron-oxide nanoparticles synthesized by high temperature plasma processing

C. Balasubramaniam, B. Joseph, P. Gupta, N.L. Saini, S. Mukherjee, D. Di Gioacchino, A. Marcelli

**International Conference on Perspectives in Nonlinear Dynamics (PNLD 2013), University of Hyderabad, India, 15-18 July 2013**

Role of self-similarity in the fluctuations and transport in a simple toroidal plasma

T. S. Goud, R. Ganesh, Y. C. Saxena, D. Raju and A.N.S. Iyengar

**National Workshop on Plasma Devices Technology at CEERI, Pilani on 24 July 2013**

Cold plasma and their industrial applications

Suryakant B. Gupta, Subroto Mukherjee, S. K. Nema, and Alphonsa Joseph

**INNOVAZIONE-13, G.H. Patel College of Engineering & Technology (GCET), Vallabh Vidyanagar, 16-17 August 2013**

Plasma an innovative tool for societal benefits

Suryakant B. Gupta

**Laser and Plasma Accelerator Workshop (LPAW-2013), Goa, India, 1-6 September 2013**

Relativistic Electromagnetic Solitons in cold Plasmas

Amita Das, Sita Sundar, Deepa Verma and Predhiman Kaw

Particle-In-Cell simulation of transportation of electron beam through inhomogeneous dense plasma

Chandrasekhar Shukla, Bhavesh G. Patel, Amita Das, Kartik Patel

Development of Plasma Source for the Proposed PFWA Project at IPR- A Status Report

Mohandas K.K, Milind A. Patel, Sangeeta Tripathi, Sonam Brahmabhatt, Kanchan Mahavar and Ravi A. V. Kumar

**National Symposium on High Power RF & Microwave, (HPRFM-2013), Institute for Plasma Research, Gandhinagar, 4-6 September, 2013**

High Power Pulsed Microwave Devices and their Drivers Developed in our Laboratories

Anurag Shyam, Rajesh Kumar, Rishi Verma, Rohit Shukla, Surender Sharma and Viswajeet Adhikar

Electron Cyclotron Resonance Heating (ECRH) systems on tokamak SST-1

B. K. Shukla



AXUV Bolometer Systems on ADITYA and SST-1 Tokamaks for Estimating Input Heating Power Losses

Prabhat Kumar, Kumudni Tahiliani, M.V. Gopalakrishna and Ratneshwar Jha

Initial Stage Calibration and Measurements of D-Band Super-Heterodyne Interferometer System

Umeshkumar C Nagora, Abhishek Sinha and S.K.Pathak.

Design, Assembly & Characterization of the Front End D-Band Radiometer System (130-170 GHz) for Electron Cyclotron Emission (ECE) Measurements in SST-1 Tokamak

Abhishek Sinha and Surya K. Pathak

Density Measurement in LVPD using Microwave Interferometer: A Validation of Langmuir Probe Measurements

S. Kumar, L. M. Awasthi, P. K. Srivastava, P. K. Atrey, A. K. Sanyasi, S. K. Singh, A. Chavda, K. Raval, R. Sugandhi and S. K. Mattoo

Interaction of High Power Microwave (HPM) and Plasma

Anitha V.P., Priyavandna J. Rathod, Rajesh Kumar, Renu Bahl, Anurag Shyam, Y.C. Saxena, Amita Das and P.K. Kaw

Atmospheric Pressure Microwave Plasma Arc Source Activity at FCIPT and its Applications

Vishal Jain, Anand Visani, Chirayu Patil, Bhupendra Patel, Promod K Sharma, Adam Sanghariyat, S. Mukherjee, S. K. Nema, Vivek Agarwal

Requirement Definition of Local Control Unit for R&D Source of ICH&CD system

Kumar Rajnish, Dipal Soni, Sriprakash Verma, Raghuraj Singh, Manoj A Patel, RG Trivedi, Harsha Machchhar, Gajendra Suthar, P. Ajesh, Aparajita Mukherjee, Harikrishna Jayanthi, Kartik Mohan, Akhil Jha, Rohit Anand, Rohit Agarwal

Integration and commissioning of solid-state Anode Modulator Power supply with 42 GHz, 500mS Pulsed Gyrotron

N. Rajan Babu, B.K. Shukla, Jatin Patel, Harshida Patel, Pragnesh Dhorajiya

Development of Prototype Solid State Power Amplifier for ICRF Power Source

Manoj A. Patel, JVS Hari, Raghuraj Singh, R.G. Trivedi, Kumar Rajnish, Harsha Machchhar, P Ajesh, Dipal Soni, Gajendra Suthar, Kartik Mohan, Sriprakash Verma, Rohit Anand, Rohit Agrawal, Akhil Jha, Aparajita Mukherjee

H.P.M Generation by VIRCATOR and Relativistic Magnetron using Compact and Repetitive Generator at IPR

Rajesh Kumar, Jignesh Patel, Saurabh kumar, Anitha V. P., Renu Bahl and Anurag Shyam

Inter Coil Radiation Load & Cross-Talk in an Icp Source with Multi-Coil Antennas

Dass Sudhir, P. Gupta, M. Bandyopadhyay, A. Gahlaut, G. Bansal and A. Chakraborty

A Conceptual Design Study of RF Sources, Matching Network for ITER-DNB Ion Source

Sandip Gajjar, U K Baruah, N P Singh, A Thakar, B Raval, A. Patel, D Parmar, H Dhola, R Dave, V Gupta

Experimental Verification of Mode Purity of a Low Power HE11 Mode Converter using Phase Retrieval Technique

Anjali Sharma, Parth C. Kalaria, Deepak Mandge, Ronak Shah, Vipal Rathod, Gaurav Joshi, Tarun Sharma, S.L. Rao

Status of Local Control Unit (LCU) for ITER-India Gyrotron Test Facility (IIGTF)

Vipal Rathod, Ronak Shah, Deepak Mandge, Gaurav Joshi, Anjali Sharma, Tarun Sharma, S. L. Rao

Series Ignitron Crowbar System for ITER-India Gyrotron Test Facility (IIGTF)

Gaurav Joshi, Mahesh Kushwah, Vipal Rathod, Ronak Shah, Deepak Mandge, S.L.Rao, Anjali Sharma and Tarun Sharma

Validation of Indigenously Developed Finger Contact

Rohit Agarwal, Raj Singh, Raghuraj Singh, P Ajesh, Akhil Jha, Aparajita Mukherjee, Dipal Soni, Gajendra Suthar, Harsha Machchhar, JVS Hari, Kartik Mohan, Kumar Rajnish, Manoj Patel, R.G. Trivedi, Rohit Anand, Sriprakash Verma

Traveling Wave Resonator for ICH&CD Component Testing

Akhil Jha, JVS Hari Krishna, P. Ajesh, Rohit Anand, Manoj Patel, R.G. Trivedi, Aparajita Mukherjee

Design and Development of a Multi-element 3-dB High Power Hybrid Coupler

Rana Pratap Yadav, Sunil Kumar and S.V. Kulkarni

Calorimetric Pulse Power Measurement Technique for High Power Gyrotrons

Harshida1 Patel, B K Shukla, Pragnesh Dhorajiya, Rajan babu, Jatin Patel, Mikhail Shmelev, Yury Belov, Vladimir Belousov

Arc fault protection devices for high power RF and microwave tubes and issues related to their performance  
Y.S.S. Srinivas, S.V. Kulkarni, High Power ICRH systems division

Signal Monitoring, Data Acquisition, Interlocks and Control Electronics for 91.2 MHz, 1.5 MW (ICRH) System for SST-1  
H.M. Jadav, Manoj Singh, Ramesh Joshi, Sunil Kumar, YSS Srinivas, B.R. Kadia, K. M. Parmar, Gayatri Ramesh, Atul Varia, S.V. Kulkarni and ICRH-RF Group

Mechanical Design of Water Cooling System for DST 42 GHz, 200 kW CW Gyrotron  
Atul Varia, Prashant Singh, S.V. Kulkarni & DST-Gyro Group.

Data Acquisition and Control (DAC) System for Real Time Remote Operation, Monitor and Control of the 1.5MW, 20-40 MHz ICRH System on the SST-1 Machine  
Manoj Singh, H.M. Jadav, Ramesh Joshi, Sunil Kumar, Raj Singh, YSS Srinivas, B.R. Kadia, K. M. Parmar, Gayatri Ramesh, Atul Varia, S.V. Kulkarni and ICRH-RF Group

Commissioning of 11kV, 2MVA Voltage Variation System for MW RF Power and Microwave Tubes  
Kirit Parmar, Y.S.S. Srinivas, Rajan Babu, S.V. Kulkarni and ICRH Group

Ignitron Switch Based Fast Crowbar Protection System for 1.5 MW CWRP Amplifier  
Bhavesh R Kadia, Kirit Parmar, YSS Srinivas, Atul Varia, S.V. Kulkarni and ICRH Group

Real-Time Feedback Control System for 500 KW Fast Ferrite ICRF Tuner  
Ramesh Joshi, H M Jadav, Manoj Parihar, B R Kadia, K M Parmar, A Varia, K Mishra, Y S S Srinivas, R A Yogi, Sunil Kumar and S.V. Kulkarni

Enhancement of User Interface Module for ICRH DAC Software  
Ramesh Joshi, Manoj Parihar, S.V. Kulkarni and Kiran Trivedi

Requirement Definition of Local Control Unit for R&D Source of ICH&CD system  
Kumar Rajnish, Dipal Soni, Sriprakash Verma, Manoj A. Patel, JVS Hari, Raghuraj Singh, R.G.Trivedi, Harsha Machchhar, P Ajesh, Gajendra Suthar, Kartik Mohan, Rohit Anand, Rohit Agrawal, Akhil Jha, Aparajita Mukherjee

*Surface Engineering for Research and Industrial Applications (SERIA 2013), Rajalakshmi Engineering College, Chennai, 7-9 September 2013*

Low Pressure Plasma Based Technologies for Surface Modification  
J. Alphonso, and Subroto Mukherjee.

*Career Development Workshop for Women in Physics, ICTP, Trieste, Italy, 16-20 September 2013*

Different Synthesis Routes of LaNbO<sub>4</sub> and its Effect on Structural and Electrical Properties  
Deepti Kothari

*11th International Symposium on Fusion Nuclear Technology (ISFNT-11), Barcelona, Spain, 16-20 September 2013*

Er<sub>2</sub>O<sub>3</sub> Coating: Process Optimization through Film Characterization  
P A Rayjada, N P Vaghela, N L Chauhan, Amit Sircar, E Rajendrakumar, L M Manocha and P M Raole

Status of Indian LL CB TBM program and R&D activities  
Bhattacharyay, R. and Indian TBM Team

Challenging issues in the manufacturing of the ITER Cryostat  
Anil Bhardwaj

Facilities, testing program and modeling needs for studying liquid metal magneto hydrodynamic flows in fusion blankets  
Buhler, L., Mistrangelo, C., Konys, J., Bhattacharyay, R., Huang, Q., Obukhov D., Smolentsev, S., Utili, M.

Fusion Yield measurements on JET and their Calibration  
Syme, Duncan Brian, Popovichev, Sergei, Conroy, Sean, Lengar, Igor, Snoj, Luka, Sowden, Clive, Giacomelli, L., Hermon, Gary, Allan, Paul, Macheta, Peter, Plummer, David, Stevens, Jeffrey, Prokopowicz, Rafal, Jednorog, Slawomir, Abhangi, Mitul R, Makwana, Rajnikant

Design of ITER Vacuum Vessel In-wall Shielding  
Wang, Xiaoyu, Ioki, Kimihiro, Morimoto, Masaaki, Tailhardat, Olivier, Terasawa, Atsumi, Gribov, Yuri, Barabash, Vladimir, Polunovskiy, Eduard, Dani, Sunil, Choi, Chang-ho, Sborchia, Carlo, Pathak, Haresh, Raval, Jigar

Development of Lithium meta-titanate Ceramics pebbles for Indian LLCB TBM  
Shrivastava, Aroh, Makwana, Mayank, Chaudhuri, P., Rajendrakumar, E.



MHD analysis of Lead lithium flow in a duct consisting of circular and square cross-sections under high magnetic field  
Swain, Pravat Kumar, Tiwari, Vikas, Sahu, Srikanta, Polepalle, Satyamurthy, Bhattacharyay, Rajendraprasad, Patel, Anita, Platacis, Erik, Shisko, A.

Liquid Metal MHD studies with non-magnetic and ferromagnetic structural material  
Patel, Anita

Progress in Engineering Design of Indian LL CB TBM Set for testing in ITER  
Chaudhuri, Paritosh, Ranjithkumar, S. Ranjithkumar, Sharma, Deepak, Danani, Chandan, Swami, H. L., Bhattacharya, R., Rajendra Kumar, E., Vyas, K. N.

Design and development of hydrogen isotope sensor in liquid Pb-Li  
Amit Sircar, Sanjeev Kumar Sharma, Rudreksh B Patel, P. A. Rayjada

Status of the ITER Vacuum Vessel Construction  
Choi, C. H., Alekseev, A., Sborchia, C., Ioki, K., Giraud, B., Utin, Yu., Sa, J.W., Wang, X., Barabash, V., Vertongen, P., Jucker, P., Bayon, A., Pathak, H., Raval, J., Ahn, H.J., Kim, B.C., Kuzmin, E., Savrukhin, P.

**13th IAEA Technical Meeting on Energetic Particles in Magnetically Confined Systems, Beijing, China, 17-20 September 2013**

Observation of Electromagnetic Turbulence in the Energetic Belt of LVPD plasma  
A. K. Sanyasi, L. M. Awasthi, S. K. Mattoo, P. K. Srivastava, S. K. Singh, R. Singh and P. K. Kaw

**9th International Symposium on Applied Plasma Science, (ISAPS-13), Istanbul, Turkey, 23-27 September 2013**

Single-step, continuous synthesis of sub-10 nanometer average size carbon encapsulated iron nanoparticles by thermal-plasma assisted technique  
M. Kakati

**North American Particle Accelerator Conference-2013, (NA-PAC13), Pasadena, California, USA, 29 September-4 October 2013**

Investigation of Breakdown Induced Surface Damage on 805

MHz Pillbox cavity Interior Surface  
M. R. Jana, D. Bowering, M. Chung, G. Flanagan, B. Freemire, M. Leonova, A. Moretti, A. Tollestrup, Y. Torun and K. Yonehara

**Workshop on Experimental Plasma Physics and its applications, Kathmandu University, Nepal, 6-7 October 2013**

Langmuir probe Diagnostics  
R. Rane

**25th Meeting of the ITPA Topical Group on Diagnostics, ITER Organization, 15-18 October 2013**

A Computational Study on Effect of Non-Thermal Electrons on the ECE Temperature Measurement for ITER Scenario 2  
P. V. Subhash, Nikita Chhetri, Trupti Sharma, Hitesh Kumar B. Pandya, Meharaj Begam and P. Vasu

Neutronics Analysis for XRCS Spectrometer using Discrete Ordinate Method and Comparison with MCNP  
P.V. Subhash, S. Jakhar, Russell Feder, Sajal Thomas, Sapna Mishra, Deepak Agarwal and CVS. Rao

IN DA progress in ITER ECE diagnostic system (TL & receiver)  
Hitesh Pandya, Suman Danani, Ravinder Kumar, Siddharth Kumar, Shrishail, Vinay Kumar, P. Vasu, Victor Udintsev

**COMSOL Conference, Bangalore, 17-18 October 2013**

Mode Conversion Losses in Smooth Wall Circular Waveguide  
Ravinder Kumar, Hitesh Pandya, Suman Danani, P. Vasu, Vinay Kumar

**16th International Conference on Fusion Reactor Materials (ICFRM-16), Beijing, China, 20-26 October 2013**

Compatibility study of plasma grown alumina coating with Pb-17Li under static conditions  
N. I. Jamnapara, A. Sarada Sree, E. Rajendra Kumar, S. Mukherjee, A. S. Khanna

**5th Integrated Modeling Expert Group (IMEG) Annual Meeting at ITER, Cadarache, France, 21-23 October 2013**

Tokamak Modeling Activities at ITER-India  
N Bisai, I. Bandyopadhyay and ITM Team

**10th International Conference on Tritium Science and**

**Technology, (TRITIUM 2013), Nice, France, 21-25 October 2013**

Application of Computational Fluid Dynamics for the Simulation of Cryogenic Molecular Sieve Bed Adsorber of Hydrogen Isotope Recovery System for Indian LLCB-TBM

V. Gayathri Devi, Amit Sircar and B. Sarkar

**7th Asian Conference on Applied Superconductivity and Cryogenics (ACASC 2013), Cappadocia, Turkey, 23-25 October 2013**

Fusion Magnets and Associated Technology Development Initiatives in India

Subrata Pradhan

Design, development and fabrication of indigenous 30 kA NbTi CICC for fusion relevant superconducting magnet  
Mahesh Ghate, Piyush Raj, Arun Singh, Subrata Pradhan, M.M. Hussain, and K.K. Abdulla

Quench evolution studies in second generation YBCO coated conductor against localised hot spot in liquid nitrogen bath cooled condition

Ananya Kundu, Amardas Alli, and Subrata Pradhan

Experience with in-house developed Instrumentation and Data Acquisition system for Cryo Auxiliary sub-system during the First SST-1 Plasma Campaign

Dashrath Sonara, Rohit Panchal, Rakesh Patel, Gaurang Mehuriya, Naresh Chand Gupta, Pradip Panchal, Hiren Nimavat, Vipul Tanna, and Subrata Pradhan

Optimisation of size of 3-stream (He/He/N<sub>2</sub>) plate fin heat exchanger for kW class helium plant

Ananta Kumar Sahu

Design of low pressure drop compact liquid nitrogen pre-cooling plate-fin heat exchanger for helium plant

Ananta Kumar Sahu and Ashish Narula

International Conference on Nanostructuring by Ion Beams (ICNIB-2013), Jaipur, India, 23-25 October 2013

Radiation Damage Study on Ion Beam Irradiated Tungsten  
Charulata Dube

Applications of ion induced ripple/dot patterns for plasmonic and magnetism application

M. Ranjan

**Pune Auto Cluster, Pune, 28 October 2013**

Emerging Role of Plasma Technology in Automobile & Textile Industry

Suryakant B. Gupta

**9th General Scientific Assembly of the Asia Plasma and Fusion Association (APFA-2013), Gyeongju City, Korea, 5-8 November 2013**

Plasma Characterization in RF based Negative Ion Source, ROBIN, at IPR

G. Bansal, K. Pandya, J. Soni, A. Gahlaut, H. Tyagi, M. Bandyopadhyay, R.K. Yadav, K.G. Parmar, M. Vuppugalla, H. Mistri, B. Prajapati, A. Chakraborty

First Plasma Experiments in SST-1

S. Pradhan, Z. Khan, V. L. Tanna, A. N. Sharma, P. Biswas, H. Masand, D. Raju, R. Srinivasan, A. Varadarajulu, K. J. Doshi, U. Prasad, A. Kumar, M. K. Bhandarkar, D. K. Sharma, A. K. Singh, I. A. Mansuri, C. N. Gupta, J. R. Dhongde, B. K. Shukla, P. Patel, P. K. Atrey, S. Pandya, R. Manchanda, S. K. Pathak, S. Kulkarni, P. K. Sharma, Y. S. Joisa, T. Kumuduni, S. P. Jayswal, H. S. Patel, T. J. Parekh, P. Yuvakiran, F. S. Pathan, P. Santra, S. George, P. Semwal, H. J. Dave, P. K. Chauhan, K. R. Dhanani, J. K. Tank, P.N. Panchal, R. N. Panchal, R. J. Patel, P. Gupta, Y. S. Khristi, G. I. Mahesuriya, D. P. Sonara, M. Sharma, N. C. Gupta, J. C. Patel, P. Varmora, D. J. Patel, G. L. N. Srikanth, D. S. Christian, A. Garg, N. Bairagi, G. R. Babu, A. G. Panchal, M. M. Vora, K. M. Patel, R. Sharma, C. K. Gupta, H. D. Nimavat, P. R. Shah, K. B. Patel, H. H. Chudasma, T. Y. Raval, A. L. Sharma, A. Ojha, K. R. Vasava, S. K. Patnaik, B. R. Praghi, M. Banaudha, A. R. Makwana, P. L. Thankey, A. Das

