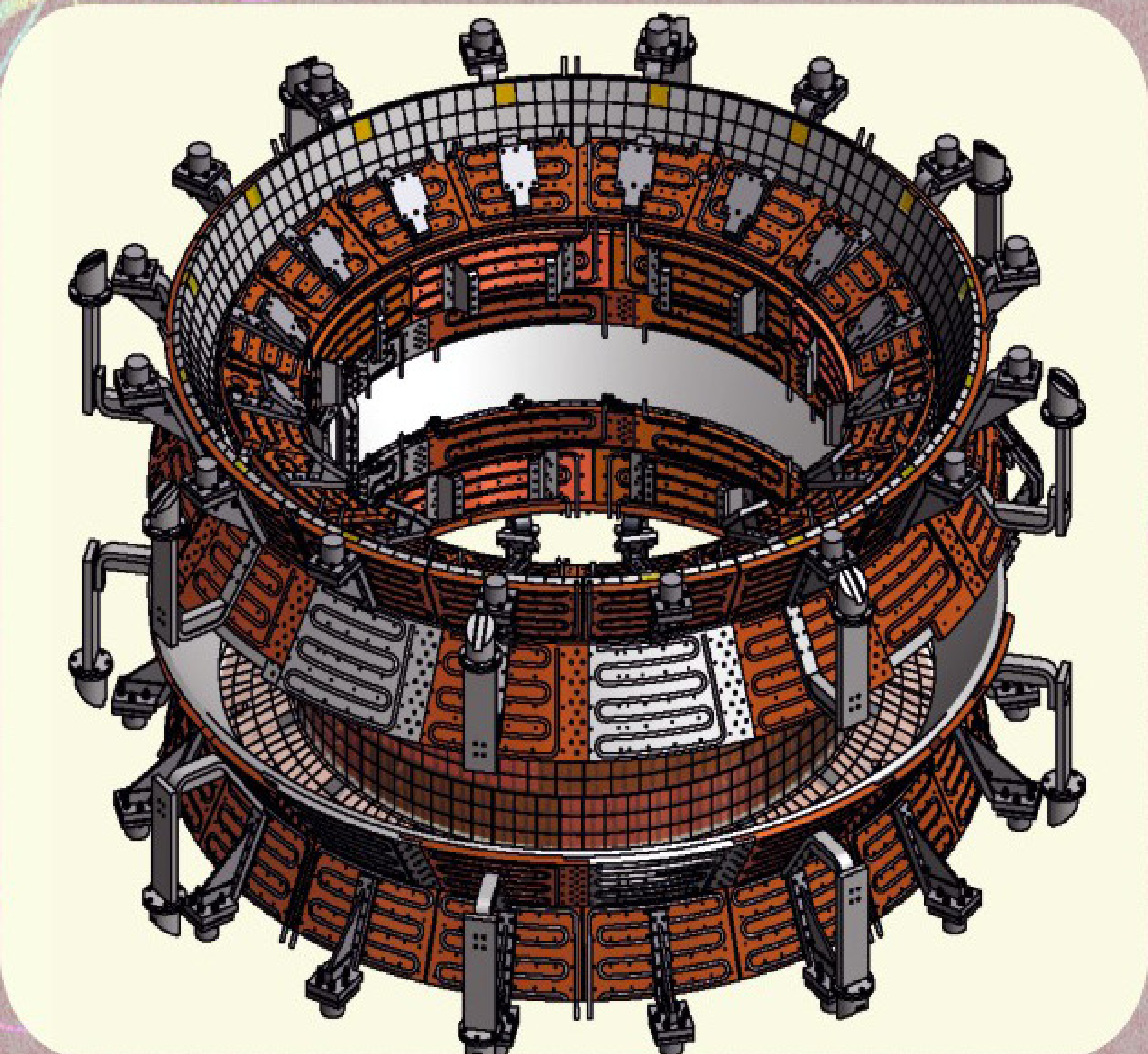
INSTITUTE FOR PLASMA RESEARCH

प्लाज़्मा अनुसंधान संस्थान



ANNUAL REPORT
2010-2011

वार्षिक प्रतिवेदन

2010-2011

On the west bank of the river Sabarmati, a few kilometers upstream of the Gandhi Ashram, a small number of low buildings are clustered on a little hillock rising among the ravines and grazing land. The pastoral setting and the quiet surroundings belie the fact that here, scientists and engineers at the Institute for Plasma Research are engaged in one of the most exciting and challenging tasks of this century – controlling thermonuclear fusion. The idea that energy can be obtained while nuclei of light elements fuse to produce heavier elements has been known for a long time; in fact it is the fusion of hydrogen that keeps the Sun shining. But the real challenge lies in trying to release this form of energy on earth by recreating the conditions of the Sun in the laboratory. The pursuit of this goal has been a worldwide effort over the last forty years. The work at the Institute is the prime expression of India's commitment to this futuristic energy source.

The Institute has a broad charter to carry our experimental and theoretical research in plasma sciences with emphasis on the physics of magnetically confined plasmas and certain aspects of the nonlinear phenomena. India's first high temperature plasma device 'Aditya Tokamak', built at IPR, produces plasmas at 5 million degrees temperature - comparable to that of the sun. The Institute also has a mandate to stimulate plasma research activities in the Universities and to develop plasma-based technologies for industries. It also contributes to the training of plasma physicists and technologists in the country. The Institute has recently embarked on an ambitious project of building a Steady State Superconducting (SST-1) Tokamak. This machine is at present undergoing pre-commissioning trials.

ITER (International Thermonuclear Experimental Reactor) is an important step on the path to develop nuclear fusion as a viable, long-term energy option. Realizing the importance of nuclear fusion to the future national energy security, India has joined ITER as an equal partner along with China, the EU, Japan, Korea, the Russian Federation and the United States of America. The Institute for Plasma Research is the domestic agency responsible to design, build and deliver advanced systems and sub-systems for ITER, which have been assigned to India under this agreement. This is being done through an organization called ITER-India.

While IPR prepares for meeting its commitment to ITER, it has been realized that it is imperative to start planning a long-term programme aimed at developing indigenous competence in all aspects of fusion science and technology with a view to be ready to take up designing and building a demo reactor after the successful operation of ITER. This is the charter of the National Fusion Programme, under which strong links are being forged between educational institutions and IPR.

साबरमती नदी के पश्चिमी तट पर, गाँधी आश्रम से कुछ किलोमीटर की दूरी पर उजान में, तंग घाटी तथा कम चारावाही भूमि पर एक छोटे टीले के ऊपर कुछ संख्या में छोटी-छोटी इमारतों का एक समूह है। ग्राम्य परिवेश एवम् शान्त वातावरण यहाँ पर वास्तव में प्लाज़्मा अनुसंधान संस्थान में वैज्ञानिक तथा अभियन्ता जो कि इस सदी के सर्वाधिक उत्तेजक एवम् चुनौतीपूर्ण कार्य नाभिकीय संलयन के नियंत्रण में लगे हुए है, को मिथ्या सिद्ध करते हैं। यह विचार कि हल्के तत्त्वों के नाभिकीय संलयन से भारी तत्त्वों के निर्माण द्वारा ऊर्जा प्राप्त होती है, लम्बे समय से ज्ञात है और वास्तव में हाइड्रोजन के संलयन द्वारा ही सूर्य ऊर्जा प्रदान करता है। परंतु मुख्य चुनौती, प्रयोगशाला में सूर्य जैसी परिस्थितियाँ उत्पन्न करके पृथ्वी पर इस प्रकार की ऊर्जा को प्राप्त करने के प्रयास में है। पिछले चालीस से अधिक वर्षों से इस उद्देश्य की प्राप्ति एक विश्वव्यापी लक्ष्य बन चुकी है। संस्थान में चल रहा कार्य मुख्यत: भविष्य की इस ऊर्जा स्रोत के लिए भारतीय प्रतिबद्धता को दर्शाता हैं।

संस्थान के पास चुम्बकीय परिसीमित प्लाज़्मा भौतिकी एवम् अरैखिक घटनाओं के कुछ मुख्य पहलुओं पर जोर देते हुए प्लाज़्मा विज्ञान में प्रायोगिक एवम् सैद्धान्तिक शोधकार्य करने के व्यापक लक्ष्य हैं। IPR में निर्मित भारत का प्रथम उच्च तापीय प्लाज़्मा संयंत्र 'आदित्य टोकामॉक' सूर्य की तरह 5 मिलियन डिग्री तापक्रम पर प्लाज़्मा का निर्माण करता है। संस्थान के पास विश्व विद्यालयों में प्लाज़्मा शोध को प्रोत्साहित करने के तथा उद्योगों में प्लाज़्मा पर आधारित तकनीकों को उत्पन्न करने के अधिदेश भी हैं। देश में प्लाज़्मा भौतिकविदों और प्रौद्योगिकीविदों के प्रशिक्षण में यह योगदान भी देता है। संस्थान आजकल एक महत्वकांक्षी योजना, एक स्थायी-अवस्था अतिचालक टोकामॉक (SST-1) के निर्माण में लगा हुआ है। वर्तमान में इस मशीन का कमीशन-पूर्व परीक्षण किया जा रहा है। ITER (अंतराष्ट्रीय तापनाभिकीय प्रायोगिक रिएक्टर) अर्थपूर्ण, दीर्घ अवधि ऊर्जा विकल्प के रूप नाभिकीय संलयन के विकास की दिशा में एक महत्वपूर्ण कदम है। भविष्य की राष्ट्रीय ऊर्जा सुरक्षा में नाभिकीय संलयन के महत्व को ध्यान में रखते हुए भारत चीन, यूरोपीय संघ, जापान, कोरिया, द रशियन फेडरेशन तथा संयुक्त राज्य अमेरिका के साथ बराबर के भागीदार की तरह ITER से जुड़ गया है। ये सभी कार्य ITER - India नामक एक संगठन के द्वारा किये जा रहे है।

इस समझौते कि अंतर्गत भारत को प्रदत्त ITER के लिए उन्नत प्रणालियों तथा उप-प्रणालियों का अभिकल्पन, निर्माण तथा प्रेषण के उत्तरदायित्व के लिए प्लाज़्मा अनुसंधान संस्थान एक आंतरिक संस्था है। IPR जब ITER के लिए अपनी प्रतिबद्धता निभाने की तैयारी कर रहा है तब यह अनुभव किया गया कि ITER के सफल प्रचालन के पश्चात एक डेमो रिएक्टर के अभिकल्पन तथा निर्माण की तैयारी के लिए संलयन विज्ञान तथा तकनीकी के सभी पहलुओं में स्वदेशी क्षमता के विकास को लक्ष्य बनाने के लिये एक दीर्घ अवधि का कार्यक्रम प्रारंभ करना आवश्यक हो गया है। शैक्षिक संस्थाओं एवं IPR के बीच मजबूत सबंध स्थापित करना राष्ट्रीय संलयन कार्यक्रम के चार्टर मे निहित है।

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Institute for Plasma Research

Bhat, Gandhinagar 382428

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EXECUTIVE SUMMARY

It gives me great pleasure to announce that the Institute for Plasma Research is entering into the Silver Jubilee of its existence. Established in the year 1986, this institution has grown manifold in its research activities in various area of plasma physics. Towards the realization of a power plant using controlled thermo-nuclear fusion by magnetic confinement, a number of initiatives have been taken in developing many state-of-the-art technologies. This has been possible because of active support of Department of Atomic Energy, India and the participation in International Thermo-nuclear Experimental Reactor (ITER) project . Furthermore, this institute has made considerable contributions to the fundamental plasma sciences and the application of plasma technologies to the industries.

During the past one year, in Aditya, ample efforts were continued to expand the operational window for experiments. Some of these experiments were specifically aimed at understanding the plasma breakdown in the Superconducting Steady-state Tokamak (SST-1). Pre-ionization experiments with different kinds of Radio-frequency schemes were done. While the Ion-Cyclotron Resonance (ICR)scheme has been demonstrated successfully, experiments with Electron-Cyclotron Resonance and Lower Hybrid (LH) frequency schemes are being continued. The necessary equipments and subsytems for wall conditioning with boronization are mostly ready and the experiments will be started in a short while. The diamagnetic energy of the Aditya plasma has been measured to be in the range 0.4 – 1.2 kilo-Joules during the current flat top regime and scales linearly with the net input power. Infrared Thermography of limiter tiles have shown higher surface temperatures for silicon carbide tiles compared to graphite tiles.

The assembly of the refurbished SST-1 has begun as scheduled from June 2010 and has been progressing well. With modified and validated ultra low direct current (DC) joint resistances all the sixteen toroidal field (TF) magnets have been successfully tested in cold with supercritical helium and with full design value of current. These tests have also validated the extended period of operation of power supplies with required currents. The maintenance of the helium cryogenic system was undertaken and has been completed this year. The vessel modules have been fully tested in a special hot nitrogen baking facility and hence this baking facility has also been validated for use in SST-1. Since the machine is getting assembled, the diagnostic systems are being readied and tested. ICR heating system is also being tested to operate in the first phase of SST-1 operation. The LH current drive system is being upgraded and the Neutral beam injector is being tested in the test-stand for improved ion currents.

Other technological developments under the eleventh five year plan are progressing well. Material development, process development, facilities creation along with man power development are being pursued in these programmes through collaboration with various national and international institutions. Good progress has been made towards development of CICC conductors and auxiliary facilities for superconducting magnet winding and testing, cryopanel component development, material and fabrication development required for high heat flux divertors etc. The research and development of the Lead-Lithium Cooled Ceramic breeder concept of Indian

Test Blanket Module (TBM) for ITER is progressing well. The set up for the Negative Ion Beam source studies has been completed with the procured source and experiments are being carried out. The neutronics laboratory has been augmented with various detectors and a fool-proof shielding for the whole laboratory is being designed and will be fabricated soon.

With a number of experiments that have been planned, basic plasma physics activities have entered a new exciting phase. Some of the new experiments under the eleventh five year plan have already started; plasma wakefield acceleration experiment, microwave-plasma interaction experiment, laser blow off experiments, flowing plasma experiment etc., and some others are about to start: multi-cusp plasma device, dusty plasma experiment etc. Controlling electron temperature gradient (ETG) in the Large Volume Plasma Device and hence studying its effect on turbulence has yielded very interesting results. On the theoretical and computational front, laser-plasma interaction, non-linear physics, generalized electron magneto-hydro dynamics (EMHD) simulations, basic plasma studies, global gyro-kinetic studies, molecular dynamics (MD) and particle-in-cell (PIC) simulations etc are the various heads under which studies are being carried out for exploring and understanding many basic and complex physics problems. The computational facilities available presently have to be expanded to cater to the growth of these activities. These experimental set ups and the computational infrastructure have attracted young researchers to the field of plasma physics. This participation by young scientists will be able to provide man power for the future growth in this and relates areas.

The facilitation center for industrial plasma technology (FCIPT), working as a suitable link between the institute and the industries, has undertaken development of more challenging and environment friendly technological projects. Disposal of petroleum waste using plasma pyrolysis, hospital waste management on a bigger scale, nano-silver studies for its anti-microbial properties, etc. are some of the projects on which work is being done. While keeping the main mandate of developing industrial plasma applications, FCIPT is also promoting the awareness of plasma science among Indian student community which is expected to help in getting trained man-power for our country's future fusion programme.

Director,
IPR.