Cryogenics systems performances in SST-1

V.L. Tanna, P. Panchal, R. Panchal, R. Patel, G. Mahesuriya, D. Sonara, N.C. Gupta, J. C. Patel, L.N. Srikanth G., A. Garg, D. Christian, N. Bairagi, K. Patel, R. Sharma, P. Shah, H. Nimavat, J. Tank and S. Pradhan

Tangential viewing Infrared Imaging Video Bolometer developed for the ADITYA tokamak and comparison of its results with 2-D plasma power loss model

Santosh P. Pandya, Shamsuddin Shaikh, Kanchan Mahavar, Zubin Shaikh, Shwetang N. Pandya, Kumar Ajay, J. Govindarajan and ADITYA team

UGC Sponsored National Seminar on Plasma Science and Technology, Nabajyoti College, Kalgachia, Barpeta, 6-7 November 2013



Encapsulated magnetic nanoparticles for biomedical applications

M. Kakati

***ACOUSTICS 2013: Technologies for a Quieter India, CSIR-National Physical Laboratory, New Delhi, 10-15 November 2013***

Studies on plastic deformation with low Carbon steel tensile specimens by Acoustic Emission method

SV Ranganayakulu, M Premkumar, R Gowtham, B. Ramesh Kumar

***55th Annual meeting of APS Division of Plasma Physics, Denver, Colorado, USA, 11-15 November 2013***

Observation of intermittency with varying toroidal magnetic field in a simple toroidal plasma

T. S. Goud, S. Jaiswal, U. Kumar, R. Ganesh, Y.C. Saxena, and D. Raju

Dynamics of the self-organized toroidal dust flow structures in plasma

Devendra Sharma

***Topical Conference on Atomic Processes in Plasmas (ISAMP-TC-2013), Institute for Plasma Research, Gandhinagar, 18-20 November 2013***

Spectroscopic Studies of Edge Region Plasma in Fusion Machines

N.Ramasubramanian

Spectroscopy Diagnostics in ITER

Vinay Kumar

***14th Asia-Pacific Conference on Non-Destructive Testing-2013 (APCNDT-13), Mumbai, 18-22 November 2013***

Simulation Study and Development of Ultrasonic Inspection Technique for Cu-W Monoblock Divertor Assembly

Kedar Bhope, Mayur Mehta, M.S. Khan, S.S. Khirwadkar

Role of Infrared Thermography for development of Divertor Plasma facing components

Yashashri Patil, S.S. Khirwadkar, M. S. Khan, S. Pandya, M. Mehta, T. Patel, N. Patel, P. Mokaria, P. Patel

Ultrasonic Evaluation Report of Cu-W Monoblock Divertor Assembly

Kedar Bhope

***DAE-BRNS National Symposium on Nuclear Instrumentation (NSNI 2013), Bhabha Atomic Research Centre, Mumbai, 19-21 November 2013***

Instrumentation Bus Systems and Communication Methods for DNBPS Fast Controller

Rasesh Dave, Hitesh Dhola, Aruna Thakar, N. P. Singh, Darshan Parmar, Amit Patel, Bhavin Raval, Sandip Gajjar, Vikrant Gupta and Ujjwal Baruah

Using Voltage to Frequency conversion for close loop control in HVPS

Hitesh Dhola, Amit Patel, Aruna Thakar, Rasesh Dave, Darshan Parmar, Sandip Gajjar, Bhavin Raval, Vikrant Gupta, N. P. Singh and Ujjwal Baruah

Design and Development of Interlock System for ITER-India Gyrotron Test Facility (IIGTF)

Ronak Shah, Vipal Rathod, Deepak Mandge, S.L. Rao, Gaurav Joshi, Anjali Sharma, Tarun Sharma

***Indian Particle Accelerator Conference, (InPAC-2013), Variable Energy Cyclotron Centre, Kolkata, 19-22 November, 2013***

Adaptation of Fast Responding Power Supply for Radial Position Control in SST-1

Dinesh Kumar Sharma, Kiritkumar B. Patel, Akhilesh Kumar Singh and Jasraj Dhongde

Design of a Compact Electron Cyclotron Resonance (ECR) Ion Source

Sudhirsinh Vala, C.V.S Rao, T.K. Basu

Minimisation of Error in the Phase of Reflection Coefficient using Least Square Technique for Ion Cyclotron Resonance Heating

Raj Singh

Design Study of SLIT- Aperture Based Extraction System for an H<sup>+</sup> Ion Source

B. Choksi, S.K. Sharma, V. Prahlad, P. Bharathi, Z. Marafatia and U.K. Baruah

Performance of the large Current H<sup>+</sup> Ion Source: Operational Aspects

S.K. Sharma, P. Bharathi, V.B. Vadher, L.K. Bansal, L.N. Gupta, D. Thakkar, B. Choksi, C.B. Sumod, K. Qureishi, S. Rambabu, S.L. Parmar, N. Contractor, B. Pandya, A.K. Sahu, V. Prahlad, P.J. Patel and U.K. Baruah

Multifaceted Beam Dump for INTF Negative Ion Beam Diagnostic

Dass Sudhir, M. Bandyopadhyay, R. Pandey, J. Joshi, A. Yadav, C. Rotti, A. Chakraborty

Static Thermal Analysis and Experimental Evaluation of Heat-Pipe Oven for Plasma Wakefield Accelerator Experiment

Milind A. Patel and Krunal Patel, K.K. Mohandas and Ravi A.V. Kumar.

Development of Plasma Source for Plasma Wakefield Accelerator Experiment at the Institute for Plasma Research

K.K. Mohandas, Sangeeta Tripathi, Sonam Brahmhatt and Ravi A.V. Kumar

***Nanoscale Excitations in Emergent Materials (NEEM 2013), Ahmedabad, 25-26 November 2013***

Optical Anisotropy in metallic nanoparticles arrays

M. Ranjan

***28th PSSI National Symposium on Plasma Science and Technology on Fusion Science and Technology (Plasma 2013), KIIT University, Bhubaneswar, 3-6 December 2013***

Nonlinear Dynamics of Relativistically intense Waves in Cylindrical and Spherical Geometry

Arghya Mukherjee and Sudip Sengupta

Multiple Double Layer Formation in High Pressure Glow Discharge

Manash Kumar Paul, P. K. Sharma, A. Thakur and S. V. Kulkarni

Diagnostics of Reverse Polarity Planar DC Magnetron

S. Chauhan, M. Ranjan, S. Mukherjee

Sheath Formation in Electronegative Glow Discharges in the Presence of Two Species of Positive Ions

R. Moulick and K.S. Goswami

Study of Electric Potential in a Magnetized Electronegative Plasma

A. Phukan, P. J. Bhuyan and K. S. Goswami

Effect on Electron Energy Probability Function in presence of Dust in Low Pressure Argon Additive Hydrogen Plasma

B Kakati, B. K. Saikia and M. Bandyopadhyay

Dust Charging in Low Pressure Filamentary Plasma in an Improved Multicusp Device

D. Kalita, B Kakati, B.K. Saikia and M. Bandyopadhyay

Anomalous Collisional Absorption of Intense Laser Pulses in Under-Dense Plasma

M. Kundu

Investigation of Force Balance Dynamics in a Thermal Plasma Torch

Vidhi Goyal and G. Ravi

Plasma Sheath Boundary Identification

Vara Prasad, K. P. Mehta, Joydeep Ghosh, A. Sarma, D. Sarma, P. Chattopadhyay

Transient Evolution of Electron Energy Distribution Function of Solitary Electron Holes in Laboratory plasmas

Mangilal Choudhary, S. Kar and S. Mukherjee

Study of Transition from Coherent To Turbulent Regime with Variation in Torodial Magnetic Field

Umesh Kumar, T. S. Goud, R. Ganesh, Y. C. Saxena, D. Raju

Synchronization between Two Plasma Sources with Unidirectional Coupling

Neeraj Chaubey, S. Mukherjee, A. N. Sekar Iyengar, A. Sen

Estimation of Electric Fields on Plasma Pattern in an RF Produced Magnetized Plasma

P. Bandhyopadhyay, D. Sharma, U. Konopka and G. Mrofil

Electron Trapping in Nonlinear Ion Acoustic Wave

Debraj Mandal and Devendra Sharma

Focusing/ Defocusing of a Gaussian Electromagnetic Beam in a Multi-Ionized Plasma

Shikha Misra and S. K. Mishra

Estimation of Design Parameters for a Helicon Source

N. Sharma, M. Chakraborty, N. K. Neog, and M. Bandyopadhyay

Spectroscopic Diagnostics of UV Ionized Lithium Metal Vapor Plasma for Plasma Wakefield Accelerator Experiment

Mohandas K. K, Sangeeta Tripathi, Sonam Brahmhatt and Ravi A. V. Kumar

Auxiliary Filaments Influence on Plasma Parameters in the Target Region of a Double Plasma Device

P. Hazarika, M. Chakraborty, B. K. Das, M. Bandyopadhyay



Experimental Measurement of Electron Energy Distribution Function of Solitary Electron Holes

S. Kar, M. Choudhary, and S. Mukherjee

Experimental Investigation of Counter Propagating ExB Drifts in Magnetized Plasma Column Using Planar Directional Probe

S. K. Karkari, H. Kabariya, C. Soneji and D. Patel

Sheath Characteristics in a Very Low Temperature and Low Density Positive Ion-Negative Ion Plasma

M.K. Deka, N.C. Adhikary and H. Bailung

Design and Testing of Proto- type Magnet for Cesium Plasma Confined in a Multi-line Cusp Magnetic Field

N. Ramasubramanian and P. K. Chattopadhyay

Non-linear Studies in Cold Cathode Argon Glow Discharge Plasma

Anu Philip, Jacob George, Sajith Mathews T, P.J Kurian, P. K Chattopadyay

Characteristic Study of Plasma Waves by Varying the Applied RF Frequency and Electron Temperature in Single Frequency Capacitive Discharges

Sarveshwar Sharma, and M. M. Turner

Observation and Theory of Electron Temperature Gradient Turbulence in Laboratory Plasma

S. K. Singh, L. M. Awasthi, S. K. Mattoo, P. K. Srivastava, A. K. Sanyasi, Amit Patel, R. Sugandhi, R. Jha, R. Singh and P. K. Kaw

Study of Plasma Response to Electron Energy Filter in LVPD

A. K. Sanyasi, L. M. Awasthi, S. K. Mattoo, P. K. Srivastava, S. K. Singh, R. Singh and P. K. Kaw

Turbulence Study in the Near EEF Target Plasma of LVPD

A.K. Sanyasi, L.M. Awasthi, S.K. Mattoo, S.K. Singh, P.K. Srivastava, R. Singh and P.K. Kaw

Stability of Bernstein-Greene-Kruskal (BGK) Modes in Q-Nonextensive Collisionless Plasmas

Anup K Mandal and Rajaraman Ganesh

Phase-Mixing of Electrostatic Modes in Arbitrary Mass Ratio Cold Magnetized Plasmas

Chandan Maity, Nikhil Chakrabarti, and Sudip Sengupta

Long Range Correlations and Hurst Exponent in a Toroidal Magnetized Plasma

T. S. Goud, U. Kumar, R. Ganesh, Y. C. Saxena, D. Raju, and A.N.S. Iyengar

Wall Charging of a Helicon Antenna Wrapped Dielectric tube filled with RF Produced Plasma

Kshitish Barada, P. K. Chattopadhyay, J. Ghosh, Devendra Sharma and Y. C. Saxena

Main Vacuum Pumping System of SST -1 Tokamak

Ziauddin Khan, Firozkhan Pathan, Siju George, Kalpesh Dhanani, Yuvakiran Paravastu, Pratibha Semwal and Subarata Pradhan

Design and Development of A 200KV, 15MA High Voltage Power Supply

Amal S, Urmil M Thaker, Kumar Saurabh and Ujjwal K Baruah

Testing of High Speed Profibus Link VME V6PFB Profibus Card and Simens DC Simoreg Master (6ra70)

Dinesh Kumar Sharma and SST -1 Power System Team

Radiation Damage Study of Graphite Exposed to Helium Ions

N.J Dutta, N.Buzarbaruah, S.R Mohanty, P.M.Raole, T. Dash, B.B. Nayak

Application of AACMM in Quality Control for Development of Superconducting Magnet Components

Mahesh Ghate, Dhaval Bhavsar, Arun Panchal, Subrata Pradhan

Development of Experimental Helium Cooling Facility for Testing of LLCB TBM First Wall Mock - Ups

Brijesh Kumar Yadav, Ankit Gandhi , Aditya Kumar Verma, T Srinivas Rao, E. Rajendra Kumar, Mausam Sarkar and K.N,Vyas

MDSplus Integration with ICRH DAC Software

Ramesh Joshi, Manoj Parihar, H.M. Jadav, S V Kulkarni & ICRH Group

Engineering Design of Epics Based Prototype for ICRH DAC System

Ramesh Joshi, Manoj Singh, S. V. Kulkarni, Kiran Trivedi

Codac Core Based Control System for 300KV Accelerator Based 14-Mev Neutron Generator

Vismaysinh Raulji, Praveenlal E V, Hitesh Mandaliya,, Rachana Rajpal, Rajnikant Makwana and Sudhirsinh Vala

Design Fabrication, Testing and Integration of 1.5 Kv, 1.5a Screen Grid Power Supply for 200kw, 91.2 Mhz CWRF Amplifier

Bhavesh R.Kadia, YSS Srinivas, Kirti Parmar, H.M. Jadav, S.V. Kulkarni & ICRH Group

Design and Development of a Line Neutron Source Based on Internal Electrostatic Confinement Fusion Scheme

N. Buzarbaruah, N.J. Dutta, M.K. Deka, S.R. Mohanty, M. Bandhopadhyay, P.M. Raole, R. Verma and A. Shyam

Field Simulation of Ohmic Ramp-down In Aditya-Need for Correction Coils for Improvement of magnetic null

A. Amardas, R.L. Tanna, J. Ghosh, P.K. Chattopadhyay, C.N. Gupta, S.B. Bhatt, and the Aditya team

Joining of Graphite to Heat Sink Material by Direct Vacuum Brazing using Active Metal Filler Material

K.P.Singh, S.S. Khirwadkar, Malti Verma, S.Kanpara. M.S. Khan, S. Belsare, Nikunj Patel, Prakash Mokaria

Cryogenic Operation Strategy for the SST - 1 Device  
V.L. Tanna, Cryogenic Team (SST-1) and S. Pradhan

General Purpose Signals Acquisition System for Acquiring, Storing and Integrating Electrical Signals

Vijay Vadher, Paresh Patel, L. K. Bansal, Karishma Qureshi, Dipal Thakkar, Vishnu Patel, L. N Gupta, C. B. Sumod and U. K. Baruah

Timing Control Circuit For Real – Time Control of Events in Aditya Tokamak

Praveenlal E.V, Prakash Naicker, Rachana Rajpal, Pravesh Dhyani, Joydeep Ghosh, R.Tanna, P.K.Chattopadhyay and Aditya team

Variable Duty Cycle & Variable Amplitude Multi Pulse Generation Facilities Development in the PXIE System for Different mode of ICRH operations

Manoj Singh, H.M. Jadav, Ramesh Joshi, Sunil Kumar, YSS Srinivas, B.R.Kadia, K.M.Parmar, Gayatri Ramesh, Atul Varia , S. V. Kulkarni and ICRH - RF Group

Acceptance Tests of Cryogenic Components for SST-1

Rajiv Sharma, Hiren Nimawat, Nitin Bairagi, Pankil Shah, Ketan Patel, Srikanth, D.Sonara, V.L. Tanna and S.Pradhan

Ramp Based Measurement Circuit for Langmuir Probe Diagnostic

Pramila, Jignesh Patel, Rachana Rajpal, R.Jha

Design and Development of IGBT Based Circuit for Switching Off the Plasma for Wave Experiments in Afterglow Plasma

Minish Shah, Rachana Rajpal, Sayak Bose, P.K. Chattopadhyay

Liquid Nitrogen Distribution Boxes For Cool Down Of 80K Thermal Shields of SST-1

R. Panchal, GLN. Srikanth, K. Patel, P. Shah, V. L. Tanna and S. Pradhan

Base Pressure is the Determining Factor for Blob Formation in Argon Plasma

G. Sahoo, R.Paikaray, S.Samantaray, P. Das, D.C. Patra, N. Sasini, J. Ghosh, A. Sanyasi

Variation of Intensity of Atomic Lines in Atmospheric Gas Plasma Produced by Washer Plasma Gun

P. Das, R. Paikaray, S. Samantaray, G.Sahoo, D. C. Patra, N. Sasini, J.Ghosh, A.Sanyasi, M.B. Chowdhuri

Recent Run - Time Experience and Investigation of Impurities in Turbines Circuit of Helium Plant of SST-1

P. Panchal, R. Panchal R. Patel, G. Mahesuriya, J. Tank, D. Sonara, Srikanth LN, K. Patel, D. Christian, A. Garg, N. Bairagi, P. Shah, H. Nimavat, R. Sharma, V.L. Tanna and S. Pradhan

Design of an Experimental Setup for Determining Hydrogen Isotopes Solubility in Liquid Lead Lithium

Sudhir Rai, Amit Sircar and Sanjeev Kumar Sharma

Studies of Out-Gassing Rate Carried Out for Various Materials to be used in Cryoadsorption Cryopump

Samiran Mukherjee, Paresh Panchal, Agarwal Jyoti, Ranjana Gangrady, Ravi Prakash N.

Degassing Measurement Studies Carried Out for Various Forms of Activated Carbon

Samiran Mukherjee, Sapana Guru, Pratik Nayak, Jyoti Agarwal, Ranjana Gangradey

Indigenous Development of Single Barrel Hydrogen Pellet Injector System

Samiran Mukherjee, Paresh Panchal, Pratik Nayak, Pramit Dutta, Naveen Rastogi, Alaap Jagdale, Haresh Patel, Ranjana Gangradey, Ravi Prakash N.