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Entering into its successful 25th year, the institute has considerably expanded its research activities. Till 2007, the emphasis has been on plasma physics, its applications and tokamak research. Since then India joined ITER as a full partner and with it emphasis on fusion related technologies has grown considerably at IPR. Accordingly, a number of R&D activities related to subsystems that will be part of a fusion reactor based on tokamak concept have been taken up. Test Blanket Module (TBM) and Super Conducting Magnet Technologies are some of them. While expanding into these programmes as well as contributing to ITER through a dedicated setup through ITER-India, our work on the fundamental plasma sciences that includes basic experiments, theory, simulations and tokamak research continued during these years. The Facilitation Centre for Industrial Plasma Technologies (FCIPT) has been in the forefront of developing environmentally and economically viable technologies for many applications. During the XI plan period, IPR has started supporting the Centre of Plasma Physics at Guwahati.

A. SUMMARY OF SCIENTIFIC & TECHNOLOGICAL PROGRAMMES

Scientific programme of the institute can broadly be categorised into five main areas as following: 1) magnetically confined fusion plasma experiments 2) Fusion Technology Developements 3) Basic Experiments 4) Theoretical and Computational Physics and 5) Industrial Plasma technologies.

A.1 Fusion Plasma Experiments

A.1.1 Aditya Tokamak

A.1.1.1 Status of the Device

Experiments for upgrading the operation window have been continued in this year also. Recently, different control experiments haven been initiated. With negative converter operation it has been possible to extend plasma duration upto 250 msec very close to original Aditya design value. Preionization always helps for the successful start-up of tokamak discharge. Different kind of preionization (ICR, LH and ECR) experiments are planned. Among them ICR preionization has already been successfully operated in Aditya tokamak. Approximately 90 kiloWatt of radio frequency (RF) power around 24 MHz was used for plasma breakdown without loop voltage. The optimisation study of rf preionization is ongoing. Position control with fast feedback power supply has been carried out. Gas puff system for density feedback has been made ready. This also needs real time density measurement which is being tried now. Experiments with SIC limiter has been carried out. It has been observed that SIC has not performed better than usual graphite limiter. New graphite limiter with backing facilities has been put back into the machine. It has shown improvement in discharge. At present, discharges with 80 kAmp plasma current of 90 msec duration with less runaway electron are achieved regularly. In these discharges plasma density is of the order of 10^{13} cm^{-3} and temperature is around 400 eV. Aditya is planning to carry out boronization experiment shortly. Boronization system is ready to be implemented. Shutters for windows needed for bornization experiment have been procured and the expected time for bornization experiment is around Novembor 2011. Vessel baking is another aspect of Aditya operation up gradation. Necessary works for vessel baking has already been started.

A.1.1.2 Diagnostic Developments

Microwave reflectometry (fixed frequencies, 22 GHz and 35 GHz) has been successfully operated to measure edge and core density fluctuations. Charge Exchange diagnostics is now upgraded. Charge exchange counts on all three channels could be realized as a result of the drastic cut down of the reflecting spurious photons flux on CEMs. Data has been taken on regular basis on three energy channels during APPS shots. Estimated ion temperature from Charge Exchange diagnostics is around 70 eV. The proposed Time of Flight Diagnostics system is at the final stage of fabrication and will soon be followed by assembly, calibration and testing. Conceptual design of an Infrared Imaging Video Bolometer (IRVB) has been completed. Test experiments were conducted with some aluminum foil. Software for analysis has also been developed during this finantial year successfully demonstrated. Infrared camera based diagnostics has been deployed in Aditya to study inboard and outboard limiter. Observation has been made during Aditya shots not only to monitor the temperature but also for estimating the energy balance during plasma discharge. The Vacuum Ultra Violet (VUV) spectrograph is installed in Aditya tokamak and being operational throughout this year collecting spectral data in the range of 100 A to 1700 A. This enables us to estimate the central temperature of the Aditya discharges. Absolute calibration of the VUV spectrograph is underway using branching ratio techniques. For this another half meter spectrograph operating in the visible region has been mounted on the Aditya tokamak to simultaneously measure the spectra in the visible range. The fast camera observing the total plasma light is installed in the Aditya tokamak and fast images with a time resolution of ~ 200 microsecond has been obtained. The data are currently being analyzed and the analysis will continue in coming months. Analysis of emissivity data of oxygen is continuing with modeling with STRAHL code. The neutral profile inside the Aditya tokamak is measured and reported in a publication. Alignment and Calibration for the Aditya Thomson scattering system is over and is ready for regular operation. The imaging diagnostics for Aditya is presently operational. The data acquired from the earlier shots are being analyzed with the collaboration from IIT Kanpur.

A.1.1.3 Heating and Current Drive Systems

Lower Hybrid Heating Drive (LHCD)
Preparation activities for carrying out proposed LHCD experiments on ADITYA have been carried out. The experiments would immediately start after the successful testing of crowbar unit with HVPS and wire-burn test.

Electron Cyclotron Resonance Heating (ECRH)
A 42GHz ECRH system has been finalized to carry out the ECRH breakdown, start-up and heating experiments in tokamaks. This 42GHz ECRH system corresponds to fundamental harmonic at 1.5T operation. Since the absorption of ECR waves at fundamental harmonic is efficient, the 42GHz system would give reliable breakdown at 1.5T operation. This system would be used in Aditya tokamak to carry out various experiments at second harmonic ECRH breakdown at 0.75T operation. This may provide valuable information for the planned pre-ionization experiments in ITER. The detailed technical specifications have been generated for a 42GHz 500kW ECRH system for tokamak Aditya and SST-1. The procurement of 42GHz/500kW/500ms Gyrotron, transmission line and two vacuum barrier windows is in advance stage. The layout of 42GHz ECRH system is being prepared and work on other subsystems (Mechanical, electrical, DAC and launcher etc.) has also been started for both the tokamaks (SST-1 and Aditya).

Regulated High Voltage Power Supply (RHVPS) for Gyrotron system : In order to operate the Gyrotron in pulsed condition, the work on RHVPS has been initiated. The electronic cards for handshaking between RHVPS and ECRH DAC have been tested. The fibre-optic cables are laid and mounting of repeater cards is also done. The communication between ECRH data acquisition control and RHVPS control system has been tested successfully. The RHVPS is under commissioning stage to carry out 10-Joule wire test for successful acceptance of RHVPS for safe and reliable operation of Gyrotron.

Ion Cyclotron Resonance Heating (ICRH)
After the first phase of second harmonic heating experiments carried out on Aditya and its encouraging results last year, the second phase experiments are carried out. During the high power operation, a gas barrier in VTL section initiated a few arcing phenomena and the issue is addressed immediately by opening part of the VTL section. A new improved gas barrier with ceramic as dielectric is made ready. All the transitions on inner and outer conductors are contoured suitably for increasing voltage withstand capability. The gas barrier has shown excellent leak tightness better than 1E-9 mbar.lit/sec and withstands the DC voltage of 35KVDC. The new gas barrier is successfully installed and being regularly used for high power ICRH experiments. The planned pre-ionization experiments is initiated. In first phase, second harmonic experiments were conducted up to 110 kW RF power. Although few signatures of heating were observed, many diagnostics had observed presence of RF in their results and hence it was decided to repeat the experiments after proper grounding and shielding of the diagnostics as well as that of Aditya ports. In second phase, pre-ionization experiments were conducted on Aditya using same antenna to have pre-ionization as well as heating. Initially RF power was introduced before Ohmic power and effect of pre-ionization was observed. In second phase RF plasma was produced without Ohmic and was observed that it spreads all over the tokamak vessel in presence of Toroidal magnetic field. The detailed analysis of the results is in progress.

A.1.1.4 Experiments and Results

Diamagnetic measurements : In tokamak, the plasma kinetic pressure is balanced by the sum of the poloidal magnetic pressure and any change in the toroidal magnetic pressure. Although in a purely ohmic heating case the toroidal magnetic pressure increases and, thus the tokamak plasma becomes paramagnetic, any change in the toroidal magnetic flux is traditionally referred as the diamagnetic flux. The measurement of this flux can be used to determine several quantities that are related to the plasma kinetic pressure, namely, poloidal beta, total stored energy and energy confinement time. Similarly, the poloidal beta obtained from diamagnetic flux measurement can be used to separate the internal inductance of plasma from (poloidal beta + inductance)/2 measurement, which gives us information on plasma shape. These parameters are essential for the efficient operation of tokamak machine.

The magnitude of diamagnetic flux is quite small, typically 10^{-3} times of vacuum toroidal flux. Therefore the flux measurement is severely affected by several factors, e.g., vibration of diamagnetic loop and its flux linkage with various external currents, namely the currents in magnetic field coils, eddy current in the vessel and plasma current. The mechanical vibration of diamagnetic loop in space varying toroidal field produces a spurious noise during the plasma discharge. The inevitable error in the alignment of diamagnetic loop in the poloidal plane causes the loop to have pick-ups of currents in various field coils and the eddy current on the vessel. The pick-ups of currents in external coils and the eddy current in the vessel need to be compensated from diamagnetic loop signal accurately for a reliable measurement. We have adopted asymmetric compensation loop method to measure diamagnetic flux in ohmic as well as radio frequency (RF) heated plasma of Aditya tokamak. The tokamak was operated at toroidal magnetic field ~0.75 T on the axis, plasma current ~100 kA and plasma duration ~90 ms. The RF power of 30-70 kW was injected at 24.8 MHz in some discharges. The result is presented in Fig.ure A.1.1.4.1. It is observed that diamagnetic signal has contribution from currents in TF coils and misalignment of diamagnetic coils in the vessel can also give some contributions due to BV current and plasma current (in that order) and needs to be corrected. The appropriately corrected diamagnetic fluxes have been used to determine poloidal beta, total stored energy and energy con-

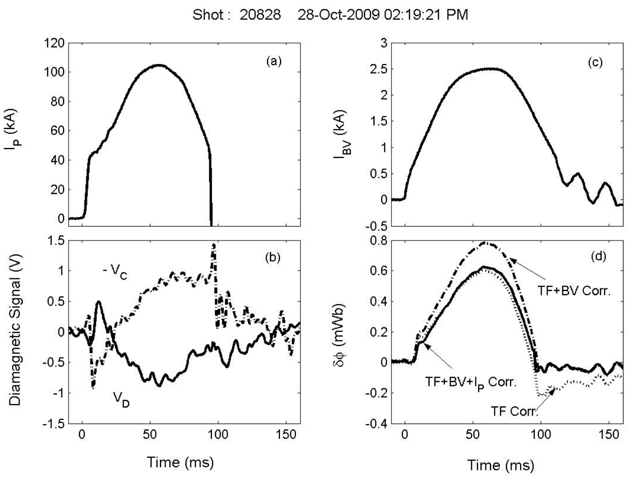

Figure A.1.1.4.1 (a) Plasma current, (b) raw signals of diamagnetic and compensating loops, (c) vertical field current, (d) diamagnetic flux after applying different corrections.

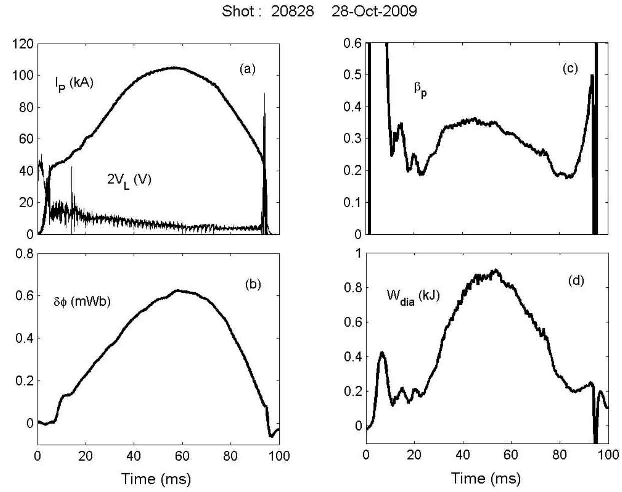

Figure A.1.1.4.2 (a) Plasma current and loop voltage in a typical plasma discharge, (b) diamagnetic flux, (c) poloidal beta, and (d) stored diamagnetic energy.

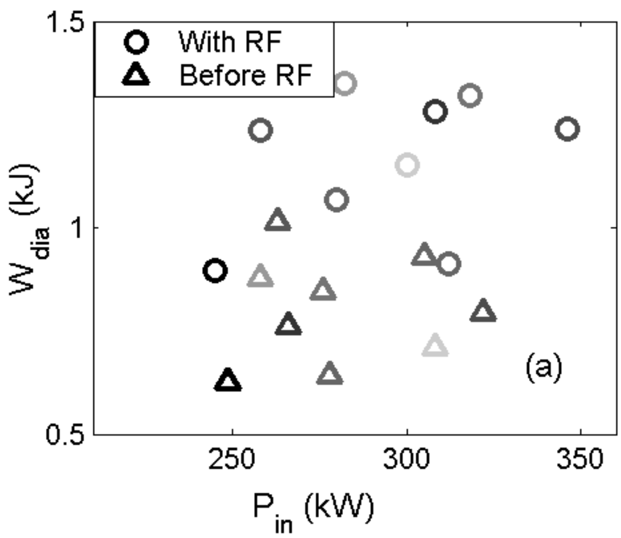

Figure A.1.1.4.3. Stored energy measured with diamagnetic loop, Wdia, as a function of absorbed input power Pin at the flattop of the plasma current for various plasma discharges. The color indicates measurements in the same discharge.

finement time for Aditya discharges. An example of quantities derived from the measurement of diamagnetic flux is shown in Figure A.1.1.4.2. By using these measurements and by making sure that the diamagnetic energy measurement is a good indication of thermal energy in ohmically heated plasma, we have determined the energy confinement time. It is observed that stored energy is in the range 0.4 to 1.2 kJ and scales linearly with the net input power. The energy confinement time is in the range 2-4 ms and scales linearly with the chord averaged plasma density. The latter clearly indicates that Aditya plasma follows the Alcator or Neo-Alcator scaling for energy confinement. We have also carried out measurement of stored energy in ion cyclotron radio frequency (ICRF) heated plasma in Aditya and find that increase in the stored energy is from 20 % to 40 % of its value in ohmically heated Aditya discharges [see Figure A.1.1.4.3]. It should be noted that even with ICRF heating, the ohmic confinement physics dominates because RF power is typically one third of the ohmic power.

Spectroscopy Diagnostics : Last year we have installed a high frame rate camera (6000 frames per second at 512 × 512 pixel resolution) along with an imaging fiber bundle on Aditya tokamak for tangential imaging of the fast evolving plasma. We also performed the field of view calibration for this camera mounted on Aditya tokamak using a novel technique. During this year we have acquired images of Aditya tokamak normal discharges with high frame rate (up to 5000 frames/sec). The images of normal Aditya discharges taken with exposure time of 200 microseconds is shown in the figure A.1.1.4.4.