Design, Development and Characterization of Interlock System for 42 GHz ECRH System on Aditya and SST-1 Tokamak

Rajan Babu.N, B K Shukla, Harshida R.Patel, Jatin Patel, Pragnesh B. Dhorajiya and ECRH Division

Optimization Study of ITER-VVPSS Tank

Gaurav Jogi, Girish Gupta, Vipul More, Avik Bhattacharya, Jagrut Bhavsar, Mukesh Jindal, Vaibhav Joshi, Mitul Patel, Rajnikant Prajapati, Amit Palaliya, Saroj Jha, Manish Pandey and Anil Bhardwaj

Engineering Validations of SST-1 Magnet System

A.N.Sharma, K. Doshi, U.Prasad, Y. Khristi, P. Varmora, M. Banaudha, B. Parghi and Pradhan

Design Optimization of the Transporter Frame for the Cryostat Lower Cylinder

Avik Bhattacharya, Girish Gupta, Jagrut Bhavsar, Mukesh Jindal, Gaurav Jogi, Vipul More, and Anil Bhardwaj

Design of an Extractor for Hydrogen Isotopes in Liquid Lead Lithium

Rudresh B. Patel, Sudhir Raj and Amit Sircar

Overview of Instrumentation and Control of ITER Cryostat

Dileep Shukla, Mukesh Jindal, Girish Gupta, Anil Kumar Bhardwaj

Commissioning of - 70KV Solid State Crowbar System

YSS Srinivas, N. Rajan Babu, KM Parmar, Bhavesh Kadia, Chetan Virani, Pragnesh Dhorajiya, Jigalraj Vansia, Shefali Dalakoti, Doshi Ravikumar, Brahmhatt Tushar, Patil Gajendra, Anil Vishwakarm and S V Kulkarni

Simulation of Scenarios of LHCD Antenna for Pre-ionization in SST1 Machine

P.K. Sharma, K. K. Ambulkar, S. Dlakoti, C.G.Virani, P.R. Parmar, A. L. Thakur

Control and Monitoring of High Power RF Dummy Load

Harsha Machchar, R. G. Trivedi, and Aparajita Mukherjee

Conceptual Design of I-Q Demodulator Technique for ICH & CD Source

Dipal Soni, Kumar Rajnish, Manoj A Patel, Sriprakash Verma, RG Trivedi, Raghuraj Singh and Aparajita Mukherjee

Cooldown Characteristics of LN<sub>2</sub> Transfer Lines and Chevron Shielding For NBI Cryo - Condensation Pumps

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Vacuum And Cryogenic Performance Study of a Cryostat Used for testing Different Cryopanel

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Design and Analysis of Cryostat PHTS Circular Bellows

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Thermal Stress Analysis of the Cryo- Adsorption Cryopump

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Neutronic Analysis of X-Ray Survey Spectrometer for ITER using Attila

P.V. Subhash, Russel Feder, Sajal Thamos, Sapna Mishra, and Deepak Aggarwal

Design and development of Prototype of FPGA Based 8 Channel Fiber Optics Serial Data Link for Digital Signals

Jignesh Soni, R. Patel, T.Vasoya, R. K. Yadav, H. Tyagi, H.Mistry, A. Gahlaut, K. G. Parmar, G. Bansal, K. Pandey, M Bandyopadhyay and A. Chakraborty

Design Development and integration of Signals Conditioning Electronics for Probe Diagnostics in ROBIN

Himanshu Tyagi, J. Soni, R. K. Yadav, G. Bansal, K. Pandya, A. Gahlaut, H. Mistry, K. Vora, K. G. Parmar, B. Prajapati, V. Mahesh, M. Bandyopadhyay and A. Chakraborty

CFD Analysis of the Cryo - Adsorption Cryopump

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Integration and Remote operation of 10kv, 400mA high Voltage Power Supply with ROBIN DACS

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- Stepper Motor Based Remote tuning System for 100KW, 1MHz RF Matching Network of ROBIN  
Agrajit Gahlaut, Deepak Parmar, K. G. Parmar, Bhavesh Prajapati, Mahesh V, Gourab Bansal, Jignesh Soni and Arun K. Chakraborty
- Enhanced Oxygen and Carbon Removal from Vacuum Vessel wall Of Aditya Tokamak Using Discharge Cleaning with Ar - H<sub>2</sub> Mixture  
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S. K. Sinha, S. Yadav & P. M. Raole
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Pramit Dutta, Ranjana Gangradey, Ravi Prakash, N. Hemant Patel, Krishna Kumari K
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J. Mishra, S. Mukherajee, P. Nayak, P. Panchal, N. Rastogi R. Gangradey, N. Raviprakash
- Development of Wireless Mobile Robot with Real time Obstacle Avoidance and Path Planning using FPGA  
Naveen Rastogi, Ravi Prakash N, Pramit Dutta, Pratik Bhimani, Pranav Manvar
- Development of LabVIEW™ Based Application for Interfacing of Cryo Pump with ROBIN DACS  
Radhika Gupta, J Soni, H. Tyagi, R. K. Yadav, H. Mistry, K. Pandya, G. Bansal and A. Chakraborty
- Dynamic Navigation Simulation of an Articulated Multi - Link Arm for In - Vessel Inspection Tasks in a Tokamak  
Naveen Rastogi, Ravi Prakash, Pramit Dutta, Nirav Virpara
- Studies of Adsorption Characteristic of Various Activated Carbons Down To 4.5K  
S. Kasthuriengan, Upendra Behra, Samiran Mukherajee, Ranjana Gangradey
- PXI Based Data Acquisitions and Control System for Single Barrel Pellet Injection System  
Naveen Rastogi, Haresh Patel, Samiran Mukherjee, Alaap Jagdale, Ranjana Gangradey
- Development of Two Series Ignitron Based Crowbar Protection System for 42 GHz & 82.6 GHz Gyrotron in SST-1  
Pragnesh Dhorajiya, Shefali Dalakoti, Harshida Patel, Krunal Ingle, Jatin Patel, K. Sathyanarayan, Rajanbabu and B. K. Shukla
- Real Time Interfacing Of 3D CAD Simulation in Delmia with Articulated Robotic Arm  
Naveen Rastogi, Ravi Prakash, Pramit Dutta, Nikunj Kachhadia, Archit Sureja, Nirav Virpara
- Self-localization and Coordination Control of an articulated Manipulator using Photogrammetry & Stereo Vision Solution  
Naveen Rastogi, Ravi Prakash, Pramit Dutta, Archit Sureja, Ankita Patel
- Commissioning, Interfacing, Testing and Operation of - 10KV, 400MA High Voltage Power Supply with ROBIN for Beam Extraction  
K. G. Parmar, A. Gahlaut, V. Mahesh, R. K. Yadav, Deepak Parmar, J. Soni, G. Bansal, B. Prajapati, H. Mistri, K. Pandya, M. Bandyopadhyay, and A. Chakraborty
- A Comparison Study of Various Seismic Analysis Methods  
S. S. Sandhu, Y. Dileep
- Thermal Characterization of FBG Sensors for Nuclear Fusion Reactor Relevant Applications  
M. Sai Shankar, M. Manohar, R. L. N. Sai Prasad and B Ramesh Kumar
- Upgradation of Fiber Optic Based Analog Signal Link for

- ECRH System on SST-1  
Harshida Patel, B. K. Shukala, Jatin Patel, N. Ranjan Babu, Pragnesh Dhorajiya and Chetan Virani
- Probing Argon-Hydrogen Magnetron Sputtering Discharge Plasma with Ion Acoustic Wave  
P. Saikia, B. K. Saikia
- Development of Plasma Based Process for Improvement of Surface Properties of Steel  
J. Alphonsa, P. Saikia, G. Jhala, R. Rane, S. B. Gupta, B. K. Saikia and S. Mukherjee
- Non-Thermal Atmospheric Pressure Plasma Jet on Bio - Medical Application  
Abhijit Majumdar, Vishal Jain, Chiruya Patil, Akshay Vaid, Suborto Mukherjee
- Investigation of the Role of Shroud Gas in DC Non-Transferred Arc Plasma Torch  
Yugesh. V, Gavisidhyah Hiremath, G. Ravi, and K. Ramchandran
- Experimental Setup for Producing Tungsten Coated Graphite Tiles Using Plasma Enhanced Chemical Vapor Deposition Technique for Fusion Plasma Applications  
Sachin Singh Chuhan, Uttam Sharma, A. K. Sanyasi, K. K. Choudhary, Jayshree Sharma, J. Ghosh
- Synthesis of Carbon Encapsulated Magnetic (Fe/Fe<sub>3</sub>C) Nanoparticles (CEMN) Optimized for Biomedical Applications  
N. Aomoa and M. Kakati
- Non-Thermal Atmospheric Pressure Plasma Jet on Bio-Medical Application  
Abhijit Majumdar, Vishal Jain, Chiruya Patil, Akshay Vaid and Subroto Mukherjee
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S. Borthakur, P. Sah, N. K. Neog, T. K. Borthakur, R. Kumar, R. Verma A. Shyam
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S. Samantaray, R. Paikaray, G. Sahoo, P. Das, D. C. Patra, N. Sasini, J. Ghosh, A. Sanyasi
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Rajesh Kumar, Saurabh Kumar, Nasir Shah, Anitha V. P. Renu Bahl and Anurag Shyam
- Fluid Simulation of Relativistic Electron Beam Driven Wake - Field Excitation In A Cold Plasma  
Ratan kumar Bera, Sudip Sengupta and Amita Das
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Ratan kumar Bera, Sudip Sengupta and Amita Das
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Narayan Behera, R. K. Singh, Manoj Gupta, D. Sharma and Ajai Kumar
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S. Jaiswal, P. Bandyopadhyay and A. Sen
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Lavkesh Lachhvani, Manu Bajpai and Sambaran Pahari

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Akanksha Gupta and R. Ganesh
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S. Adhikari and K. S. Goswami
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A. Phukan and P. J. Bhuyan
- Modelling Of Electromagnetic Fields during Plasma Startup in SST -1 Tokamak  
A. K. Singh, I. Bandyopadhyay, D. Raju, R. Srinivasan and SST – 1 Team
- 3D Character of Plasma Transport Aditya Limiter Scrape off layer: EMC3-EIRIENE Simulations and Analysis  
Bibhu Prasad Sahoo, Devendra Sharma, Ratneshwar Jha, Yhue Feng
- Statistical Mechanics of Pure Repulsive and Attractive Yukawa Systems with a Soft Core - A Molecular Dynamics Study  
Swati Baruah and R. Ganesh
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Anup K Mandal and Rajaraman Ganesh
- Equilibrium and Dynamical Studies of Strongly Coupled Yukawa Liquids - Molecular Dynamics Simulations  
Harish Charan, Rajaraman Ganesh, Ashwin Joy
- Particle-In-Cell Simulation of Non-Neutral Plasma  
Meghraj Sengupta and Rajaraman Ganesh
- A Numerical Study of Rotating Flows in Strongly Coupled Dusty Plasma  
Vikram Singh Dharodi, Amita Das and Sanat Kumar Tiwari
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Suresh Akella, B. Ramesh Kumar and Y. Harinath
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Aditya KS, Ganesh. J, Chowdhury, S. Bruner, J. Vaclavick, L. Villard
- Conceptual Design of an In-Vessel Inspection Robotic System for Tokamak Environment  
Prabhat Kumar, Prateek Patel, Dainel Raju, Jatinkumar Dave, Vaibhav Ranjan and Mehul Naik
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S. Purohit, M. B. Chowdhuri, Y. S. Joisa, J. V. Raval, J. Ghosh, R. Jha and Aditya Team
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Mayank Goswami, Prabhat Munish, Anupam Saxena, Manoj Kumar and Ajai Kumar
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Niral Virani, M. B. Choudhuri, R. Manchanda, Nilam Ramayia, K. M. Jadeja, S. B. Bhatt, R. L. Tanna, C. N. Gupta and Aditya Team
- Improved Charge Collector Diagnostics for Electron Plasma in Smartex - c  
Lavkesh Lachhvani, Karan Rathod, Manu Bajpai and Sambaran Pahari
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Santosh P. Pandya, Kumar Ajay Snehlata Gupta, Priyanka Mishra Rajani D. Dhingra J. Govindrajan and ADITYA – Team
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Santosh P. Pandya, Shamsuddin Shaikh, Kanchan Mahavar, Shwetang N. Pandya, Kumar Ajay, J. Govindarajan and SST-1 Team
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Preliminary Design Considerations for Erosion / Deposition Monitor in ITER

Rajwinder Kaur, R. Huxford, G. Vayakis, J. Govindarajan, P. Andrew and M. Walsh

Experimental and Monte-Carlo Absolute Efficiency Calibration of HPGE  $\gamma$ -Ray Spectrometer for Application in Neutron Activation Analysis

S. Tiwari, S. Jakhar, M. Abhangi, R. Makwana, V. Chaudhari, C.V.S Rao, T. K. Basu

Development of PXI based DAQ in Lab VIEW for SMART-TEX –C

Yogesh Govind Yeole, Lavkesh Lanchhvani, Sambran Pahari and Manu Bajpai

Spectroscopic Diagnostics for Washer Gun Plasma in SYMPLE

Piyali Adhikary, M. B. Chowdhuri, Priyavandna J. Rathod, B. Ramesh Kumar and V.P. Anitha

Operation and Control System Design for Large Volume Plasma Device

R. Sughandhi, P. K. Srivastava, Amit Patel, A. K. Sanyasi, S. K. Singh, L. M. Awasthi and S. K. Mattoo

Magnetic Probe Diagnostics for SYMPLE

Anoop Suseel, Praveenlal E V, P. K. Srivastava, Priyavandna J. Rathod and Anitha V. P

Process Instrumentation Modeling for Vacuum System Automation of LVPD

P. K. Srivastava, R. Sugandhi, R. Jain, A. K. Sanyasi, S. K. Singh, Amit Patel, Kalpesh Raval, L. M. Awasthi and S. K. Mattoo

Pulser Circuit for Plasma Potential and Beam Current Measurement in LVPD

Kalpesh Raval, P. K. Srivastava, A. K. Sanyasi, Amit Patel, S. K. Singh, L. M. Awasthi and S. K. Mattoo

Design and Development of Electronics Circuit for TLP Diagnostics in LVPD

P. K. Srivastava, Kalpesh Raval, Amit Patel, S. K. Singh, A. K. Sanyasi, L. M. Awasthi and S. K. Mattoo

Smart Trigger Clock System for Generic PXI DAQ System

Tushar Raval, Atish Sharma, Imran Mansuri, Manika Sharma, S. Pradhan

Measurement of Electron Temperature Profile Using Absorption Foil Technique for ADITYA Tokamak Discharges

Jayesh V. Raval, Shishir Purohit, Sudeshna Maity, Shankar Joisa and Aditya Team

Calibration and Performance Testing Of Pulse Counting Module and Channel Electron Multiplier Detector for Charge Exchange Diagnostic in SST-1

Snehlata Gupta, Santosh P. Pandya, Hitesh Patel, Kumar Ajay

Study of neutral beam attenuation of 5MW hydrogen beam in SST-1 Tokamak

P. Bharathi, S. Ranjan, S. Thirumugam, S. K. Sharma, V. Prahlad, U. K. Barua and P. Vasu, C. Giroud, E. Delabie and N. C. Hawkes

Infrared Imaging Diagnostics for Plasma Confinement Devices

Santosh P. Pandya, Shwetang N. Pandya, Shamsuddin Shikh, Zubin Shaikh, Kanchan Mahavar, Kumar Ajay, J. Govindarajan, ADITYA and SST-1 Team

Engineering aspects of Microwave Diagnostics at ITER

K. M. Patel, V. S. Udintsev, G. Vayakis, O. Darcourt, T. Giacomini, D. Johnson, P. H. Maquet, H. B. Pandya, C. Penot, M. Portales, M. Proust, J. W. Oosterbeek, P. Sanchez, V. Vershkov, M. Walsh

100 GHz Interferometer to Measure Chord Averaged Plasma Density at SST-1 Tokamak

P. K. Atery, Umeshkumar C. Nagora and Abhishek Sinha

Ku Band Reflectometer at SST-1 Tokamak

P. K. Atrey and Nirav Joshi

Conceptual Design of Cavity Ring Down Spectroscopy (CRDS) in INTF

Dass Sudhir, M. Bandyopadhyay, H. Tyagi, A. Yadav, J. Joshi, R. Pandey, J. Soni, R. Yadav, C. Rotti, A. Chakraborty

A Multi-Channel Photodiode Array System for Plasma Formation Location Studies in Aditya Tokamak

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Modeling Of Plasma Emission Spectra Using Different Computer Codes

Sharvil Patel, J. Ghosh

Development of a Penning Plasma Discharge Source with Different Anode Configuration for Simultaneous Emissions of Visible and VUV Lights

G. L. Yyas, R. Prakash, U. N. Pal, Nandini Singh, R. Manchanda and N. Halder

Outgassing Testing of Materials of ITER Cryostat  
Mukesh Jindal, Amit Palaliya, Rajnikant Prajapati, Vaibhav Joshi, Mitul Patel, Jagrut Bhavsar, Girish Gupta, Anil Bhardwaj

A Transient Finite Element Simulation for the Thermo - Mechanical Study of Lip Seal Laser Weld Joints  
Ashish Yadav, Chandramouli Rotti, Mukesh Jindal, Jaydeep Joshi, Arun Chakraborty

Study of Thermo-Behavior of Swirl Tube Element  
M. Venkata Nagaraju, Chandramouli Rotti and Arun Chakraborty

Experimental Evidence of Multiple Current free Double Layers in an Expanding Plasma Produced using Helicon Antenna  
Kshitish Barada, P. K. Chattopadhyay, J. Ghosh, Devendra Sharma and Y. C. Saxena

Synthesis of Carbon Encapsulated Magnetic (Fe/Fe<sub>3</sub>C) Nanoparticles (CEMN) Optimized for Biomedical Applications  
N. Aomoa and M. Kakati

Development of duplex Plasma based process for improvement of surface properties of steel  
R. Rane

Data acquisition Techniques for randomly occurring Non-thermal Arcs  
Rashmi S. Joshi, Keena R. Kalaria and Suryakant B. Gupta

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Simulation Study of Atmospheric Pressure Dielectric Barrier Discharge Plasma in Air and its Experimental Validation  
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Conceptual study of prototype Electrode-less Microwave Plasma Arc Source at FCIPT for Coal Gasification application  
Vishal Jain, Anand Visani, P. K. Sharma, S. K. Nema

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Urja ke vaikalpik srot (In Hindi)

Pratibha Gupta

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Magnetron Sputtering for Thin film deposition

R. Rane

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Experimental Observation of Electron Temperature Gradient Turbulence in Finite Beta Laboratory Plasma and Theoretical Model of Secondary Instabilities

S. K. Singh, L. M. Awasthi, S. K. Mattoo, P. K. Srivastava, R. Jha, R. Singh and P. K. Kaw

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Complex Flow Patterns in Dusty Plasmas (Yukawa fluids)

Sanat Kumar Tiwari

Evolution of Coherent structures in Viscoelastic fluids

Vikram S Dharodi, Amita Das, and Sanat Kumar Tiwari

Study of Relativistic Electromagnetic Cusp Solitons in Plasma

Deepa Verma, Amita Das and Predhiman Kaw

Nonlinear evolution of the Weibel instability of counter streaming electrons

Chandrasekhar Shukla, Bhavesh G. Patel, Amita Das, Kartik Patel

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Emission of electrostatic waves at the sheath boundary of a dual-frequency capacitive discharge investigated by particle-in-cell simulation

Sarveshwar Sharma, and M. M. Turner

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Conceptual Design of EPICS Based Implementation for ICRH DAC System

Ramesh Joshi, Manoj Singh, S. V. Kulkarni, and Kiran Trivedi

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Evolution of Relativistically intense Space Charge Waves in a Cold Homogeneous Plasma

Sudip Sengupta

***International workshop on new horizons in Nuclear Reactor Thermal Hydraulics and Safety, (IWNRTHS), BARC, Mumbai, 13-15 January 2014***

CFD Studies on cooling finger mock-up of helium cooled divertor

S. Rimza, K. Satpathy, S. Khirwadkar and K. Velusamy

***11th International Symposium on Surface Protective Coatings (SSPC INDIA-2014), Ahmedabad, 19-21 January 2014***

Corrosion resistance offered by plasma nitrocarburized stainless steels

J. Alphonsa, J. Ghanshyam, Narendra Chauhan, P. Rayjada, and S. Mukherjee

***High Energy Density Science (in Asia), Busan Korea, 19-22 January 2014***

Sheet modelling of relativistically intense plasma waves

Sudip Sengupta

***National conference on Emerging Trends in Engineering, Technology & Management (NCEETM – 2014), Indus University, Ahmedabad, 31 January – 1 February 2014***

Thin Film Coating of Chromium Nitride on Ferrous Substrates by Magnetron Sputtering Technique for Improved Wear and Corrosion Resistance

D. Dave, B. Ganguli, B. Rana

Surface Modification of Titanium by Glow Discharge Plasma Nitriding

D. Patel, S. Thakar, B. Ganguli, D.K. Basa

***1st International Conference on Structural Integrity (ICONS 2014), IGCAR, Kalpakkam, India, 4-7 February 2014***

Structural Assessment of ITER-VVPSS Tank

Gaurav Jogi, Girish Gupta, Avik Bhattacharya, Vipul More, Anil Bhardwaj

Finite Element Analysis of Modified 9Cr-1Mo bead-on-plates

Zuberuddin M

Design and Analysis of Divertor Cooling Pipe and VS Coil Feeder Bellows of Cryostat

Saroj Kumar Jha, Girish Gupta, Avik Bhattacharya, Manish Pandey, Gaurav Jogi, Vipul More, Anil Bhardwaj

High Temperature Tensile Properties of Tungsten

Charu Lata Dube, Alpesh Patel, Shailesh Kanpara, Yashashri Patil, Sameer S. Khirwadkar

Structural Characterization of Laser treated SS304 and SS316L(N) plates

Pardhu Yella, Venkateswarlu P, Koteswararao V. Rajulapati, P. Prem Kiran, Ramesh Kumar Buddu, Raole P.M, and K. Bhanu Sankara Rao

Comparative studies on heat flux and thermal stresses analysis during conduction mode and keyhole mode in the laser beam welding

Suresh Akella, Y. Harinadh, and B. Ramesh Kumar

***7th Annual International Conference of Antenna Test and Measurement Society (ATMS-2014), Chennai, India, 11-12 February 2014***

Design and Development of Small Active and Passive Loop Antennas for Measurement of Shielding Effectiveness as per IEEE Std. 299

Veerendra Singh Jadaun, P. K. Srivastava, L. M. Awasthi, Kanhiya Lal

***National Symposium on Emerging Plasma Techniques for Materials Processing and Industrial Applications (N-SEP-MI 2014), University of Pune, Pune, 13-15 February 2014***

Biomedical Waste Disposal and Syn Gas Recovery from Petroleum Waste using Thermal Plasma Technology.