A newly procured visible spectrometer (half meter) is installed viewing Tokamak mid-plane with ICCD and spectra in the visible region recorded simultaneously with VUV spectrometer (which was installed last year) for absolute intensity calibration of the VUV spectrometer using branching ratio method. The spectra from the half-meter visible spectra and the VUV spectrometer in a single Aditya discharge (shot# 22354) is shown in the following figures:

The VUV spectra shown in Figure A.1.1.4.5 are at different times into the discharge in the wavelength range of 100 to 1800 A, whereas the spectra obtained with half meter visible spectrometer shown in Figure A.1.1.4.6. has a wavelength window of 4200 Angstom centered at 6562 A obtained at plasma current flat top. The big peak in the visible spectra is the H-alpha at 6562.8 A. The half-meter visible spectrometer is intensity-calibrated using a *Labsphere* and calculations are underway to obtain VUV intensity calibrations from the branching ratio of H-alpha and Lyman Alpha.

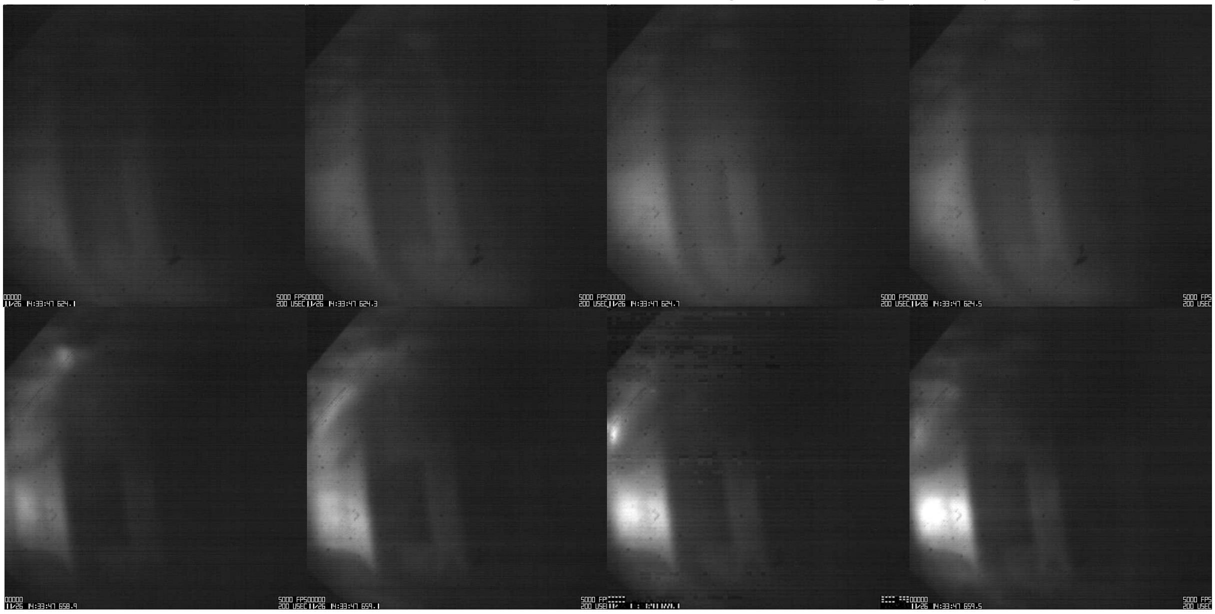

Figure A.1.1.4.4 : Time evolution of plasma formation and termination of a typical Aditya tokamak discharge. Pictures taken with 5000 FPS with an exposure time of 200 micro seconds. Top four pictures are during plasma formation and the bottom four pictures are during plasma termination.

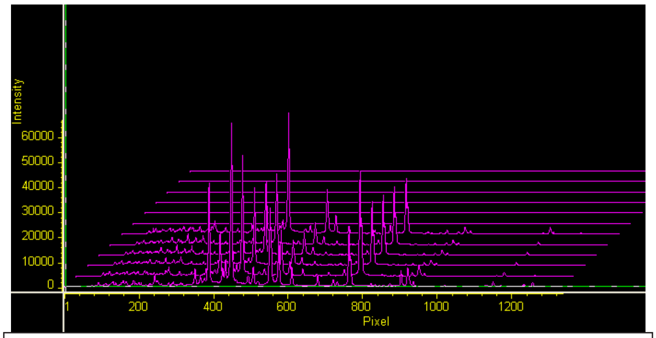

Figure A.1.1.4.5. Vacuum Ultra Violet Spectral data

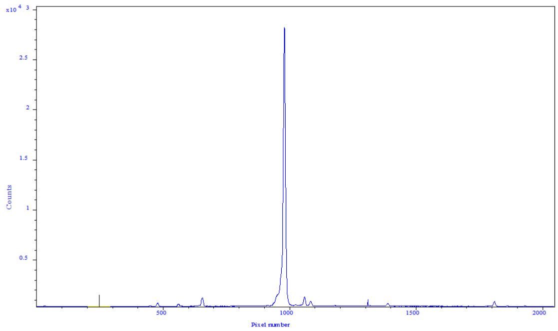

Figure A.1.1.4.6. Visible range Spectral data

Impurity transport has been studied in the Aditya tokamak using the spectral lines at 650.024 nm having transition of 2p3p 3D3-2p3d 3F4 from Be-like oxygen ion (O4+). The oxygen impurity transport in both high and low magnetic field regions of Aditya tokamak in a single discharge using simultaneous measurements of the spatial absolute intensity profiles of aforesaid visible O4+ spectral line in the high and low magnetic field regions in combination with one-dimensional impurity transport code, Strahl is carried out. Manuscript is in preparation.

Infrared Thermography of Aditya Limiter: This activity is carried out throughout the year and observations were taken for two different Limiters having tile material SiC and Graphite. Observations shows higher temperature rise of the front surface of Tile for the SiC limiter as compared to the tile having the Graphite material as tiles. Other observations shows movement of the plasma column in radial direction i.e. inboard-outboard. Sputtering of the material from the limiter is observed during discharge initiation and also during discharge termination.

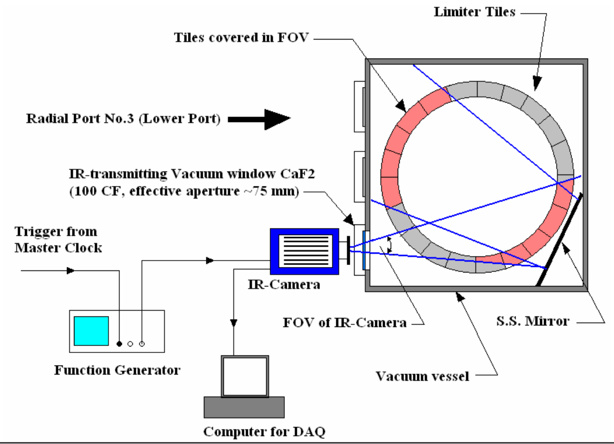

Figure A.1.1.4.7.Diagnostic layout of infrared thermography of Aditya limiter

Metal foil calibration facilty for Infrared Imaging Video Bolometer (IRVB) : Further development is made in the calibration facility of the ultra thin metal foil used as a radiation sensing element in IRVB diagnostic. Due to manufacturing process and coating of high emissivity paints leads to non uniformity in the foil thickness and also it alters the local value of the thermal diffusivity. Therefore it adversely affects in estimation of the radiated power calculation. In order to obtain accurate measurement of the radiated power, local deviation of thermal properties & foil thickness needs to be determined experimentally. Experiments were performed to determine the spatial variation of the product of thermal conductivity (k) & foil thickness (tf) and Thermal diffusivity (α). These parameters are experimentally obtained by scanning the metal foil using the He-Ne Laser source of known power density. Variation in parameters is determined by fitting surface plot. Absolute plasma radiation can be confidently determined after including these measured parameters.

Deposited Layer Substrate (DeLaS) Module development for IRVB : An innovative idea was emerged during the de-

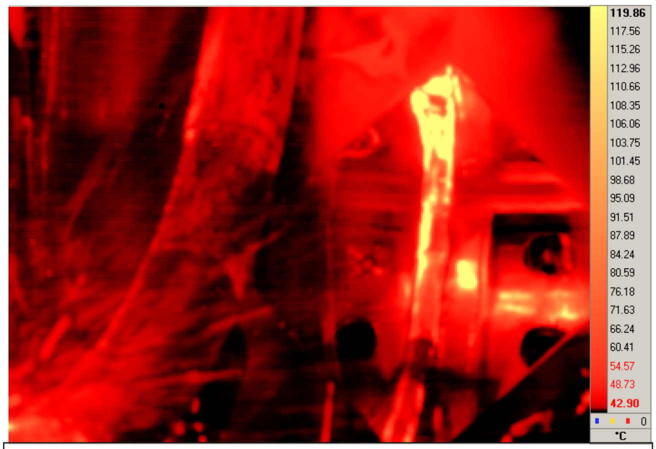

Figure A.1.1.4.8. Infrared image of the Aditya limiter

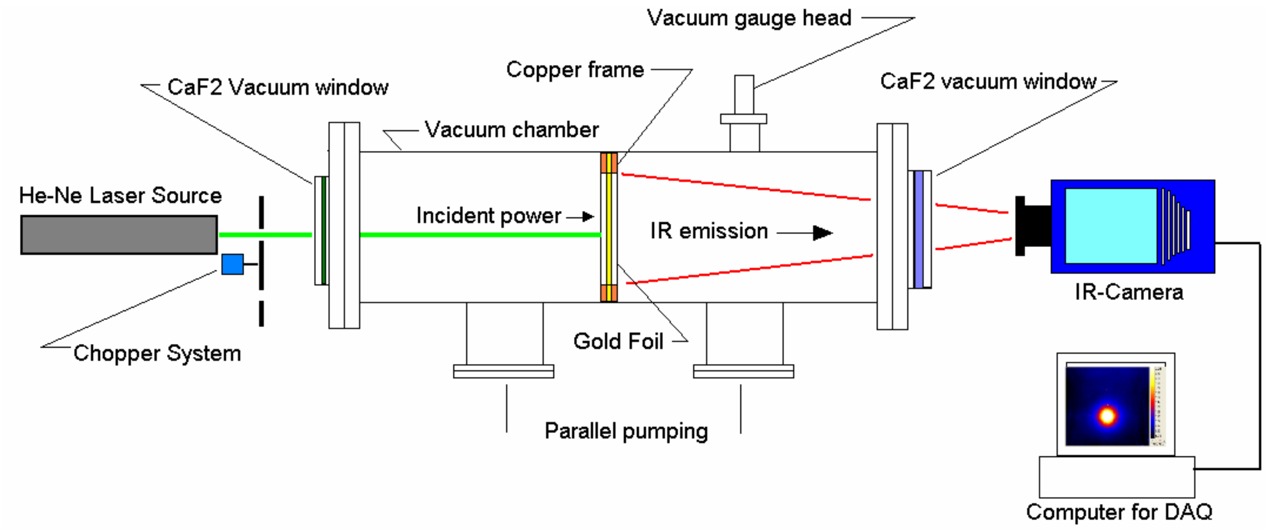

Figure A.1.1.4.9. Metal foil calibration facility for IRVB

velopment of the IRVB diagnostic. Thermal detector based an innovation in the radiation sensing module of IRVB has been proposed and proved with the basic experiments. After encouraging results of the demo experiment, systematic experiments are planned to develop prototype of the proposed module. The proposed module is promising and it solves most of the present problems associated with this diagnostic. A prototype module having multilayer deposited on the Infrared transmitting substrate is developed and tested.

Conceptual Design of IRVB diagnostic for Aditya Tokamak
Before going to deploy the IRVB diagnostic on SST-1 Tokamak (Phase-I), some test experiments are planned on Aditya Tokamak to gain experience. For this purpose conceptual design of IRVB is made and design is optimized for the adequate SNR. Based on the conceptual design engineering design is initiated.

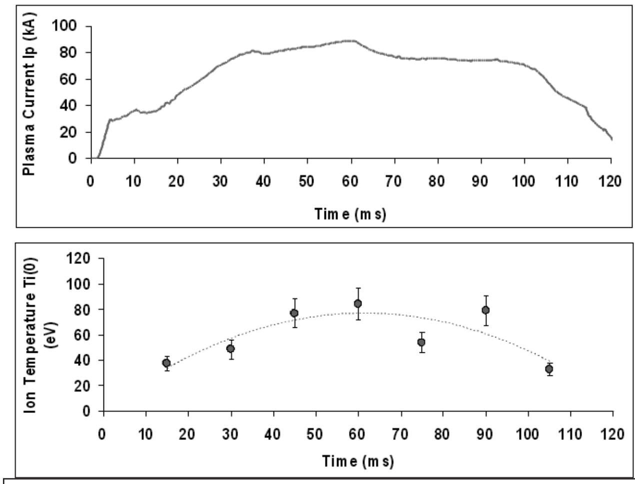

Figure A.1.1.4.10 For Plasma Shot#21743: (a) Evolution of plasma current with time (b) Temporal variation of central ion temperature Ti(0) during flat top of the current profile.

Neutral Particle Analyser Group : Analysis of Charge Exchange Signals (CX neutral-Count at three energy channels) obtained for various APPS shots from October 2010 onwards has been done and the Core Ion Temperature estimated. Evolution of Core Ion temperature with APPS time, compared with the electron temperature for the same shot can be seen. With an adequate SNR (>30) at energy channels, Core-ion temperature Ti (0) during flattop of the plasma current can be seen to be rising up to 200 eV during ohmically heated plasma discharges which is slightly above 40% of the average core-electron temperature (typical 450 eV).

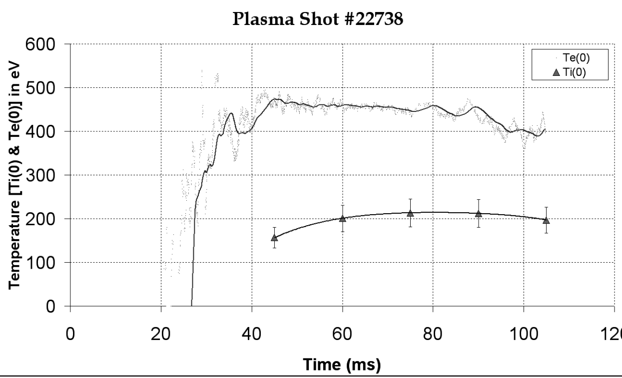

Figure A.1.1.4.11 Temporal variation of central electron temperature Te(0) and central Ion temperature Ti(0).

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

A.1.2.1 Status of the Device

SST-1 mission **:** The Team comprising of the SST-1 Cryogenics Division, SST-1 Magnets Division, SST-1 Assembly Division, SST-1 Vacuum Division, SST-1 Power Systems Division, SST-1 Data Acquisition Division, SST-1 Operations and Control Division & SST-1 Plasma Control Physics Division have made significant progress during 2010-11 towards the refurbishment of the machine. All the identified problem areas belonging to each of these divisions have been reviewed with domain knowledge experts and have been attended. The remedial measures were based on the principles of laboratory scale conceptual validations, laboratory scale prototype validations and finally testing the components and sub-systems in simulated experimental or engineering scenarios. Only after a meticulous chain of tests adhering to a strict QA/QC on each of these components and sub-systems, they were declared assembly-ready. The refurbished SST-1 assembly has begun as scheduled from June 2010 and has been progressing in an accelerated pace. Even though the re-assembly is envisaged for a total time period of twenty four months from June 2010, it is expected to be finished ahead of schedule. The cool-down activities of the SST-1 is aimed to begin towards the end of 2011. Additionally, the first plasma physics experiments are also being planned.