S. K. Nema

Development of laboratory scale fusion grade tungsten coatings for target and first wall components of fusion reactors.

Uttam Sharma, Sachin Singh Chouhan, A. K. Sanyasi, K. K. Choudhary, Jayshree Sharma, J. Ghosh

**International Corrosion Prevention Symposium for Research Scholars (CORSYM-2014), Indian Institute of Technology Bombay, India, 20-21 February 2014**

Effect of Temperature on the Corrosion Resistance Properties of A-286 Precipitation Hardening Stainless Steel after Plasma Nitrocarburising Process

J. Alphonsa, J. Aniket, G. Jhala, S Mukherjee and V.S. Raja

**National Conference on Recent Trends in Chemical Sciences (RTRSC2014), Manipal University, Jaipur, 21-22 February 2014**

Advanced Plasma Based Technologies for Surface Modification

S. K. Nema

**International Conference on Recent Trends in Physics (ICRTP-2014), Devi Ahilya University, Indore, 22 - 23 February 2014**

Development of Experimental Setup for Plasma Nitriding. Uttam Sharma, Sachin Singh Chouhan, A. K. Sanyasi, K. K. Choudhury, Jayshree Sharma, J. Ghosh

**An Interactive workshop on "Applications of Plasma in Textiles", Man Made Textile Research Association (MANTRA), Surat, 26 February 2014**

Plasma Technologies for Textiles Developed at Institute for Plasma Research

S. K. Nema

**11th International Fatigue Congress (FATIGUE 2014), Melbourne, Australia, 2-7 March 2014**

Low Cycle Fatigue and Creep-Fatigue Interaction Behaviour of Reduced Activation Ferritic Martensitic (RAFM) Steels with Varying W and Ta Contents

R. Sandhya, Vani Shankar, K. Mariappan, M.D. Mathew, T. Jayakumar, E. Rajendra Kumar

**7th International Conference on the Physics of Dusty Plasmas (ICPDP 7), New Delhi, India, 3-7 March 2014**

Equilibrium properties and phase transitional study of strongly coupled pair ion plasmas

Swati Baruah, R. Ganesh and K. Avinash

A comparative study of Molecular Dynamics simulation and a viscoelastic fluid model for two dimensional shear flows

Akanksha Gupta, Aswin Joy, and Rajaraman Ganesh

The equilibrium and dynamical properties of gravitationally compressed Yukawa – A Molecular dynamics study

Harish Charan and Rajaraman Ganesh, Ashwin Joy

MD simulation of 1D, 2D and 3D structure formation in vertically aligned dust chains

P.J. Bhuyan, N. Das, S. Bhattacharjee, and Tunell W. Hyde

Experimental Characterization of a Complex Plasma

S. Jaiswal, P. Bandyopadhyay and A. Sen

Vortex studies in Strongly Coupled Dusty Plasma

Vikram Singh Dharodi, Amita Das and Sanat Kumar Tiwari

Dust removal by external positive pulse in cogenerated dusty plasma

Sanjib Sarkar, M. Bose and S. Mukherjee

Molecular dynamics study of vapor-liquid phase transition phenomena in study plasmas

M. Kundu, K. Avinash, A. Sen, R. Ganesh

Dynamics of a drag driven dust fluid in a confining potential

L. Modhuchandra, D. Sharma and P. K. Kaw

Electron energy probability functions in an electrostatically plugged multicusp dusty plasma

B. Kakati, D. Kalita, B. K. Saikia and K. S. Goswami

Dust charging in presence of two species positive ions

B. K. Saikia, B. Kakati, S. S. Kausik and M. Bandyopadhyay

Sheath formation in low pressure discharges in presence of dust

R. Moulick and K. S. Goswami

Effect Non-Maxwellian plasma on dust charging

Shikha Misra S. K. Mishra and M. S. Sodha

MD simulations of the expansion of three dimensional dusty plasma

V. Saxena, J. Meyer, R. L. Merlino, K. Avinash and A. Sen

Effect of strong coupling on the mach cone structure in a complex plasma

P. Bandyopadhyay, Sangeeta, A. Sen

**3rd International Conference on Materials, Processing and Characterization (ICMPC 2014), GRIET, Hyderabad, 8-10 March 2014**



Welding Process Model for temperature and residual stress analysis

Y. Harinadh, S. Akella, Ramesh Kumar Buddu

*International Symposium on Innovation in Materials Science & Technology: Current Scenario (ISIMST-2014), S. P. University, Gujarat, 14-15 March 2014*

Er2O3 deposition for Fusion; Parameter dependence  
P A Rayjada, N P Vaghela, A. Labana, N L Chauhan, Amit Sircar, E Rajendrakumar, L M Manocha and P M Raole

*Optics'2014: International Conference on Light, Calicut, India, 19-21 March 2014*

Structural Modification of Stainless Steel Surface Using Pulsed Lasers

Venkateshwarlu, Pardhu Yella, Ramesh Kumar Buddu, K. Bhanu SankaraRao, Raole P.M., Koteswararao V. Rajulapati, P. Prem Kiran

*International Conference on Advances in Manufacturing and Materials Engineering (ICAMME), NITK, Surathkal, 27-29 March 2014*

A Welding simulation of dissimilar materials SS304 and Copper

Suresh Akella, Yaggadi Krishna, Vemanaboina Harinadh, and Ramesh Kumar Buddu

#### Awards And Achievements

*Application of Multi-Layer Insulation (MLI) On SST-1 Cryogenic Surfaces*

N. Bairagi, H. Mimavat, R. Sharma, V. L. Tanna and S. Pradhan won **first prize** of the “PSSI – Z.H. Sholapurwala Award for Fusion Research” under the ‘Nuclear Fusion and Technology – Experimental’ category for poster presentation at 28th PSSI National Symposium on Plasma Science and Technology on Fusion Science and Technology (Plasma 2013), KIIT University, Bhubaneswar, 3-6 December 2013

*A PMT Array Based Diagnostics to Measure Spatial and Temporal Behavior of Halpha Emission from Aditya Tokamak*  
Nilam Ramaiya, Ajay Kumar, M. B. Choudhuri, R. Manchanda, Niral Virani, Aniruddh Mali and J. Ghosh won **first Prize** in Plasma Diagnostic Category at 28th PSSI National Symposium on Plasma Science and Technology on Fusion Science and Technology (Plasma 2013), KIIT University, Bhubaneswar, 3-6 December 2013

*Disruption Characterization and Database Generation for Itpa Disruption Database from Aditya Tokamak Discharges*

R.L. Tanna, V.K. Panchal, Pintu kumar, K.A. Jadeja, S.B. Bhatt, C.N. Gupta, U. Dhobi, P.K. Atrey, Y.S. Josia, C.V.S. Rao, D. Raju, R. Jha, P.K. Chattopadhyay, J. Ghosh, A. Sen and ADITYA team won **first prize** Z.H. Sholapurwala Best poster presentation award for Fusion Research, at 28th PSSI National Symposium on Plasma Science and Technology on Fusion Science and Technology (Plasma 2013), KIIT University, Bhubaneswar, 3-6 December 2013

*Properties of incompressible shear flows in strongly coupled complex plasma*

Akanksha Gupta and R. Ganesh won **Best poster presentation** award in the field of “Fusion theory, Simulation and Modeling” at 28th PSSI National Symposium on Plasma Science and Technology on Fusion Science and Technology (Plasma 2013), KIIT University, Bhubaneswar, 3-6 December 2013

*Study of Linear and Nonlinear Evolution of Buneman instability*

Roopendra Singh Rajawat, Sudip Sengupta and Predhiman K. Kaw won **Best poster** award in Basic plasma category at 28th PSSI National Symposium on Plasma Science and Technology on Fusion Science and Technology (Plasma 2013), KIIT University, Bhubaneswar, 3-6 December 2013

*Data Acquisition Techniques for Occurring Ares on a Dielectric Surface*

Rashmi S. Joshi, Keena R. Kalaria, and Suryakant B. Gupta won **Best Poster** award in Industrial Plasma Section at 28th PSSI National Symposium on Plasma Science and Technology on Fusion Science and Technology (Plasma 2013), KIIT University, Bhubaneswar, 3-6 December 2013

*High Voltage Direct Current Water Load Bank*

Rohit Agarwal, Aparijita Mukherjee, Gajendra Suthar, Kartik Mohan, P. Ajesh, Raghuraj Singh, and R. G. Trivedi won **second prize** of the **Z.H. Sholapurwala Best Poster Presentation Award** for Fusion Research 2013 at 28th PSSI National Symposium on Plasma Science and Technology on Fusion Science and Technology (Plasma 2013), KIIT University, Bhubaneswar, 3-6 December 2013

*Development of Epics based Software Toolkit for Critical Heat Flux Computations for Divertor Mockups Testing at High Heat Flux Test Facility*

S.K. Doddi, Ritesh Sungandi, R. Swamy and S. Khirwadkar

won second **Best Paper Z.H. Solapurwala Award** at 28th PSSI National Symposium on Plasma Science and Technology on Fusion Science and Technology (Plasma 2013), KIIT University, Bhubaneswar, 3-6 December 2013

*Experimental Study of Thermal Characteristic of Different Thin Metal Foils For Infrared Imaging Video Bolometer and Comparison with FEM Simulations*

Kanchan Mahavar, Santosh P. Pandya, Hitesh Patel, Shamsuddin Shaikh, Zubin Shaikh Shwetang N. Pandya, Kumar Ajay Mishra and J. Govindrajan won **second Best Poster Z.H. Solapurwala Award** at 28th PSSI National Symposium on Plasma Science and Technology on Fusion Science and Technology (Plasma 2013), KIIT University, Bhubaneswar, 3-6 December 2013

Ms Pratibha Gupta, won **first prize** trophy in Hindi slogan competition and **second prize** trophy in English slogan competition on the topic “Safety in Mining and Milling Activity and Chronic Respiratory Diseases”. The trophies were awarded at the 30th Department of Atomic Energy (DAE) Safety and Occupational Health Professionals Meet (SOHPM) jointly organized by Atomic Energy Regulatory Board (AERB) and Uranium Corporation of India Limited (UCIL), held at Narwapahar, Uranium Corporation of India Limited, UCIL, Jharkhand from 18-20 December 2013.

IPR Hindi Magazine “Plasma Jyoti” magazine has won jointly with Tata Memorial center, Mumbai’s Spandan magazine the “**Shrestha Rajbhasha Patrika**” award in the DAE aided institutes category for the second consecutive year 2012-2013.

Self-excited Dust-Torus in DC Glow discharge  
Manjit Kaur, Sayak Bose, P. K. Chattopadhyay, D. Sharma, J. Ghosh, and Y. C. Saxena won **Best Poster Award** at 7th International Conference on the Physics of Dusty Plasmas (ICPDP 7), New Delhi, India, 3-7 March 2014

#### **E.4 Invited Talk Delivered by IPR Staff**

##### **DHIRAJ BORA**

Gave an Invited talk on “ITER H&CD Systems and RF Activities at IPR” at 20th Topical Conference on Radio Frequency Power in Plasmas. Sorrento, Italy, 25-28 June 2013

Gave an invited talk on “Fusion Science Activities at IPR” at PSSI-CEERI Plasma Scholars’ Colloquium (PSC) & NW, CEERI, Pilani, 22 July 2013

Gave Dr. Vikram Sarabhai Memorial Lecture 2013 on “Fusion Research at IPR” at Vikram Sarabhai Space Centre, Trivandrum, India, 12 August 2013

Gave a Colloquium talk on “ITER - A Burning Plasma Experiment” at Physical Research Laboratory, Ahmedabad, 14 August 2013

Gave an Over View Talk on “Indian Fusion Programme including ITER-India activities” at 9th Asia Plasma and Fusion Association Conference (APFA-2013), Gyeongju City, S. Korea, 5-8 November 2013

Gave an Invited talk on “Fusion - An alternate Energy source” at Physical Research Laboratory Alumni Meeting, Ahmedabad, 11 November 2013

Gave an Invited talk on “Materials Challenges for ITER program and India’s initiatives” at DWIH, Symposium, Science City, Ahmedabad, 16 November 2013

Chaired a session at the Global Energy Landscape Round Table Discussion, Monaco ITER International Fusion Energy Days, Monaco, 2 December 2013

Gave the key-note address on “Fusion - An Alternate Source of Energy” at 7th National Level Science Symposium-2014 on Recent Trends in Science and Technology, Organized by Christ College, Rajkot, 23 February 2014

Gave a talk on “Fusion & ITER - Relevance to Today’s Energy Scenario, at Centre for Science and Society, Ahmedabad, 23 February 2014

##### **VISHAL JAIN**

Gave an Invited talk on “Syn-gas Production by Coal Gasification using Microwave Plasma Gasification Technologies for India” at “National Mission on Clean Coal Technology” in THERMAX, Pune, 29 April 2013

##### **P. A. RAYJADA**

Gave an Invited talk on “Er<sub>2</sub>O<sub>3</sub> coating for Hydrogen barrier: Process optimization” at Princeton Plasma Physics Laboratory, USA, 23 April 2013

##### **SARVESHWAR SHARMA**



Gave an Invited talk on “Investigation of Ion and Electron Kinetic Phenomena in Capacitively Coupled Radio-Frequency Plasma Sheaths: A Simulation Study” at Aero-thermal & Plasma Physics Laboratory (APPL), National Chiao Tung University, Taiwan, 8 May 2013

Gave an Invited talk on “Study of stochastic heating in single and dual frequency capacitive discharges using particle-in-cell simulation”, Low Temperature Plasma Teleseminar, Plasma Science Center, University of Michigan and PPPL, USA, 30 August 2013

### **C. JARIWALA**

Gave an invited talk on “Thin Film Processing by Plasma Technique for Photovoltaic Applications: a-Si:H thin films” at Staff Development Programme (SDP) on “Advances in Material Science & Technology” at SVNIT, Surat, Gujarat, 3-7 June 2013

Gave an invited talk on “Plasma Enhanced Chemical Vapour Deposition (PECVD) Basics and Application for Processing of Thin Film Solar Cells” at TEQIP-II sponsored Staff Development Programme (SDP) on Thin Films and Vacuum Technology (TFVT-2013), SVNIT, Surat, Gujarat, 9-13 December 2013

### **SURYAKANT B. GUPTA**

Gave an Invited talk on “Cold plasma and their industrial applications”, at National Workshop on Plasma Devices Technology at CEERI, Pilani, 24 July 2013

Gave an Invited talk on “Plasma an innovative tool for societal benefits-INNOVAZIONE-13” at G. H. Patel College of Engineering & Technology GCET- Vallabh-Vidyanagar, 16-17 August 2013

Gave an Invited talk on “Emerging Role of Plasma Technology in – Automobile & Textile Industry, Pune Auto cluster, 28 October 2013

Gave a Keynote talk on “Societal benefits of plasma technology and role of Engineers”, at 4th Nirma University International Conference on Engineering NUiCONE - 2013, Ahmedabad, on 28 November 2013

Gave an Invited talk on “Lab VIEW based DAQ system for indigenously developed space like environmental simulation facility - SPIX-II”, at Instrumentation and control Engineer-

ing department of Nirma Institute of technology, Nirma University, 23 January 2014

Gave an Invited talk on “Indigenously developed plasma technologies available for commercial exploitation”, at Workshop on Facilitating Technology Acquisition-organized by DSIR-CII, Ahmedabad, 24 January 2014

Gave an Invited talk on “Role of plasma science in Contemporary Engineering & Technology”, at 1st International Conference on contemporary Issues in Engineering and Technology” Mehsana, 19-21 March 2014

### **PARTH C. KALARIA**

Gave an Invited talk on “Mode Purity Estimation of the Gyrotron RF beam” at 38th International Conference on Infrared, Millimeter, and Terahertz Waves (IRMMW-THz), Mainz, Germany, 1-6 September 2013

### **APARAJITA MUKHERJEE**

Gave an Invited talk on “Progress on ITER Ion Cyclotron and Electron Cyclotron Heating and Current Drive Source Package – Indian Contribution to ITER Project” at National Symposium on High Power RF & Microwave, (HPRFM-2013), Institute for Plasma Research, Gandhinagar, 4-6 September 2013

### **S.S. KHIRWADKAR**

Gave an Invited talk on “Status of Divertor Technologies and Test Facilities Developments at IPR” at 11th International Symposium on Fusion Nuclear Technology, (ISFNT-11), Barcelona, Spain, 16-20 September 2013

### **RAJARAMAN GANESH**

Gave an Invited talk on “Understanding classical pure electronic and ionic systems via computer simulations” at the Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR) on 31 October 2013

### **DILSHAD SULAIMAN**

Gave an Invited talk on “Progress in ITER In-wall Shielding Manufacturing” at Monaco-ITER International Fusion Energy Days 2013 (MIIFED 2013) at Monaco, 2-4 December 2013

**R. SRINIVASAN**

Participated in “Round table discussion on DEMO” as an Indian member at Monaco-ITER International Fusion Energy Days 2013 (MIIFED 2013) at Monaco, 2-4 December 2013

**C. BALASUBRAMANIAN**

Gave an Invited talk on “Thermal Plasma for Nanomaterial synthesis and studies” at UGC, Academic Staff College, Saurashtra University, Rajkot, 11 December 2013

**M. RANJAN**

Gave an Invited talk on “Plasma for Plasmamionics” at UGC, Academic Staff College, Saurashtra University, Rajkot, 11 December 2013

**C ROTTI**

Gave an Invited talk on “CuCrZr development for High Heat Flux (HHF) applications” at National Conference on Physics & Chemistry of Advanced Materials (NCPACAM-2013), 18-19 December 2013

**S. SUNIL**

Gave an Invited talk on “Waves from Space” at Sardar Patel University, Academic Staff College, Vallabh Vidyanagar, Gujarat, 7 February 2014

**N.RAMASUBRAMANIAN**

Gave an Invited talk on “Plasma - the fourth state of matter” at Sardar Patel University, Academic Staff College, Vallabh Vidyanagar, Gujarat, 7 February 2014

**I. BANDYOPADHYAY**

Gave an Invited talk on “Present Activities at ITER-India & IPR” at General Atomics during the PAC meeting on 14 February 2014

**S.K. NEMA**

Gave an Invited talk on “Advanced Plasma Based Technologies for Surface Modification” at National Conference on Recent Trends in Research in Chemical Sciences (RTRCS-2014), Manipal University Jaipur on 21-22 February 2014.