A.1.2.2 Technological Developments

SST-1 Magnets Division : All the SST-1 TF magnet winding packs were modified with validated ultra low DC joint resistances. These joints have inherent characteristics of enhanced cryogenic stability and are leak tight to helium at all operating environment apart from being mechanically robust. These joints fabrications in all the sixteen TF magnets followed a very strict QA/QC. The detailed QA/QC was developed on the basis of several process validations and engineering qualifications involving laboratory and actual experiments. All these joints fabrications were completed within two hundred days starting from April 2010 as against a duration projection of ten months. All these prepared SST-1 TF magnets were further equipped with qualified potential breakers at their supercritical supply inlets and outlets. These isolators were capable of withstanding a potential drop up to 5000 V DC during any off-normal scenarios of the magnet operations such as quenching of the magnets. The manifolds integrated on to each of the magnets have built-in flexibilities to account for both thermal and electro-mechanical stresses resulting from the cool-down and charging of the magnets. Starting June 2010, each of the sixteen SST-1 TF magnets were tested in cold with supercritical helium at the inlet (4 bar, 4.5 K) in full transport currents. During the tests, the magnet winding packs was carrying a net current in excess of 1 million ampere in a maximum field of 2.2 T. Each of the SST-1 TF magnets have experimentally demonstrated excellent current carrying ability with the designed temperature margin and head room in excess of 1.5 K, energy margin in cryo-stable conditions in excess of 600 mJ cm-3 and expected normal zone characteristics following a quench event. All these magnets have experimentally shown joint resistances in the range of 100-1100 pico-ohms. These resistances are by far the best joint resistances obtained for Tokamak magnets involving

Figure A.1.2.2.1 A fully assembled magnet is getting prepared to be tested

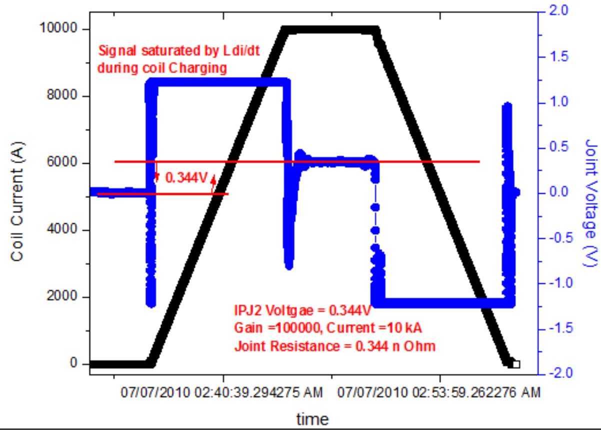

Figure A.1.2.2.2. A typical joint resistance measurement from a PXI module

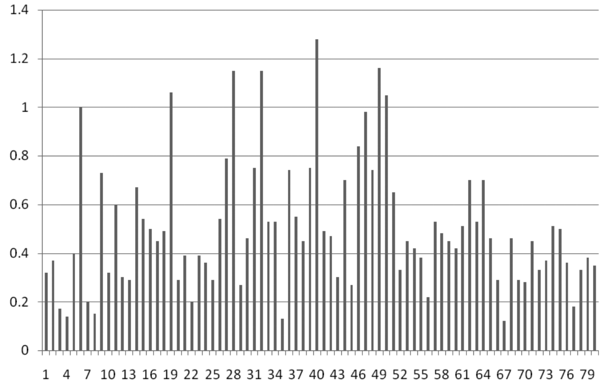

Figure A.1.2.2.3 Sub nano-ohm as measured joint resistance from all coils, which are the contemporary best

cable-in-conduit conductor in the global scenario. The tests of these magnets were completed in twenty three campaigns in a record time of 225 days. All the SST-1 TF magnets and their auxiliaries have been cleared for the machine assembly. There have been significant progresses on the SST-1 superconducting Poloidal Field Magnets also. The PF-3 top magnet was damaged during the last SST-1 campaign carried out in 2006 where the turns of two intermediate adjacent layers were damaged. This magnet winding pack was also salvaged after establishing the processes and engineering of bridge type joints with superconducting shunts involving cable-in-conduit-conductors. This magnet however will be fully tested in cold with current in the first half of 2011 prior to it being declared as assembly-ready.

SST-1 Cryogenics Division : This division had completed the service maintenance of the helium cryogenic system after a gap of nine years. During this phase of the work, the designed refrigeration, liquefaction and the mixed mode (i.e. refrigeration and liquefaction) capability of the liquid helium facility along with the cold circulator operation up to 300 gm/s across a pressure head of 500 mbar. With these system level achievements, the helium facility was fully geared up for the SST-1 magnet test campaigns since May 2011. During the twenty three magnet test campaigns, the helium facility performed in a text book fashion without any problems. The facility was continuously working on 24 X 7 bases during the entire campaign duration of 10-12 days in both refrigeration and mixed modes. These valuable experiences have not only strengthened the reliability of the helium cryogenic facility but also have added confidence to its fail-safe operation during the SST-1 operations scheduled towards the end of 2011-12. On the inventory and recovery side of the helium facility, additional augmentations have been carried out so as to accept more through-put during the off normal operations such as quenches. The 80 K thermal shields of the SST-1 are cooled with single phase nitrogen. The single phase nitrogen at 6 bar would be generated from the existing LN2 arrangement through a Boosting System. This Boosting system has been conceptualized and contracted to an industry and would be realized prior to the cool-down of the magnets planned towards the end of 2011. All the 10000A vapor cooled current leads have been fabricated in-house following a strict QA/QC. Several of those have been tested up to the rated currents of 10000 A as per the SST-1 TF and PF charging scenarios in a specially developed cryogenics test facility. These validations tests have demonstrated that all the current leads have been performing as per the design parameters.

Compressor		LN2 Precooling		Turbine Parameter	Turbine A Parameter		Turbine B Parameter		Turbine C Parameter	
PT230	14.01	DPT433	33.45	Inlet Pressure	PT522A	13.52	PT522B	5.30	PT522C	11.57
PT218	1.05	FCV432	11.81	Inlet Temp	TE441	37.95	TE455	16.00	TE450A	9.60
PT233	3.50	TT487	81.94	Outlet Pressure	PT523A	6.16	PT523B	1.08	PT523C	4.11
FT238(g/s)	138.03	TT347(C)	-2.45	Outlet Temp	TE476	32.75	TE457	15.15	TE479	8.96
PCV225 / 229	20.10	MCD Critical Parameter		Speed	ST540A	1747.00	ST540B	1463.00	ST540C	1252.00
JT198C	440.00	PT605	1.30	Bearing Temp	TT555A	6.75	TT555B	6.85	TT555C	16.85
JT198B	1.00	TT606	5.54	Bearing Pressure	PT525A	13.47	PT525B	13.44	PT525C	11.11
PCV223	12.50	LT607(mm)	280.40	Break Pressure	PT526A	10.60	PT526B	12.03	FCV428C	35.95
COMP C	100.64	LT607(ltr)	378.50	Cold Box			FCV428A	100.00	TT031	5.90
COMP B	0.31	WT601	195.70	Outlet Temp	TT479	8.96	OTHER		TT419	4.53
TT184(C)	16.40	FCV444	15.99	Outlet flowrate(g/s)	CL_FLOW	4.00	TT463	14.15	PT419	4.06
Purifier Pressure Drop		FCV446	15.17	CC Speed in Hz	ST410	0.02	FCV435	26.93	FT419	60.50
PT706	14.09	FCV443	0.00	Return Temp	TT451	121.18	FCV436	22.03	PT396	1.03
PT715A	13.96	FCV445	63.87	Return Pressure	PT338	3.06	FCV420	100.00	TT425	271.30
DIFF	0.13	FCV447	0.00	HP Pressure	PT353	13.60	FCV421	4.00	LT449	651.70

Figure A.1.2.2.4 A typical complex parameter maps of the helium facility during operation