Gave an Invited talk on “Biomedical Waste Disposal and Syn Gas Recovery from Petroleum Waste using Thermal Plasma Technology”, at National Symposium on “Emerging Plasma Techniques for Material Processing and Industrial Application” (EPMI 2014), University of Pune, 13-15 February 2014  
Gave a Popular talk on “Plasma and its Applications” at Rani Durgavati University, Jabalpur, 23 March 2014

**P.M. RAOLE**

Gave an Invited talk on “Surface characterization of Plasma and ion modified materials for Industrial and fusion related applications” in a theme meeting on Recent Advances in Materials Characterization by Surface Analytical Techniques, Organized by National Centre for Compositional Characterization of Materials (NCCCM), BARC, Hyderabad, February 20-22, 2014

Gave an Invited talk on “A perspective on research and developments of Fusion Reactor Materials” at International Symposium on Innovation in Materials Science & Technology: Current Scenario (ISIMST-2014), DoMS, S. P University, Gujarat, 14-15 March 2014

*Invited talks given at 28th PSSI National Symposium on Plasma Science and Technology on Fusion Science and Technology (Plasma 2013), KIIT University, Bhubaneswar, 3-6 December 2013*

YOGESH C. SAXENA gave an Invited talk on “Fusion Science and Technology”

MRIDUL BOSE, SANJIB SARKAR, S. MUKHERJEE, J. PRAMANIK gave an Invited talk on “Experiments on Co-generated Dusty Plasma”

P. K. CHATTOPADHYAY gave an Invited talk on “Basic Plasma Experiments at IPR”

N. RAMASUBRAMANIAN gave an Invited talk on “Quiescent Plasma Experiment: An Add-on”

SUBRATA PRADHAN & SST-1TEAM gave an Invited talk on “Steady-state Superconducting Tokamak (SST-1)”

J. GHOSH and ADITYA TEAM gave an Invited talk on “Recent Experiments and Upgradation Plans for Aditya Tokamak

A. K. SAHU gave an Invited talk on “The Giant Superconducting Magnet System of 10,000 Tons Mass for Fusion Experiment at Cadarache, France”



J. ALPHONSA, P. SAIKIA, G. JHALA, R. RANE, S. B. GUPTA, B. K. SAIKIA and S. MUKHERJEE gave an Invited talk on “Development of Duplex Plasma Based Process for Improvement of Surface Properties of Steel”

RAJESH KUMAR, SAURABH KUMAR, NASIR SHAH, ANITHA V. P. RENU BAHL and ANURAG SHYAM gave an Invited talk on “HPM Development at IPR for Plasma Physics Applications”

RAJESH KUMAR SINGH gave an Invited talk on “Laser-Blow-Off of Thin Film: Spectral and Dynamical Behaviour in Different Experimental Conditions”

SUDIP SENGUPTA gave an Invited talk on “Modeling of Relativistic Longitudinal Plasma Waves”

MEGHRAJ SENGUPTA, RAJARAMAN GANESH gave an Invited talk on “Numerical Experiments in Pure Electron Plasmas Confined in Toroidal and Cylindrical Traps”

M. BANDYOPADHYAY and NNBD TEAM gave an Invited talk on “Diagnostics in Indian Test Facility (INTF) for ITER – Diagnostic Neutral Beam”

SANTOSH P.PANDYA, SHWETANG N.PANDYA, SHAM-SUDDIN SHAIKH, ZUBIN SHAIKH, KANCHAN MAHAVAR, KUMAR AJAY, J. GOVINDRAJAN, ADITYA and SST-1 TEAM gave an Invited talk on “Infrared Imaging Diagnostics for Plasma Confinement Devices”

*Invited talks given at 7th International Conference on the Physics of Dusty Plasmas (ICPDP 7), New Delhi, India, March 3-7, 2014*

AMITA DAS gave keynote talk on “Collective Dynamics in Strongly Coupled Dusty Plasmas”

HARISH CHARAN, RAJARAMAN GANESH and ASHWIN JOY gave an Invited talk on “Molecular dynamics of Yukava liquids in gravitation: Equilibrium, Instability and Transport”

S. K. MISHRA, K. AVINASH and PREDHIMAN K. KAW gave an Invited talk on “Cooling of diverter region in fusion devices via thermionic/ Schottky emission of electrons”

SANAT KUMAR TIWARI, AMITA DAS, VIKRAM S. DHARODI, PREDHIMAN KAW and ABHIJIT SEN gave

an Invited talk on “Kelvin-Helmholtz Instability in Strongly coupled dusty plasma medium”

P. BANDYOPADHYAY gave an Invited talk on “Experimental investigation of solitonic waves in complex plasmas”  
DEVENDRA SHARMA gave an Invited talk on “Self-organized dust dynamics with boundary phenomena”

ASWIN J. and ABHIJIT SEN gave an Invited talk on “Shear Localization in Glass-Forming Yukawa Systems”

SHIKHA MISHRA, S. K. MISHRA and M. S. SODHA gave an Invited talk on “Charging of dust particles in interplanetary space plasma”

### **E.5 Talks Delivered by Distinguished Visitors at IPR**

Shri. S. C. Chetal, Ex Director, Indira Gandhi Centre for Atomic Research, Department of Atomic Energy, Kalpakam, Tamilnadu gave a talk on “Fundamentals of Pressure Vessel and Piping”

Mr. Juan Luis Fernandez Hernando, Responsible Engineer for ITER Central Interlock Systems in Control System Division of ITER organization gave a talk on “Issues related to ITER Central Interlock System and machine protection”.

Prof. Osamu Motojima, Director General, ITER Organization, France, gave a lecture on “Progress of ITER Project”.

Mr. Jaydeep Belapure, ASDEX-Upgrade, Max-Planck Institute for Plasma Physics, Garching, Germany, gave a lecture on “Non-thermal electron populations in studied with X-ray detectors”

Mr. Debaprasad Sahu, IIT Kanpur, gave a lecture on “Physics of negative ion containing plasmas: volume generation, measurement and wave induced phenomena”

Mr. Syamal Kumar Dana, Emeritus Scientist, CSIR-Indian Institute of Chemical Biology, Kolkata, gave a lecture on “Why Nonlinear Dynamics?”

Shri. S. C. Chetal, Ex Director, Indira Gandhi Centre for Atomic Research, Department of Atomic Energy, Kalpakam, Tamilnadu gave a talk on “Metallurgical Aspects of 300 Series Stainless Steel”

Dr. Jessica R. Chocha, Saurashtra University gave a talk on

“Synthesis and Characterization of Some Mixed Oxide Functional Ceramics”

Dr. Ashwin Joy, Post-Doctoral Fellow, Department of Chemical Physics, Weizmann Institute of Science, Rehovot 761 00, Israel, gave a talk on “Shear Band Direction in Amorphous Solids - An Atomistic Theory”

Dr. Tuong Hoang, CEA-IRFM, Cadarache, France, gave a talk on “IRFM Science and Technology activities & results”

Dr. Alain Becoulet, CEA-IRFM, Cadarache, France, gave a talk on “Areas of Collaborations with IPR”

Dr. D. V. Senthilkumar, Transdisciplinary Concepts and Methods, Potsdam Institute for Climate Impact Research, Telegraphenberg A 31, Postfach 60 12 03, D-14412 Potsdam, Germany, gave a talk on “Delay effects on the collective behaviors of a network of nonlinear oscillators”

Dr. Mohammed Shahabuddin, Department of Physics and Astronomy, College of Science, Saudia Arabia, gave a talk on “MgB<sub>2</sub> superconducting wire: Present status and its future prospects”

Mr. E. Krishnakumar, Tata Institute of Fundamental Research, Mumbai, gave a talk on “Negative ion formation from molecular hydrogen by electron collision”

Mr. Raj Singh, Department of Physics, Banaras Hindu University, gave a talk on “Fragmentation dynamics of atmospheric molecules under the impact of keV electrons”

Dr. Vishwa Bandhu Pathak, Instituto Superior Técnico, Lisbon, Portugal, gave a talk on “Controlled self-injection of electrons in the laser wakefield acceleration”

Dr. A T T Mostako, Laser and Photonics Lab, Indian Institute of Technology Guwahati, gave a talk on “Studies on pulsed laser deposited Mo, W and Rh thin films for First Mirror application”

Dr. Arvind Kumar Saxena, Physical Research Laboratory, Ahmedabad, gave a talk on “Study of Cluster Ions by Mass Spectrometry and Optical Spectroscopy”

Prof. Bikas K. Chakrabarti, Saha Institute of Nuclear Physics, Bidhannagar, Kolkata, gave a talk on “Quantum Annealing and Computation”

Prof. Amitava Bhattacharjee, Department of Astrophysical Sciences and Princeton Plasma Physics Laboratory, Princ-

eton University, Princeton, gave a talk on “Fast Reconnection Mediated by the Plasmoid Instability in High-Lundquist-Number Plasmas: Dynamics and Statistics”

Dr. Deepti Sethia, Fusion Reactor Materials Development and Characterization (FRMDC) Division, gave a talk on “Proton conducting ceramic development for Fusion reactor applications”

Prof. Hari Om Vats, Course Director, Centre for Space Science and Technology Education in Asia and the Pacific, Physical Research Laboratory, Thaltej, Ahmedabad, gave a talk on “Comets revolving around sun”

Dr. R. B. Grover, Director, Homi Bhabha National Institute, Mumbai, gave a talk on “Nuclear Energy: Policies, Practices and Future Growth”

Dr. B. B. Nayak, CSIR-Institute of Minerals and Materials Technology, Bhubaneswar, Odissa, gave a talk on “Developing Nanotubes based high current carrying Conductors”

Dr. Ashish Ravalia, Department of Physics, Saurashtra University, Rajkot, gave a talk on “Swift Heavy Ion Induced Modifications in the Properties of Multifunctional Oxides”

Dr. Lalit Gupta, Visiting Scientist, Korea Atomic Energy Research Institute KAERI, Daejeon, South Korea, gave a talk on “Development of Free Electron Laser Device to generate the THz radiations and its applications”

Dr. R. G. Sharma, Inter-University Accelerator Centre, New Delhi, gave a talk on “Metallic Superconductors Still Reign Supreme”

Prof. Helmut Schober, Associate Director, Science Division Institut Laue- Langevin, Grenoble, France, gave a talk on “Innovation in Instrumentation and recent scientific highlights at ILL”

Prof. James Bradley, Electrical and Electronics Engineering Department, University of Liverpool, gave a talk on “The detection and influence of negative ions in reactive magnetron sputtering”

Dr. Richard Pitts, ITER Organization, gave a talk on “Physics Basis and Design of the ITER full-W Divertor”

Prof. Frank Verheest, University of Ghent, Belgium, gave a talk on “Fundamentals of Electrostatic Solitary Structures in Multispecies Plasmas”



Mr. Huw Leggate, National Centre for plasma science and Technology, Ireland, gave a talk on “An Indo-Irish collaboration in fusion - The Institute for Plasma Research and Dublin City University”

Dr Sastry Pamidi, Florida State University, gave a talk on “High Temperature Superconducting Power Systems Research at The Florida State University Center for Advanced Power Systems”

Mr. Hemen Dave, JRF, FCIPT, gave a talk on “Study of Plasma Surface Modification of Polymers, Biomaterial and their Characterization”

Dr. Brent Covele, University of Texas at Austin, gave a talk on “Modeling the SST-1 Divertor and X-Divertor Performance with SOLPS 5.1”

Dr. Arpan Banerjee, National Brain Research Centre, Haranya, gave a talk on “Neuro Cognitive Network Dynamics Underlying Action and Perception”

## E.6 Colloquia Presented at IPR

Prof. Ram K Varma, Ex-Director, Physical Research Laboratory, Ahmedabad, on “A novel macro-scale matter wave dynamics embedded in the Lorentz trajectory – a consequence of quantum entanglement” (Colloquium #223)

Prof. Siraj Hasan, Former Director, Indian Institute of Astrophysics, Bangalore, on “A New Window to the Sun: The National Large Solar Telescope” (Colloquium #224)

Prof. S.V.S. Murty, Coordinator, PLANEX, Physical Research Laboratory, Ahmedabad, on “Mars Orbiter Mission” (Colloquium #225)

Prof. V. Krishan, Indian Institute of Astrophysics, Bangalore, on “Magnetorotational Instability in Accretion Disks” (Colloquium #226)

Prof. B. N. Goswami, Director, Indian Institute of Tropical Meteorology, Pune, on “Scaling the Potential Predictability Barrier of the Indian Summer Monsoon Rainfall: An Indian Initiative” (Colloquium #227)

Prof. B. Buti, Director, Centre for Science and Society, Founder President, Buti Foundation, New Delhi, on “Stellar Evolution from White Dwarfs to Black Holes” (Colloquium #228)

Prof. P.B.Jhala, Advisor, Plasma Textile Applications, FCIPT, Institute for Plasma Research, on “Plasma Textile Activities & Achievements at FCIPT” (Colloquium #229)

Dr. Edward Thomas, Physics Department, Auburn University, on “Controlling complexity: studies of waves and instabilities in magnetized plasmas and magnetized dusty plasmas” (Colloquium #230)

Dr. Swadesh M Mahajan, Professor, Dept of Physics, University of Texas at Austin, on “Nonlinear Effective Quantum Mechanics – A Theory of Fluidons” (Colloquium #231)

## E 7. Scientific Meetings Hosted by IPR

### National Symposium on High Power RF & Microwave (HPRFM-2013), 4-6 September 2013, IPR Gandhinagar

This symposium was held at Institute for Plasma Research (IPR) from 4 – 6 Sept. 2013. It was supported mainly by BRNS-DAE Mumbai along with CSIR, DST and DEITY. Nearly 140 participants attended this three day event. There were 24 invited talks which were delivered by RF & microwave experts from all across the national laboratories like BARC, RRCAT, CEERI, MTRDC, VECC, SINP, SAC and IUAC etc and from different universities, IITs and NITs like Nirma University, IIT Delhi etc. There were 19 oral presentations and 82 poster presentations. They presented the recent developments in RF & microwave fields. There was a great deal of interaction among presenters and participants. The symposium worked as a good platform for interaction among RF & microwave community nationwide and in essence served the purpose.

### Topical Conference on Atomic Processes in Plasmas (ISAMP-TC-2013), 18-20 November 2013, organized by Indian Society of Atomic and Molecular Physics and Institute for Plasma Research.

This conference was focused on the following topics - Atomic Data for Plasma Diagnosis; Atomic Physics of Edge Plasmas; Atomic Physics in Astrophysical, Fusion and Laser produced plasmas; Charge Exchange and Recombination Processes; Stark Broadening in Plasmas; Numerical Methods for Atomic Calculations. Around 100 physicists and students, working in the field of Atomic & Molecular Physics participated in this conference. In this conference, 24 invited talk, 6 oral presentation and 63 contributory papers were presented by distinguish scientist and student.

**A School on Advanced Characterization methods for Nanophase Materials (ACNM-2013, 22-24 November, 2013) followed by School on Nanoscale Excitations in Emergent Materials (NEEM 2013) 25-26 November 2013**

This school was held on 22, 23 November 2013 at Hotel Gateway Hotel Ummed, Ahmedabad. The Keynote address was given by Dr. Augusto Marcelli (INFN – LNF and Co-Chairperson of the Scientific Programme committee of both ANCM & NEEM) and Dr. S. Mukherjee. There were 14 lectures delivered by 12 speakers from India (RRCAT, SINP, IUAC), Italy, France, Japan and USA. The topics covered were XRD, XAFS, XANES, Raman spectroscopy, Photoemission spectroscopy, Optical spectroscopy, Muon spin resonance etc.

The Workshop was followed by **School on Nanoscale Excitations in Emergent Materials (NEEM) from 25-26 November 2013.**

The Programme Chief Guest, Ambassador of Italy to India, His Excellency Daniele Mancini, inaugurated the function while Prof. Abhijit Sen delivered the Welcome address. There were a total of 15 speakers from both India and Italy. Prof. Lidia Szpyrkowicz, the Scientific Counsellor in the Italian embassy gave a talk on “Indo – Italian educational and research collaboration possibilities”, while Shri Rajiv Kumar, affiliated to the Bilateral Cooperation Division of DST, gave an overall view of India’s re-search collaboration with Europe and other countries. Best poster awards were also presented to Ms. Jethva Sadaf Alibhai from Saurashtra University and Mr. Shammi Verma from IUAC, New Delhi.

## **E.8 MoU SIGNED**

### **E.8.1 National MOU Signed**

#### **1) MoU signed with ADIT, Vallabh Vidyanagar:**

In order to explore the possible applications of plasma technology in food sciences a MoU has been signed between A. D. Patel Institute of Technology (ADIT), Vallabh Vidyanagar and Institute for Plasma Research (IPR). For this a DBD based compact system has been developed and initial feasibility trial experiments have been conducted at ADIT, Vallabh vidyanagar campus. Further ADIT team is characterizing the experimental results. Based upon the obtained result necessary modification in existing setup will be carried out.

#### **2) MoU signed with IIT, Indore:**

A MoU has been signed between IIT, Indore and Institute for Plasma Research (IPR) for setting up a plasma nitriding system. This system will be used for surface hardening of components received from industries in and around Indore.

### **3) IPR and Commissionerate of Technical Education (CTE), Govt. of Gujarat**

An MoU between IPR and CTE was signed on 4th January, 2014 at IPR, Bhat, Gandhinagar. Prof. Dhiraj Bora, Director – IPR and Dr. Jayanti Ravi, Commissioner – Technical Education endorsed the agreement. The purpose of the MoU was to enhance the research strand capabilities of 7 Government Engineering Colleges under TEQIP-II programme of Govt. of India. The seven engineering colleges include GEC Gandhinagar, GEC Patan, BVM Vallabh Vidyanagar, GEC Bhavnagar, SSEC Bhavnagar, GEC Rajkot and LEC Morbi. It is envisaged that the MoU would facilitate the interaction between IPR scientists / engineers and the faculties of the 7 engineering colleges. IPR scientists would also get an opportunity to nurture and guide deserving faculties in their Ph.D on work relevant to IPR’s fusion programme. Apart from the upgradation of faculties, IPR will support them in upgrading their libraries by enhancing e-publications, promoting patent awareness and improve networking amongst researchers.

### **E.8.2 International MOU Signed**

#### **I. Indo-EU collaborations**

1) Agreement for cooperation between the Govt. of India and the European Atomic Energy Community in the field of Fusion Energy Research

*Tokamaks, alternative concepts for present and next generation, magnetic fusion technology, plasma theory & applied plasma physics*

2) IPR-CEA agreement [Atomic Energy and Alternative Energies Commission (CEA)]

*Plasma operation & control, heating & current drive and related technology, fusion grade material and divertor technology, advanced diagnostics, fueling and pellet, injection, fusion theory and simulation, data mining*

3) IPR-JET collaborations [Joint European Torus (JET)]

*JET RMP coils, Operation of large tokamak experiments control related diagnostics and technologies*



4) IPR-ENEA collaboration [National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA)]

*Tokamak design & prototyping, neutronics, tritium technology*

5) IPR-KIT collaboration [Karlsruhe Institute of Technology (KIT)]

*Helium cooling systems and access to KIT facilities, fusion fuel cycle related activities, neutronics related activities for fusion blanket development, liquid ceramic pebble bed characterization*

## **II. Indo-US collaborations**

1) IPR-GA collaborations [General Atomics (GA)]

*Plasma operation and scenario development, integrated modeling, participation in DIII-D experiments, operation and development of diagnostics*

2) IPR-UCLA collaborations [University of California, Los Angeles (UCLA)]

*Development of liquid metal diagnostics, thermofluid MHD experiments & simulations, solid breeder blanket design*

## **III. Other Collaborations**

1) **IPR-NFRI** collaboration [National Fusion Research Institute (NFRI)]

*Joint research activities on fusion science and technology, such as plasma operation and control, heating & current drive, diagnostics*

2) **IPR-ISEM** collaboration [Institute for Superconducting and Electronic Materials (ISEM)]

*Development of process and technology for superconducting magnet, fusion grade high current CICC, current lead and magnets for tokamaks*

3) Research grant awarded by Department of Science and Technology (DST) for 03 years under India-Taiwan Programme of Cooperation in Science & Technology (between IPR and APPL@National Chiao Tung University, Taiwan)

**Title:** Parallel Computing of Fluid Modeling with Electron

Monte-Carlo Collision for a Multi-scale RF Plasma Simulation

*Indian applicants:* Prof. P. K. Kaw, Prof. Amita Das, Dr. Sarveshwar Sharma, Dr. Shantanu Karkari

*Taiwanese applicants:* Prof. J. S. Wu, Dr. Y.S. Chen

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Audited Statements of Accounts  
as on 31st March 2014

**INSTITUTE FOR PLASMA RESEARCH**

Registration No.GUJ/88/GANDHINAGAR

**RAMANLAL G. SHAH & CO.**

CHARTERED ACCOUNTANTS

TELEPHONE : 26578819, 26575530  
FAX : 079 - 26575401  
E-MAIL : rgshahca@vsnl.net

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ELLIS BRIDGE

AHMEDABAD 380 006

**INDEPENDENT AUDITOR'S REPORT**

**Report on the Financial Statements**

1. We have audited the attached Consolidated Balance Sheet of **INSTITUTE FOR PLASMA RESEARCH, BHAT, GANDHINAGAR - 382 428** as at 31<sup>st</sup> March, 2014, Consolidated Income & Expenditure Account and also the Consolidated Receipts and Payments Account for the year ended on that date annexed thereto.

**Management's Responsibility for the Financial Statements**

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

**Auditor's Responsibility**

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

**Opinion**

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



RAMANLAL G. SHAH & CO.

CONTINUATION SHEET

- (a) in the case of the Balance Sheet, of the state of affairs of the Institute as at 31<sup>st</sup> March, 2014;
- (b) in the case of the Income & Expenditure Account, of the excess of Income over Expenditure for the year ended on that date;
- (c) in the case of the Receipts and Payments Account, of the receipts and payments for the year ended on that date.

**Emphasis of matters**

- 5. Without qualifying our opinion, we draw attention to note no. 9 of Schedule 14 regarding the Institute being in the process of identifying assets created out of externally funded projects which are eventually not claimed by the funding agency, for the purpose of their recording and accounting.

Place: Ahmedabad

Dated: 31:7:2014

For Ramanlal G. Shah & Co.,  
Chartered Accountants  
Firm Registration No. 198517W



*Sandeep R. Sutaria*

(Sandeep R. Sutaria)  
Partner  
Membership No.10228

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

**CONSOLIDATED BALANCE SHEET AS AT 31ST MARCH, 2014**

<b><u>CORPUS/CAPITAL FUND AND LIABILITIES</u></b>	<b>SCH.</b>	<b>2013-14</b>	<b>2012-13</b>
CORPUS/CAPITAL FUND	1	3,90,33,69,726.00	3,20,69,28,105.00
RESERVES AND SURPLUS	2	8,87,58,97,093.00	6,20,26,38,515.00
EARMARKED/ ENDOWMENT FUNDS	3	13,55,72,696.00	21,92,45,133.00
CURRENT LIABILITIES AND PROVISIONS	4	1,14,53,75,028.00	86,58,89,416.00
<b>TOTAL</b>		<b>14,06,02,14,543.00</b>	<b>10,49,47,01,169.00</b>
<b><u>ASSETS</u></b>			
FIXED ASSETS	5	6,84,32,54,283.00	3,90,92,54,944.00
CURRENT ASSETS, LOANS, ADVANCES ETC.	6	7,21,69,60,260.00	6,58,54,46,225.00
<b>TOTAL</b>		<b>14,06,02,14,543.00</b>	<b>10,49,47,01,169.00</b>
SIGNIFICANT ACCOUNTING POLICIES	13		
CONTINGENT LIABILITIES AND NOTES ON ACCOUNTS	14		

As per our report of even date attached.

**For Ramanlal G Shah & Co**  
Chartered Accountants  
Firm Registration No.108517W

-Sd-  
**(Prof.Dhiraj Bora)**  
Director

-Sd-  
**(Prof.R.Jha)**  
Dean

-Sd-  
**(H.K.Sharma)**  
Accounts Officer-II

-Sd-  
**(Sandeep R Sutaria)**  
Partner  
Membership No.10228

Place : Gandhinagar  
Dated : July 31,2014

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

**CONSOLIDATED INCOME AND EXPENDITURE ACCOUNT FOR THE PERIOD ENDED  
ON 31ST MARCH, 2014**

<u>A. INCOME</u>		SCH.	2013-14	2012-13
Grants- Department of Atomic Energy, Govt. of India		7	6,42,16,00,000.00	2,24,21,50,000.00
Interest Earned		8	12,54,92,474.00	23,49,11,642.00
Other Income		9	1,07,02,554.00	15,51,478.00
<b>TOTAL (A)</b>			<b>6,55,77,95,028.00</b>	<b>2,47,86,13,120.00</b>
<u>B. EXPENDITURE</u>				
Establishment Expenses		10	80,48,84,580.00	72,84,94,250.00
Other Administrative Expenses		11	72,52,40,810.00	56,11,12,676.00
National Fusion Programme (Human Resource Development Expenses)			2,20,30,108.00	2,30,49,813.00
Cash Contribution to ITER IO			1,36,84,70,920.00	-
Depreciation		12	27,00,89,497.00	21,70,38,050.00
Less : Transfer from Corpus/Capital Fund			(27,00,89,497.00)	(21,70,38,050.00)
Loss on Disposal of Capital Assets/ Write off			18,98,395.00	5,62,848.00
<b>TOTAL (B)</b>			<b>2,92,25,24,813.00</b>	<b>1,31,32,19,587.00</b>
<b>Balance being excess of Income over Expenditure/ (Excess of Expenditure over Income)</b>			<b>3,63,52,70,215.00</b>	<b>1,16,53,93,533.00</b>
Transfer to Corpus Fund for addition to Movable & Immovable Properties			96,91,10,825.00	54,42,81,859.00
Transfer From Corpus Fund for w/off to Movable & Immovable Properties			(25,79,707.00)	(6,56,858.00)
Transfer to Iter India Fund (Interest earned)			9,58,65,809.00	16,41,99,814.00
Transfer to/from unspent Grant A/c			2,57,28,73,288.00	45,75,68,718.00

SIGNIFICANT ACCOUNTING POLICIES 13

CONTINGENT LIABILITIES AND NOTES ON ACCOUNTS 14

As per our report of even date attached.

**For Ramanlal G Shah & Co**  
Chartered Accountants  
Firm Registration No.108517W

-Sd-  
**(Prof.Dhiraj Bora)**  
Director

-Sd-  
**(Prof.R.Jha)**  
Dean

-Sd-  
**(H.K.Sharma)**  
Accounts Officer-II

-Sd-  
**(Sandeep R Sutaria)**  
Partner  
Membership No.10228

Place : Gandhinagar  
Dated : July 31,2014

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

**CONSOLIDATED RECEIPTS AND PAYMENTS FOR THE YEAR ENDED ON 31ST MARCH, 2014**

RECEIPTS	2013-14	2012-13	PAYMENTS	2013-14	2012-13
<b>I. Opening Balances</b>			<b>I. Expenses</b>		
a) Cash in hand	1,68,226.00	1,54,625.00	a) Establishment Expenses	53,70,62,540.00	52,79,15,451.00
b) Bank Balances			b) Administrative Expenses	71,90,98,146.00	55,08,21,720.00
i) In Current accounts	5,21,64,492.00	7,01,86,055.00	c) National Fusion Programme (Human Resource Development Expenses)	2,20,30,108.00	2,30,49,813.00
ii) In deposit accounts	2,11,60,29,878.00	3,86,08,54,442.00	d) Cash Contribution to ITER-IO	1368470920	
iii) Savings accounts	48,69,273.00	6,72,61,293.00			
<b>II. Grant Received</b>			<b>II. Exp. on Fixed Assets, Cap. WIP &amp; Others</b>		
a) From Govt. of India- DAE	6,42,16,00,000.00	2,24,21,50,000.00	a) Purchase of Fixed Assets & other exp.	75,63,45,952.00	28,72,32,839.00
			b) Expenditure on Capital WIP	2,44,21,51,730.00	58,38,74,478.00
<b>III. Interest Received</b>			<b>III. Refund of Surplus money/Loans</b>		
a) On Bank Deposits	13,05,56,766.00	25,00,28,181.00	a) Deposits with Government Auth. & Suppliers/Security Deposits	1,53,42,892.00	-
b) Loans, Advances etc.	19,60,349.00	21,85,255.00	b) Payments against Earmarked Funds	18,19,41,770.00	16,83,47,560.00
<b>IV. Other Income</b>	82,88,017.00	12,42,418.00	c) Refund of Security Deposit	-	2,07,122.00
Royalty & Transfer Fee Income	24,14,537.00	3,09,060.00	<b>IV. Other Payments (Specify)</b>		
<b>V. Any Other receipts</b>			a) Advances to Contractors & Suppliers (Including Adv. for Capital Works)	1,76,15,46,371.00	2,40,43,78,929.00
Amount received for Earmarked/ Endowment Funds	9,81,70,597.00	19,88,73,637.00	b) Stock (Change in closing Bal.)	(6,92,878.00)	8,94,965.00
Security Deposits	98,21,088.00	29,71,768.00	c) Payment of LT Advances to Empl.	33,75,142.00	16,69,342.00
Others	-	26,53,67,965.00	d) Others	22,29,068.00	24,31,06,810.00
Receipt of LT Advances to Empl.	44,40,159.00	30,86,199.00	<b>V. Closing Balances</b>		
Sale of Capital Assets	-	60,000.00	a) Cash in hand	1,70,297.00	1,68,226.00
			b) Bank Balances		
			i) In Current accounts	3,90,30,163.00	5,21,64,492.00
			ii) In deposit accounts	99,38,61,139.00	2,11,60,29,878.00
			iii) Savings accounts	62,87,564.00	48,69,273.00
			iv) Magrin Money With Bank	22,32,458.00	-
<b>TOTAL</b>	<b>8,85,04,83,382.00</b>	<b>6,96,47,30,898.00</b>	<b>TOTAL</b>	<b>8,85,04,83,382.00</b>	<b>6,96,47,30,898.00</b>

As per our report of even date attached.

**For Ramanlal G Shah & Co**  
Chartered Accountants  
Firm Registration No.108517W

-Sd-  
**(Prof. Dhiraj Bora)**  
Director

-Sd-  
**(Dr.R.Jha)**  
Dean

-Sd-  
**(H.K.Sharma)**  
Accounts Officer-II

-Sd-  
**(Sandeep R Sutaria)**  
Partner  
Membership No. 10228

Place : Gandhinagar  
Dated : July 31,2014

**INSTITUTE FOR PLASMA RESEARCH****BHAT, GANDHINAGAR – 382 428**

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

Registration No. GUIJ/88/GANDHINAGAR

SCHEDULE FORMING PART OF BALANCE SHEET AS AT 31ST MARCH, 2014	
PARTICULARS	2012-13
<b>SCHEDULE 1- CORPUS/CAPITAL FUND :</b>	
Balance as at the beginning of the year	2,87,74,13,669.00
Add: Transfer from Unspent Grant & Addition during the year	29,27,485.00
Less: Amount trfd to Unspent Grant	-
Add : Contribution towards Corpus/Capital Fund	54,42,81,859.00
(Deduct) : Depreciation charged on Capital Assets for FY 2013-14	21,70,38,050.00
transferred to Income & Expenditure A/c	
Addition/Deduction during the year	(6,56,858.00)
( transfer to/ from I & E Account)	
<b>BALANCE AS AT 31ST MARCH, 2014</b>	<b>3,20,69,28,105.00</b>
<b>BALANCE AS AT 31ST MARCH, 2014</b>	<b>3,20,69,28,105.00</b>
<b>SCHEDULE 2 - RESERVE AND SURPLUS :</b>	
<b>1. Unspent Grant :</b>	
As per last Account	5,57,70,07,744.00
Add: Transfer from Corpus Fund	38,62,239.00
Less: Interest earned on Project Funds trfd to Iter India Fund	-
Less: Amount trfd to Earmarked Fund	24,54,50,503.00
Addition/Deduction during the year	45,75,68,718.00
( transfer to/ from I & E A/c)	
2,57,28,73,288.00	8,37,03,80,967.00
<b>2. Interest earned on Unspent Grant (ITER INDIA FUND):</b>	
As per last Account (transfer from Schedule 3 opening balance)	-
Addition/Deduction during the year	40,96,50,317.00
( transfer from I & E A/c)	
9,58,65,809.00	50,55,16,126.00
<b>BALANCE AS AT 31ST MARCH, 2014</b>	<b>8,87,58,97,093.00</b>
<b>BALANCE AS AT 31ST MARCH, 2014</b>	<b>8,87,58,97,093.00</b>

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

## SCHEDULE FORMING PART OF BALANCE SHEET AS AT 31ST MARCH, 2014

<b>SCHEDULE 3 - EARMARKED/ ENDOWMENT FUNDS :</b>	a) Opening Balance of the fund	b) Additions to the Funds	TOTAL (a+b)	c) Utilisation/ Expenditure towards objectives of funds	NET BALANCE AS AT 31ST MARCH, 2014 (a+b-c)	NET BALANCE AS AT 31ST MARCH, 2013
<b>FUND-WISE BREAK UP</b>						
<b>Endowment Funds</b>						
1 Dr.Parvez Guzdar Fund	5,43,193.00	6,60,201.00	12,03,394.00	6,19,420.00	5,83,974.00	5,43,193.00
SBI FDR	-	-	-	5,00,000.00	(5,00,000.00)	-
SBI A/C.33503533579	-	-	-	69,673.00	(69,673.00)	-
Income Accrued	-	-	-	14,301.00	(14,301.00)	-
<b>Sub Total (a)</b>	<b>5,43,193.00</b>	<b>6,60,201.00</b>	<b>12,03,394.00</b>	<b>12,03,394.00</b>	<b>-</b>	<b>5,43,193.00</b>
<b>Earmarked Fund</b>						
1 Plasma Processing Fund	2,30,38,771.00	25,75,968.00	2,56,14,739.00	-	2,56,14,739.00	2,30,38,771.00
2 ITER/INDIA FUND- SURPLUS ON T&S	11,77,83,268.00	1,19,51,159.00	12,97,34,427.00	-	12,97,34,427.00	11,77,83,268.00
<b>Sub Total (b)</b>	<b>14,08,22,039.00</b>	<b>1,45,27,127.00</b>	<b>15,53,49,166.00</b>	<b>-</b>	<b>15,53,49,166.00</b>	<b>14,08,22,039.00</b>
<b>Externally Funded Projects</b>						
1 F.C.I.P.T. - SPIX	27,94,255.00	-	27,94,255.00	23,940.00	27,70,315.00	27,94,255.00
2 F.C.I.P.T. - UV SYSTEC	8,00,905.00	-	8,00,905.00	-	8,00,905.00	8,00,905.00
3 F.C.I.P.T. - RHVPS	3,39,42,377.00	100.00	3,39,42,477.00	1,86,36,703.00	1,53,05,774.00	3,39,42,377.00
4 F.C.I.P.T. - PDS	5,24,731.00	-	5,24,731.00	-	5,24,731.00	5,24,731.00
5 F.C.I.P.T. - RCTL3	10,698.00	1,53,416.00	1,64,114.00	34,099.00	1,30,015.00	10,698.00
6 F.C.I.P.T. - PROCTOR & GAMBLE	1,15,07,624.00	-	1,15,07,624.00	1,06,35,247.00	8,72,377.00	1,15,07,624.00
7 F.C.I.P.T. - LP-RU	3,69,094.00	-	3,69,094.00	3,69,094.00	-	3,69,094.00
8 TIFAC - EMF	3,20,782.00	-	3,20,782.00	-	3,20,782.00	3,20,782.00
9 DST - TSG- GYRO- RF	6,26,87,191.00	-	6,26,87,191.00	6,16,46,608.00	10,40,583.00	6,26,87,191.00
10 DST - DADD	96,097.00	-	96,097.00	-	96,097.00	96,097.00
11 DST - J.C. Bose Fellowship	(17,035.00)	15,00,000.00	14,82,965.00	9,79,194.00	5,03,771.00	(17,035.00)
12 PRL - Phases CH 2	4,98,994.00	-	4,98,994.00	4,98,994.00	-	4,98,994.00
13 FCIP-STATS	1,41,077.00	-	1,41,077.00	1,41,077.00	-	1,41,077.00
14 FCIP-ERNS	55,906.00	6,561.00	62,467.00	-	62,467.00	55,906.00
15 FCIP-MIT	20,079.00	-	20,079.00	-	20,079.00	20,079.00
16 FCIP-DST-IPT	4,49,923.00	-	4,49,923.00	3,08,088.00	1,41,835.00	4,49,923.00
17 FCIP-BCPL	6,05,744.00	3,17,662.00	9,23,406.00	-	9,23,406.00	6,05,744.00
18 FCIP-JU-BPPS	3,65,639.00	-	3,65,639.00	3,65,639.00	-	3,65,639.00
19 FCIP-DU-CDPS	27,82,061.00	-	27,82,061.00	3,53,382.00	24,28,679.00	27,82,061.00
20 FCIP-DU-PPNS	30,73,551.00	-	30,73,551.00	86,634.00	29,86,917.00	30,73,551.00
21 FCIP-DU-WGPS	12,08,060.00	-	12,08,060.00	1,99,806.00	10,08,254.00	12,08,060.00
22 FCIP-DU-SEPS	28,69,566.00	-	28,69,566.00	12,02,148.00	16,67,418.00	28,69,566.00
23 FCIP-RCTL-IV	91,225.00	-	91,225.00	10,309.00	80,916.00	91,225.00
24 FCIP-DST-IPT-ER	3,64,836.00	-	3,64,836.00	3,64,836.00	-	3,64,836.00
25 FCIP-DST-KU	(5,89,024.00)	7,45,886.00	1,56,862.00	12,259.00	1,44,603.00	(5,89,024.00)
26 FCIP-SMIT	1,10,811.00	1,76,400.00	2,87,211.00	2,87,211.00	-	1,10,811.00
27 FCIP-ADA	30,37,063.00	14,490.00	30,51,553.00	7,12,727.00	23,38,826.00	30,37,063.00
28 FCIP-DST-PCS	22,29,088.00	-	22,29,088.00	6,97,762.00	15,31,326.00	22,29,088.00
29 DST/PAC	7,58,702.00	29,090.00	7,87,792.00	5,51,633.00	2,36,159.00	7,58,702.00
30 DST-SERC	2,36,105.00	6,60,326.00	8,96,431.00	6,60,326.00	2,36,105.00	2,36,105.00
31 DST-FAST TRACK YOUNG SCIENT	13,26,800.00	2,00,000.00	15,26,800.00	3,47,467.00	11,79,333.00	13,26,800.00
32 LPSC-THUSTER	34,88,483.00	1,07,80,000.00	1,42,68,483.00	56,53,198.00	86,15,285.00	34,88,483.00
33 DST-CZTS SOLAR	2,00,77,021.00	-	2,00,77,021.00	23,281,744.00	1,77,48,847.00	2,00,77,021.00
34 PLASMA PYROXIS JORSHOP	53,400.00	64,962.00	1,18,362.00	-	1,18,362.00	53,400.00
35 FCIP-DST-INT ITALY	8,19,027.00	801.00	8,19,828.00	5,57,547.00	2,62,281.00	8,19,027.00
36 FCIP-MOEF	4,21,305.00	-	4,21,305.00	12,678.00	4,08,627.00	4,21,305.00
37 FCIP-DST-SIKKIM	34,16,000.00	1,80,553.00	35,96,553.00	18,53,106.00	17,43,447.00	34,16,000.00
38 FCIP-CSMCRI-MoU	-	66,22,801.00	66,22,801.00	31,40,496.00	34,82,305.00	-
39 FCIP-KGP College	-	5,52,550.00	5,52,550.00	5,49,924.00	2,626.00	-
40 VSSC-MoU-IPR	-	5,00,000.00	5,00,000.00	2,12,996.00	2,87,004.00	-
41 FCIP-IT-Indore	-	9,52,889.00	9,52,889.00	-	9,52,889.00	-
42 SPACE-DEBRIS Research	-	21,99,232.00	21,99,232.00	4,10,032.00	17,89,200.00	-
43 DST-WOSA	-	5,80,000.00	5,80,000.00	2,23,225.00	3,56,775.00	-
44 DST-INSPIRE	-	19,00,000.00	19,00,000.00	4,06,132.00	14,93,868.00	-
45 IPR-CITE-GoG	-	1,99,99,000.00	1,99,99,000.00	2,01,596.00	1,97,97,404.00	-
46 IO-SA-DPPDASS	75,85,587.00	61,87,471.00	1,37,73,058.00	53,73,684.00	83,99,374.00	75,85,587.00
47 IO-SA-DPE	54,00,083.00	7,00,510.00	61,00,593.00	61,00,593.00	-	54,00,083.00
48 IO-SA-ICH & CD	-	67,33,106.00	67,33,106.00	67,33,106.00	-	-
49 IO-SA-NDD & PA	-	27,08,072.00	27,08,072.00	27,08,072.00	-	-
50 BRNS	22,474.00	-	22,474.00	22,474.00	-	22,474.00
51 CSIR Project	(1,21,210.00)	1,21,210.00	-	-	-	(1,21,210.00)
<b>Sub Total</b>	<b>17,38,35,095.00</b>	<b>6,45,87,088.00</b>	<b>23,84,22,183.00</b>	<b>13,62,75,388.00</b>	<b>10,21,46,795.00</b>	<b>17,38,35,095.00</b>
1 F.C.I.P.T. - Metal Treat	(6,84,916.00)	-	(6,84,916.00)	-	(6,84,916.00)	(6,84,916.00)
2 F.C.I.P.T. - IGCAR - PECVD	(7,63,498.00)	-	(7,63,498.00)	-	(7,63,498.00)	(7,63,498.00)
3 F.C.I.P.T. - IGCAR - EPA	(21,73,590.00)	-	(21,73,590.00)	-	(21,73,590.00)	(21,73,590.00)
4 F.C.I.P.T. - DST - UP	16,51,418.00	-	16,51,418.00	24,72,010.00	(8,20,592.00)	16,51,418.00
5 F.C.I.P.T. - MNTI	(63,591.00)	9,976.00	(53,615.00)	-	(53,615.00)	(63,591.00)
6 F.C.I.P.T. - DST2	(50,84,085.00)	-	(50,84,085.00)	71,627.00	(51,55,712.00)	(50,84,085.00)
7 F.C.I.P.T. - FULTREX	(1,28,860.00)	1,89,854.00	60,994.00	60,994.00	-	(1,28,860.00)
8 BRNS - EPIA - AD	27,22,790.00	-	27,22,790.00	32,92,319.00	(5,69,529.00)	27,22,790.00
9 RRF -TKB	(10,07,892.00)	12,60,000.00	2,52,108.00	7,56,035.00	(5,03,927.00)	(10,07,892.00)
10 PEF - I	(3,68,426.00)	3,65,786.00	(2,640.00)	-	(2,640.00)	(3,68,426.00)
11 BARC - EED - Project	(5,03,47,773.00)	1,23,36,137.00	(3,80,11,636.00)	76,19,450.00	(4,56,31,086.00)	(5,03,47,773.00)
12 DGFPS-P&D	14,01,652.00	-	14,01,652.00	14,91,267.00	(89,615.00)	14,01,652.00
13 FCIP-SPX-II	1,32,596.00	-	1,32,596.00	25,82,596.00	49,40,922.00	1,32,596.00
14 FCIP-BRIST	(3,31,694.00)	5,08,921.00	1,77,227.00	2,32,802.00	(55,575.00)	(3,31,694.00)
15 FCIP-DST TRITON	(4,45,657.00)	-	(4,45,657.00)	31,047.00	(4,76,704.00)	(4,45,657.00)
16 FCIP-DST-HIFED	16,21,985.00	53,025.00	16,75,010.00	27,56,464.00	(10,81,454.00)	16,21,985.00
17 FCIP-CORR	(1,95,824.00)	-	(1,95,824.00)	-	(1,95,824.00)	(1,95,824.00)
18 FCIP-EXCEL	(33,574.00)	4,80,000.00	4,46,426.00	4,97,966.00	(51,540.00)	(33,574.00)
19 FCIP-DST-KULLU	20,93,941.00	-	20,93,941.00	25,85,471.00	(4,91,530.00)	20,93,941.00

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

SCHEDULE FORMING PART OF BALANCE SHEET AS AT 31ST MARCH, 2014

	a) Opening Balance of the fund	b) Additions to the Funds	TOTAL (a+b)	c) Utilisation/ Expenditure towards objectives of funds	NET BALANCE AS AT	NET BALANCE AS AT
					31ST MARCH, 2014 (a+b-c)	31ST MARCH, 2013
<b>SCHEDULE 3 - EARMARKED/ ENDOWMENT FUNDS:</b>						
20 FCIPT-DST-KH	2,12,842.00	8,63,692.00	10,76,534.00	12,24,307.00	(1,47,773.00)	2,12,842.00
21 FCIPT-DST-MANTRA	13,68,606.00	-	13,68,606.00	15,33,315.00	(1,64,709.00)	13,68,606.00
22 FCIPT-DST-SPC	33,19,104.00	-	33,19,104.00	71,72,749.00	(38,53,645.00)	33,19,104.00
23 DST-YOS Professor PKK	-	-	-	12,40,645.00	(12,40,645.00)	-
24 TA-CAD-ENG/IN (*)	(3,81,91,150.00)	-	(3,81,91,150.00)	-	(3,81,91,150.00)	(3,81,91,150.00)
25 TA-FEEDER (*)	(5,81,937.00)	-	(5,81,937.00)	-	(5,81,937.00)	(5,81,937.00)
26 IO-TASK-SPMC (*)	(1,00,77,661.00)	-	(1,00,77,661.00)	65,06,502.00	(1,65,84,163.00)	(1,00,77,661.00)
<b>Sub Total</b>	<b>(9,59,55,194.00)</b>	<b>1,85,17,391.00</b>	<b>(7,74,37,803.00)</b>	<b>4,44,85,462.00</b>	<b>(12,19,23,265.00)</b>	<b>(9,59,55,194.00)</b>
<b>BALANCE FOR YEAR 2013-14</b>	<b>(*) 21,92,45,133.00</b>	<b>9,82,91,807.00</b>	<b>31,75,36,940.00</b>	<b>18,19,64,244.00</b>	<b>13,55,72,696.00</b>	<b>21,92,45,133.00</b>
(*) Rs. 40,96,50,317 transferred to Schedule 2						<b>62,88,95,450.00</b>

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**SCHEDULE FORMING PART OF BALANCE SHEET AS AT 31ST MARCH, 2014**

PARTICULARS	2013-14	2012-13
<b>SCHEDULE 4 - CURRENT LIABILITIES AND PROVISIONS:</b>		
<b>A. CURRENT LIABILITIES :</b>		
1. Sundry Creditors		
a) For Goods	1,75,99,582.00	94,28,721.00
2. Other Current Liabilities		
a) Security Deposits	3,03,21,762.00	3,37,05,336.00
b) Other Liabilities	41,48,833.00	37,34,288.00
<b>TOTAL (A)</b>	<b>5,20,70,177.00</b>	<b>4,68,68,345.00</b>
<b>B. PROVISIONS</b>		
1. Gratuity	12,39,23,884.00	11,29,61,031.00
2. Superannuating/Pension	81,26,25,840.00	57,71,04,846.00
3. Accumulated Leave Encashment	13,14,92,065.00	11,01,53,872.00
4. Outstanding Expenses	2,49,59,690.00	1,85,26,746.00
5. Audit Fees Payable	3,03,372.00	2,74,576.00
<b>TOTAL (B)</b>	<b>1,09,33,04,851.00</b>	<b>81,90,21,071.00</b>
<b>TOTAL (A+B)</b>	<b>1,14,53,75,028.00</b>	<b>86,58,89,416.00</b>

**INSTITUTE FOR PLASMA RESEARCH**  
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SCHEDULE FORMING PART OF BALANCE SHEET AS AT 31ST MARCH, 2014											
SCHEDULE 5 - FIXED ASSETS											
DESCRIPTION	Rate	GROSS BLOCK				DEPRECIATION			NET BLOCK		
		Cost as at beginning of the year	Addition during the year	Ded. during the year	Cost as at the year end	Up-to beginning of the year	for the year	on deductions	Total up to the year end	As at the Current year - end	As at the Previous year - end
<b>A. FIXED ASSETS:</b>											
<b>1 LAND:</b>											
a) Freehold		4,36,440.00	-	-	4,36,440.00	-	-	-	4,36,440.00	4,36,440.00	4,36,440.00
1. Bhat Land		56,75,519.00	-	-	56,75,519.00	-	-	-	56,75,519.00	56,75,519.00	56,75,519.00
2. GIDC Land		83,52,433.00	-	-	83,52,433.00	-	-	-	83,52,433.00	83,52,433.00	83,52,433.00
<b>3. CPP Land</b>											
<b>2 BUILDINGS:</b>											
On Freehold Land											
a) Bhat Main Building	1.63%	22,99,62,536.00	8,04,042.00	-	23,07,66,578.00	-	37,36,294.00	-	5,96,02,107.00	17,11,64,472.00	17,40,96,725.00
b) CPP Admin Building	1.63%	37,13,522.00	-	-	37,13,522.00	-	81,135.00	-	20,30,538.00	16,82,984.00	17,64,119.00
c) Guest House/Hostel Building	1.63%	5,90,75,896.00	5,18,279.00	-	5,95,94,175.00	-	9,91,660.00	-	37,68,799.00	5,58,25,376.00	5,62,98,957.00
d) Staff quarters	1.63%	28,55,711.00	-	-	28,55,711.00	-	46,548.00	-	14,19,174.00	14,35,597.00	14,82,545.00
e) ICPIP Building	1.63%	8,02,33,282.00	23,46,974.00	-	8,25,80,256.00	-	13,26,930.00	-	32,51,946.00	7,93,28,310.00	7,83,08,266.00
f) Additional Building	1.63%	71,695.00	43,720.00	-	1,15,415.00	-	-	-	1,15,415.00	1,15,415.00	71,695.00
g) Laboratory & Auxil. Building	1.63%	19,58,50,971.00	67,50,778.00	-	20,26,01,749.00	-	64,012.00	-	1,60,030.00	18,90,39,038.00	18,56,49,196.00
h) Approach Road	1.63%	39,27,112.00	-	-	39,27,112.00	-	84,674.00	-	84,674.00	37,67,082.00	38,31,094.00
i) HVAC Building	1.63%	1,03,89,409.00	-	-	1,03,89,409.00	-	-	-	-	1,03,04,735.00	-
<b>3 PLANT MACHINERY &amp; EQUIPMENTS</b>											
a) CPP IPR Machinery & Equip	4.75%	1,01,23,804.00	-	-	1,01,23,804.00	-	5,29,819.00	-	60,87,633.00	40,36,171.00	45,65,990.00
b) Scientific Equipments	4.75%	3,70,65,602.23.00	79,72,19,136.00	82,07,779.00	4,49,55,71,380.00	-	20,27,79,553.00	59,42,414.00	1,55,20,71,204.00	2,94,35,003,735.00	2,35,13,25,686.00
b1) Scientific Equipments at IGCAR	4.75%	-	4,13,12,188.00	-	4,13,12,188.00	-	-	-	33,87,090.00	3,79,25,098.00	-
c) Workshop Equipments	4.75%	61,70,337.00	-	4,77,280.00	56,93,057.00	-	1,73,573.00	3,68,812.00	3,68,812.00	20,56,139.00	23,38,180.00
d) Workshop Tools	4.75%	1,90,926.00	-	10,777.00	1,80,149.00	-	1,086.00	10,335.00	1,04,763.00	15,386.00	16,914.00
e) Machinery & Equipment	4.75%	3,94,390.00	-	-	3,94,390.00	-	20,923.00	-	2,18,421.00	1,75,969.00	1,96,892.00
f) Mechanical Works Equipment	4.75%	4,37,833.00	-	-	4,37,833.00	-	6,732.00	-	4,18,610.00	19,223.00	25,955.00
g) Vehicle	4.75%	7,22,80,648.00	1,69,72,164.00	2,57,934.00	8,89,94,878.00	-	40,77,591.00	2,45,253.00	3,12,68,008.00	5,77,26,870.00	4,48,44,978.00
4 FURNITURE, FIXTURES	6.33%	3,97,61,009.00	1,51,03,768.00	2,88,000.00	5,45,76,777.00	-	1,48,17,091.00	2,13,180.00	1,67,32,339.00	3,78,44,439.00	2,49,43,918.00
5 OFFICE/GEN. EQUIPMENTS	4.75%	41,21,001,146.00	5,59,10,378.00	10,42,129.00	46,69,68,395.00	-	3,84,44,651.00	9,24,198.00	30,41,89,326.00	16,27,79,069.00	14,54,31,272.00
6 COMPUTER / PERIPHERALS	16.21%	1,42,95,030.00	11,27,609.00	-	1,54,22,639.00	-	3,97,099.00	-	80,36,508.00	73,86,131.00	66,35,621.00
7 ELECTRIC INSTALLATION	4.75%	18,68,86,122.00	2,06,12,380.00	-	20,74,98,502.00	-	84,51,083.00	-	8,76,89,638.00	11,98,08,864.00	10,76,47,567.00
8 LIBRARY BOOKS/ JOURNALS	4.75%	-	-	-	-	-	-	-	-	-	-
<b>TOTAL FOR CURRENT YEAR</b>		<b>5,03,93,55,585.00</b>	<b>96,91,10,825.00</b>	<b>1,02,83,899.00</b>	<b>5,99,81,82,511.00</b>		<b>27,00,89,497.00</b>	<b>77,04,192.00</b>	<b>2,09,77,807,957.00</b>	<b>3,90,04,01,555.00</b>	<b>3,20,39,59,934.00</b>
<b>PREVIOUS YEAR</b>		<b>4,50,91,7,897.00</b>	<b>54,42,81,860.00</b>	<b>69,95,943.00</b>	<b>5,04,12,03,814.00</b>		<b>21,70,38,080.00</b>	<b>63,39,085.00</b>	<b>1,83,72,43,878.00</b>		
<b>B. CAPITAL WORK-IN-PROGRESS</b>		70,52,95,010.00	2,44,21,51,730.00	20,45,94,012.00	2,94,28,52,726.00		-	-	-	2,94,28,52,728.00	70,52,95,010.00
<b>TOTAL</b>		5,74,46,50,595.00	3,41,12,62,555.00	21,48,77,911.00	8,94,10,35,299.00		27,00,89,497.00	77,04,192.00	2,10,77,807,957.00	6,84,32,54,283.00	

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**SCHEDULE FORMING PART OF BALANCE SHEET AS AT 31ST MARCH, 2014**

PARTICULARS	2013-14	2012-13
<b>SCHEDULE 6 - CURRENT ASSETS, LOANS, ADVANCES ETC.:</b>		
<b>A. CURRENT ASSETS :</b>		
1. <u>Inventories:</u>		
a) Stores and spares	69,49,346.00	76,42,224.00
2. <u>Cash balances in hand</u> (including cheques/drafts and imprest)		-
IPR	1,06,748.00	1,31,745.00
ITER-India	58,787.00	25,789.00
CPP	4,762.00	10,692.00
3. <u>Bank Balances:</u>		
a) <u>With Scheduled Banks:</u>		
- On Current Accounts		
State Bank of India, IPR Branch, Gandhinagar (IPR)	1,42,23,038.00	3,82,77,788.00
State Bank of India, Naroda Branch, Ahmedabad (IPR)	34,65,315.00	76,85,560.00
State Bank of India, IPR Branch, Gandhinagar (ITER-India)	2,06,32,495.00	27,47,497.00
State Bank of India, Naroda Branch, Ahmedabad (ITER-India)	7,09,315.00	34,53,647.00
State Bank of India, Sonapur, Guwahati (CPP-IPR)	62,20,228.00	11,18,874.00
State Bank of India, CPP, Guwahati	-	1,18,908.00
State Bank of India, PRF, Guwahati	-	1,28,775.00
Money Margin With Bank - Guwahati	22,32,458.00	-
- On Deposit Accounts		
State Bank of India - (IPR)	26,26,69,359.00	34,22,65,127.00
State Bank of India - (ITER-India)	73,11,91,780.00	1,76,36,78,856.00
State Bank of India - ( CPP-IPR)		1,00,85,895.00
- On Savings Accounts		-
State Bank of India, S.B.No. 30767137485	67,336.00	35,02,716.00
<b>TOTAL (A)</b>	<b>1,04,85,30,967.00</b>	<b>2,18,08,74,093.00</b>
<b>B. LOANS, ADVANCES AND OTHER ASSETS :</b>		
1. <u>Loans:</u>		
a) Staff		
House Building Advance (Including accrued interest)	2,54,96,194.00	2,58,79,932.00
Computer Advance (Including accrued interest)	1,06,68,028.00	1,09,08,199.00
Vehicle Advance (Including accrued interest)	43,39,584.00	53,71,778.00
2. <u>Advances and amounts recoverable in cash or in kind or for value to be received:</u>		
a) Advances to Non Govt. Contractors & Suppliers (Including adv. for Capital Works)	5,12,03,90,882.00	3,48,45,01,227.00
b) Advances to Govt. Institutions/Organisations (Refer Note 6 of Schedule-14)	94,77,43,937.00	82,32,10,905.00
c) Deposit with Government Authorities	1,12,86,942.00	72,78,291.00
d) Deposit with Others	67,21,896.00	65,71,896.00
e) TDS Receivable	13,19,858.00	9,99,614.00
f) Advance for Travelling Expenses	1,85,10,163.00	1,31,37,025.00
g) General Advance	5,65,168.00	5,84,624.00
h) Festival Advance	34,500.00	42,000.00
i) LTC Advance	16,65,836.00	9,23,761.00
j) Medical Recovery	2,92,899.00	1,84,573.00

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

**SCHEDULE FORMING PART OF BALANCE SHEET AS AT 31ST MARCH, 2014**

PARTICULARS	2013-14	2012-13
<b>SCHEDULE 6 - CURRENT ASSETS, LOANS, ADVANCES ETC:</b>		
k) Prepaid Expenses	15,00,000.00	2,13,391.00
3. <u>Income Accrued:</u>		
a) On Bank Fixed Deposits	1,78,93,406.00	2,47,64,916.00
<b><u>TOTAL (B)</u></b>	<b>6,16,84,29,293.00</b>	<b>4,40,45,72,132.00</b>
<b><u>TOTAL (A+B)</u></b>	<b>7,21,69,60,260.00</b>	<b>6,58,54,46,225.00</b>

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**SCHEDULE FORMING PART OF INCOME & EXPENDITURE FOR THE YEAR ENDED 31ST MARCH, 2014**

PARTICULARS	2013-14	2012-13
<b>SCHEDULE 7 - GRANTS/SUBSIDIES :</b>		
(Irrevocable Grants & Subsidies Received)		
1) Central Government (Dept. of Atomic Energy, Govt. of India)	6,42,16,00,000.00	2,24,21,50,000.00
<b>TOTAL</b>	<b>6,42,16,00,000.00</b>	<b>2,24,21,50,000.00</b>
<b>SCHEDULE 8 - INTEREST EARNED :</b>		
1) On Term Deposits & Savings Deposits:		
a) With Scheduled Banks- State bank of India	12,36,85,256.00	23,27,26,387.00
2) On Loans:		
a) Employees/Staff		
- On Vehicle Advance	2,22,524.00	4,59,337.00
- On Computer Advance	5,72,946.00	6,27,307.00
- On House Building Advance	10,11,748.00	10,98,611.00
<b>TOTAL</b>	<b>12,54,92,474.00</b>	<b>23,49,11,642.00</b>
<b>SCHEDULE 9 - OTHER INCOME :</b>		
1) Miscellaneous Income	76,26,961.00	9,47,950.00
2) Rent	6,61,056.00	2,94,468.00
3) Royalty & Transfer Fee Income	24,14,537.00	3,09,060.00
<b>TOTAL</b>	<b>1,07,02,554.00</b>	<b>15,51,478.00</b>

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**SCHEDULE FORMING PART OF INCOME & EXPENDITURE FOR THE YEAR ENDED 31ST MARCH, 2014**

PARTICULARS	2013-14	2012-13
<b><u>SCHEDULE 10 - ESTABLISHMENT EXPENSES :</u></b>		
a) Salaries and Wages	24,77,86,000.00	25,42,84,631.00
b) Allowances and Bonus	31,02,98,669.00	26,39,33,520.00
c) Contribution to Provident Fund (Including NPS Contribution)	1,77,20,597.00	1,74,26,381.00
d) Staff Welfare Expenses	5,29,087.00	2,72,915.00
e) Expenses on Employees' Retirement and Terminal Benefits	26,69,39,716.00	20,14,69,115.00
f) NPS charges	70,597.00	1,31,516.00
Less: PF Contribution Receipt for PF Trust on Option change CPF to GPF	(3,84,60,086.00)	(90,23,828.00)
<b><u>TOTAL</u></b>	<b>80,48,84,580.00</b>	<b>72,84,94,250.00</b>
<b><u>SCHEDULE 11 - OTHER ADMINISTRATIVE EXPENSES ETC. :</u></b>		
a) Purchases- Consumable Stores & Spares	27,15,68,457.00	13,94,06,477.00
b) Electricity and Power	8,72,15,080.00	7,10,99,598.00
c) Repairs and Maintenance	10,83,67,965.00	6,11,24,553.00
d) Rent, Rates and taxes	2,78,72,207.00	1,95,19,076.00
e) Transport Hire Charges	2,55,78,586.00	2,43,71,482.00
f) Postage & Telegraph	9,75,866.00	8,00,042.00
g) Telephone and Trunk	68,00,148.00	46,46,896.00
h) Printing and Stationary	27,36,473.00	20,43,907.00
i) Travelling and conveyance Expenses	1,96,47,152.00	1,96,71,025.00
j) Travelling Expenses-International	5,77,18,373.00	5,90,61,134.00
k) T.A.to Candidates	4,46,079.00	48,707.00
l) Expenses on Seminar/Workshops	39,81,892.00	67,50,317.00
m) Membership	65,372.00	40,808.00
n) Auditors Remuneration - Internal	2,16,100.00	1,55,892.00
o) Auditors Remuneration - Statutory	1,40,450.00	1,40,450.00
p) Professional/Legal Charges	6,18,912.00	7,97,669.00
q) Security Expenses	1,96,28,367.00	1,49,41,393.00
r) Freight and Cartage Expenses	14,14,808.00	21,18,115.00
s) Visiting Scientist Expenses	32,64,243.00	27,27,953.00
t) Advertisement and Publicity	40,42,681.00	54,70,429.00
u) Admin / Office Exp	9,98,943.00	15,14,130.00
v) Book Grant to Research Student	4,27,950.00	5,60,456.00
w) Short term Research Programme	8,15,363.00	6,97,930.00
x) Honorarium	19,24,589.00	4,94,676.00
y) Medical Expenses	1,32,48,619.00	1,27,21,673.00
z) Leverages	32,186.00	67,419.00
aa) Bank Charges	24,27,411.00	22,45,732.00
ab) Remuneration & Wages	3,06,32,072.00	2,54,42,712.00
ac) Canteen Subsidy	30,86,896.00	23,80,664.00
ad) Collobrative Research Expenses	81,56,062.00	6,53,56,247.00
ae) Technical & Professional Consultancy	2,02,23,975.00	1,46,95,114.00
af) Excess Interest Charged on LTA written off	9,67,533.00	-
<b><u>TOTAL</u></b>	<b>72,52,40,810.00</b>	<b>56,11,12,676.00</b>

**INSTITUTE FOR PLASMA RESEARCH**  
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**SCHEDULE FORMING PART OF INCOME & EXPENDITURE FOR THE YEAR ENDED 31ST MARCH, 2014**

PARTICULARS	2013-14	2012-13
<b>SCHEDULE 12 - DEPRECIATION :</b>		
a) Building	39,02,103.00	38,29,975.00
b) Staff Quarters Building	46,548.00	46,548.00
c) Scientific Equipments	20,61,66,143.00	16,11,15,097.00
d) Workshop Equipments	1,73,573.00	1,98,995.00
e) Workshop Tools	1,086.00	1,086.00
f) Furniture & Fixture	40,77,591.00	34,33,440.00
g) Office/General Equipments	21,28,428.00	14,83,098.00
h) Computers/Peripherals	3,84,44,651.00	3,39,18,464.00
i) Electric Installations	3,97,099.00	3,64,485.00
j) Library Books/Journals	84,51,083.00	78,34,264.00
k) Guest House Building	9,91,860.00	9,83,412.00
l) Lab Building	33,60,916.00	18,99,171.00
m) Machinery & Equipment	5,29,819.00	5,29,818.00
n) Mechanical Works	20,923.00	20,923.00
o) Vehicle	6,732.00	7,460.00
p) FCIPT Building	13,26,930.00	13,07,802.00
q) Approach Road	64,012.00	64,012.00
<b>TOTAL</b>	<b>27,00,89,497.00</b>	<b>21,70,38,050.00</b>

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**SIGNIFICANT ACCOUNTING POLICIES**

**SCHEDULE- 13:**

**1. BASIS FOR PREPARATION OF ACCOUNTS**

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

**2. INVENTORY VALUATION**

Stores & spares are valued at the weighted average cost.

**3. INVESTMENT**

Investments are valued at cost.

**4. FIXED ASSETS**

Fixed Assets are recorded at cost which includes incidental expenses incurred up to the date of Commissioning of assets.

**5. DEPRECIATION**

- i) Depreciation is provided on Straight Line Basis at the rates specified in Schedule XIV of Companies Act, 1956.
- ii) Depreciation on additions to Assets other than Buildings and Library Books/Journals is provided on prorata basis from the month of addition. Depreciation on additions to Buildings and Library Books/Journals is provided at 50% of the applicable rate.

**6. GOVERNMENT GRANTS**

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

**7. FOREIGN CURRENCY TRANSACTION**

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

**8. CONTRIBUTIONS TO PROJECTS**

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

**9. EXTERNALLY FUNDED PROJECTS**

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

**10. RESEARCH & DEVELOPMENT**

Revenue expenditure on research and development is charged against the grant of the year in which it incurred, Capital expenditure on research and development is shown as an addition to fixed assets. Expenditure on research and development resulting into tangible asset is accounted as fixed assets. Whereas that resulting into an intangible asset of enduring nature is not capitalized. The Impact of which is not quantifiable.

**11. RETIREMENT BENEFITS**

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

As per our report of even date attached.

Institute for Plasma Research  
 Bhat, Gandhinagar

**For Ramanlal G Shah & Co.,**  
 Chartered Accountants  
 Firm Registration No.108517W

-Sd-  
**(Prof. Dhiraj Bora)**  
 Director

-Sd-  
**(Prof. R. Jha)**  
 Dean

-Sd-  
**(H.K.Sharma)**  
 Accounts Officer-II

-Sd-  
**(Sandeep R Sutaria)**  
 Partner  
 Membership No. 10228

Place : Gandhinagar  
 Dated : July 31, 2014

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

**NOTES TO THE ACCOUNTS****SCHEDULE- 14:**

- 1 a** Hitherto, as per rules of ITER India Empowered Board, separate set of accounts & records were to be maintained and separate Audited Statement of Accounts were to be presented for the ITER-India Project w.e.f. April 1, 2008. However, in accordance with Department Atomic Energy directive vide their letter No. 18/1/2010-R&D-II/9309 Dated October 5, 2010, Audited Statements of Accounts for ITER-India project are to be presented on branch accounting concept. Accordingly, the necessary effects to accounts for the above directive of Department have been made as on March 31, 2014.
- b** The Central Government vide its letter No. 19/01/2006 - R&D - II / VOL.II /352 dated May 29, 2009 has approved administrative and Financial merger of Centre of Plasma Physics, Guwahati with Institute for Plasma Research, Gandhinagar on as is where is basis with immediate effect. Accordingly liabilities and current assets of CPP as on May 28, 2009 are taken over at their book value and fixed assets are taken over at their net written down values as on May 28, 2009. Necessary changes are made in the Accounting Policies of CPP-IPR for period May 29, 2009 onwards. As a part of the above merger, the Government of Assam has funded certain financial obligations (including certain Contingent liabilities) of CPP-IPR outstanding as on March 31, 2008 aggregating to Rs.72,92,204.00. Outstanding Balance as on 31.03.2014 is Rs.12,90,512.00 which is shown under other liabilities.

**2 CONTINGENT LIABILITIES:**

- (i) Contingent Liabilities in respect of claims not acknowledged as debts Rs.--NIL-- (Previous year Rs. NIL).  
(ii) Guarantees and Letter of Credits given by Bank Rs.14403.51 Lakhs ( Previous Year Rs.23915.89 Lakhs).

**3 CAPITAL COMMITMENTS**

Estimated value of Contracts remaining to be executed on Capital Account and not provided for Rs.1,35,078.89 Lakhs ( Previous Year Rs.1,22,946.71 Lakhs).

**4 DEPRECIATION**

Depreciation for the year 2013-2014 Rs.27,00,89,497/- (Previous Year Rs.21,70,38,050/-) has been debited to the Income & Expenditure Account and the like amount has been transferred from the Corpus Fund to the Income & Expenditure Account.

**5 FOREIGN CURRENCY TRANSACTION**

i) Value of Imports Calculated on F.O.B. Basis :	2013-14	2012-13
- Capital Goods	2,30,11,16,531.00	50,20,84,107.00
- Consumables & Spares	7,81,01,588.00	5,79,55,882.00
ii) Expenditure in foreign currency :		
- Travel	4,37,18,589.00	4,13,19,625.00
- Cash Contribution to ITER-Organisation	1,36,84,70,920.00	-
- Technical Consultancy	37,44,209.00	5,83,388.00
iii) Earnings :		
- Value of Exports on F.O.B. basis	Nil	Nil

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

- a** An amount of Rs. 29.53 Crore (Previous year Rs.16.55 Crore) has been paid to Indira Gandhi Centre for Advance Atomic Research for collaborative research on Development of ITER Test Blanket Modules.
- b** An amount of Rs.53.00 Crore (Previous year Rs. 53.00 Crore) has been paid to Bhabha Atomic Research Centre for collaborative research on Development of ITER Test Blanket Modules.
- 7** One reactor for aprox.Rs.8.00 Laes (Rupees 8 Lakhs) included in present value of Assets is lost. No provision is made for loss, as lower has decided the case in favor of the Institute and matter is pending before Hon. High Court of Gujarat.
- 8** Institute is considering adopting policy for capitalisation and accounting of new patents in line with Accounting principle of AS-26.
- 9** Institute is in the process of identification for recording and accounting of Assets acquired out of utilization of externally funded projects, which are not eventually claimed by funding agencies.
- 10** No Insurance Policy is taken for the Movable & Immovable assets as per the usual practice.
- 11** Previous year's figures have been regrouped wherever necessary to correspond with current year's figures.
- 12** Balances of Suppliers/Contractors are subject to confirmations & adjustment, if any.

As per our report of even date attached.

**For Ramanlal G Shah & Co.,**  
Chartered Accountants  
Firm Registration No.108517W

-Sd-  
(Prof. Dhiraj Bora)  
Director  
Place : Gandhinagar  
Dated : July 31, 2014

-Sd-  
(Prof.R.Jha)  
Dean

-Sd-  
(H.K.Sharma)  
Accounts Officer-II

-Sd-  
(Sandeep R Sutaria)  
Partner  
Membership No. 10228

Audited Statements of Accounts  
as on 31st March 2014

**INSTITUTE FOR PLASMA RESEARCH**

Employees Provident Fund

## IPR EMPLOYEE'S PROVIDENT FUND.

BALANCE SHEET AS AT 31<sup>ST</sup> MARCH, 2014

2012-13	CORPUS/CAPITAL FUND AND LIABILITIES		2013-14
	<b>MEMBERS PF SUBSCRIPTION :</b>		
	(Net of Loans & including Interest on Subscription)		
15,94,32,103.75		Balance as on 1st April 2013	17,39,31,566.08
3,57,17,390.00		Addition During the year	3,72,58,065.00
<u>2,12,17,927.67</u>	<b>17,39,31,566.08</b>	Less : Debit During the year	<u>1,09,10,175.17</u>
			<b>20,02,79,455.91</b>
	<b>INSTITUTE'S PF CONTRIBUTION :</b>		
	(Including Interest )		
5,13,63,946.67		Balance as on 1st April 2013	4,39,83,148.67
74,41,304.00		Addition during the year	20,90,505.00
<u>1,48,22,102.00</u>	<b>4,39,83,148.67</b>	Less : Debits during the year	<u>3,13,27,634.52</u>
			<b>1,47,46,019.15</b>
	<b>LAPSE &amp; FORFEITURE A/c</b>		
16,42,343.49		Balance as on 1st April 2013	16,42,343.49
<u>-</u>	<b>16,42,343.49</b>	Addition during the year	<u>-</u>
			<b>16,42,343.49</b>
	<b>CURRENT LIABILITIES :</b>		
95,862.00		Sundry Credit Balances.	95,862.00
<u>60,44,511.00</u>	<b>61,40,373.00</b>	IPR A/c	<u>96,637.00</u>
			<b>1,92,499.00</b>
	<b>INCOME &amp; EXPENDITURE A/c</b>		
2,08,97,623.17		Openig Balance	2,50,74,918.17
<u>41,77,295.00</u>	<b>2,50,74,918.17</b>	Add/Less : Tranfer from Income & Expenditure A/c	<u>59,35,327.00</u>
			<b>3,10,10,245.17</b>
<b>25,07,72,349.41</b>	<b>TOTAL</b>		<b>24,78,70,562.72</b>
	<b>ASSETS</b>		
<b>21,67,97,147.00</b>	FIXED DEPOSIT with State Bank Of India / Public Financial Institute.	20,01,13,852.00	
<b>27,08,874.28</b>	S/B A/c with : State Bank Of India	<u>14,62,748.59</u>	20,15,76,600.59
<b>3,00,55,063.13</b>	Interest accrued but not due on Fixed Deposits with a Scheduled Bank / Public Financial Institute.	4,49,34,401.13	4,49,34,401.13
	<b>Income-Tax Deducted at source :</b>		
10,09,574.00	Balance as on 1st April 2013	12,11,265.00	
2,01,691.00	Addition during the year	1,48,296.00	
<u>-</u>	Less : Refund Received	<u>0.00</u>	13,59,561.00
<b>25,07,72,349.41</b>	<b>Total</b>		<b>24,78,70,562.72</b>

Note : Loan transactions are merged with members subscription accounts. **Rs. 36,45,350/-** were given during the year ended as on 31st March 2014, **Rs.67,41,622/-** are outstanding in loan accounts.

Examined and Found correct.  
**For Ramanlal G Shah & Co**  
Chartered Accountants  
Firm Registration No.108517W

-Sd-  
**(Dr.R.Jha)**  
Professor  
Chairman

-Sd-  
**(H.K.Sharma)**  
Accounts Officer-II. IPR  
Member

-Sd-  
**(Sandeep R Sutaria)**  
Partner  
Membership No.10228

Place : Bhat, Gandhinagar  
Dated : July 16, 2014

**IPR EMPLOYEE'S PROVIDENT FUND.**

**INCOME AND EXPENDITURE ACCOUNT FOR THE PERIOD  
ENDED ON 31<sup>ST</sup> MARCH, 2014**

2012-13	<u>INCOME</u>	2013-14
1,54,944.00	Interest On Savings Bank Account & Others	1,46,287.00
2,11,28,945.00	Interest On Fixed Deposit	2,19,76,628.00
-	Commission/Brokerage Received on Fixed Deposits	-
<b>2,12,83,889.00</b>	<b>TOTAL</b>	<b>2,21,22,915.00</b>
<b><u>EXPENDITURE</u></b>		
1,38,62,706.00	Interest on Members Subscription	1,50,97,224.00
32,43,455.00	Interest on Institute's Contribution	10,90,354.00
433.00	Bank Charges	10.00
41,77,295.00	Excess of Income over Expenditure/Expenditure over Income transferred to Income & Expenditure A/c	59,35,327.00
<b>2,12,83,889.00</b>	<b>TOTAL</b>	<b>2,21,22,915.00</b>

Examined and Found correct.  
**For Ramanlal G Shah & Co**  
Chartered Accountants  
Firm Registration No.108517W

-Sd-  
**(Dr.R.Jha)**  
Professor  
Chairman

-Sd-  
**(H.K.Sharma)**  
Accounts Officer-II. IPR  
Member

-Sd-  
**(Sandeep R Sutaria)**  
Partner  
Membership No.10228

Place : Bhat, Gandhinagar  
Dated : July 16, 2014