SST-1 Vacuum Division : This division shoulders the critical multiple role of refurbishing the SST-1 vessel module and sectors especially with the baking channels as per the operational requirements as well as providing critical services on leak testing of all the vacuum components. Additionally, SST-1 vacuum division carries out leak testing of the

Figure A.1.2.2.5 A vessel module getting ready for the baking in a dedicated baking facility after instrumentation all the 80 K shield components, nitrogen and helium headers etc. During 2010-11, SST-1 vacuum division has carried out the repair of all the baking channels on all the eight vacuum vessel modules successfully. These modules have been fully tested in representative conditions in a special baking facility in excess of 150^{o}C for eight hours and have been found to be leak tight post baked. Now all these modules have been released for the octant assembles on the SST-1 machine shell. These experiences have not only added confidence to a fail-proof operation of the SST-1 vacuum vessel when assembled but also had validated experimentally the SST-1 hot nitrogen baking facility. The baking and testing of the five out of eight SST-1 vessel sectors have also been completed. The auxiliaries of the SST-1 vacuum systems have also been refurbished. Field independent ASDEX gauges have been procured and have been validated for operation in environment with finite magnetic field. Actions at procuring almost vibration free vacuum pumps have also been initiated whose acoustic noises during operations are also well within the acceptable limits.

SST-1 Power Supplies Division: This division is responsible for the power supplies and the controls for the entire SST-1 Magnet System including the protection of the SST-1 magnets during its quenches. SST-1 TF power supply has been used extensively during the twenty three campaigns involving the SST-1 TF magnets as well as for testing the vapor cooled current leads. The power supply now can run for much extended period exceeding hours. The overall sequences of operations of the power supply, its interlocks and controls have thus been thoroughly validated. Operation of the power supplies in remote modes as well has been established. Experimentally fast ramp down of the power supplies in not-so-emergency scenarios of the magnet off normal scenarios have been experimentally established also. The control aspects of the SST-1 poloidal power supplies have begun. The entire power supplies for the SST-1 TF and PF magnets would be fully ready towards the end of 2011.

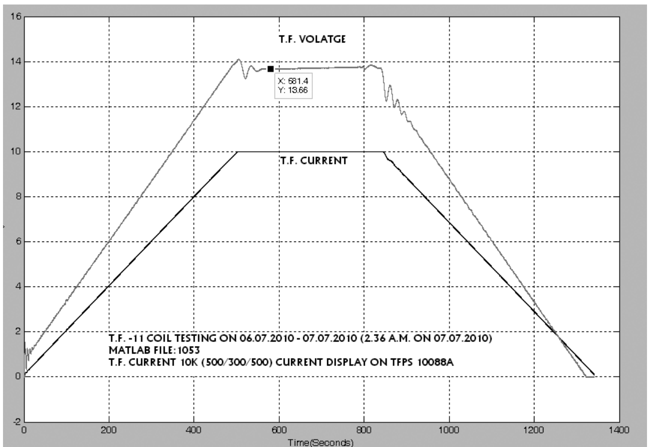

Figure A.1.2.2.6 TF Power Supply profile during the charging

SST-1 Device Integration Division: This one has an extremely critical series of tasks to be completed. These activities have begun from June 10, 2010. The reassembly of SST-1 is divided into eight phases in the run-up to the final commissioning of the machine assembly. The first phase of reassembly comprising of the all important bottom cryostat plate leveling, installation of the fully tested and assembled bottom 80 K cryostat thermal shields, TF bottom ring and cantilever placement and elevation insurance with the helium cooling provisions of the bottom ring, assembling and positioning the fully tested single phase nitrogen supply headers with radial and toroidal flexibilities, assembling and positioning of the various helium supply and some return headers with flexibilities, positioning and aligning the bottom PF-3 magnets and positioning and aligning of the bottom PF-4 and PF-5 magnets have been completed on Feb 11, 2011. The challenging second phase of reassembling the octants comprising of a pair of tested TF coils with 5 K shields, a tested vessel module, assembled and tested 80 K vessel thermal shields and a pair of outer-inter-coil-structure (OICS) have begun on the ground assembles to the required metrological accuracies. These modules along with the fully 80 K shield assembled and tested vessel sectors would next be assembled on the machine as a part of phase-II of the SST-1 reassembly. This

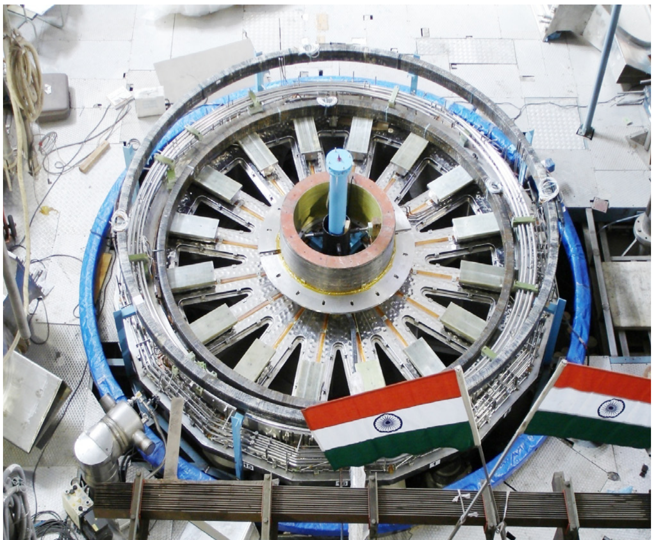

Figure A.1.2.2.7 SST-1 reassembly progress at the end of first phase of reassembly.

phase is the longest phase and would be one of the most critical phases. This phase of reassembly has begun. The entire SST-1 machine shell assembly is expected to be completed ahead of schedule. In support and leading to the preparations of the reassembly activities, an integrated effort is also extended to the SST-1 Device Integration Division by SST-1 vacuum division & SST-1 Cryogenics Division on ensuring the leak-tightness and thermal/electrical isolation of ~ 80 K cooled vessel module and sectors in a test cryostat. Each time this test is done the SST-1 baking facility would be converted to a cryostat and the tests would be done. These preparations have been completed and few of the module tests have been completed. All these test modules have demonstrated excellent leak tightness in helium at all stages of their cooling, excellent temperature distribution on the panel surfaces as well as electrical isolations in excess of giga Ohms when cold to 80 K.

SST-1 Data Acquisition Division : This along with SST-1 operation & Control Division and Electronics Section have been coordinating integrated testing for SST-1 Phase-I and Phase-II Diagnostics channels measurement in simulated representative environments following strict protocols. All SST-1 Phase-I diagnostic channels together have been tested and have established communication interfaces typical of Tokamak operation with automatic Shot number based Configurations and Data Files generations. The tests have been performed on both the modes of data acquisitions i.e. continuous acquisition & Pre/Post Trigger acquisition modes which are event based. There is at present a high degree of confidence on the fail proof data acquisition in conjugation with front-end electronics and machine central control. Recently based on the need a dedicated group from electronics division has been working on the front end signal conditioning aspects as well as on the communication purposes in actual SST-1 operational conditions. SST-1 Operation & Control Division, Electronics Division and Data Acquisition Division have jointly developed a enhanced communication link between each DAQ GUI and Central Control Status Monitoring GUI (Graphical User Interface) to establish the necessary communication interfaces. These TCP/IP based applications were successfully tested with CAMAC and PXI Data Acquisition systems at various physical locations.

SST-1 Central Control Division : This Division has been perusing an integrated GPS Based Time Synchronization System amongst various heterogeneous subsystems. Some of the GPS unit with time receiver modules (VME, PXI, PCI) have been integrated. The VME based application of the TF power supply has been upgraded and has enabled remote operation of the power supplies. Communication interface & Timing system interface testing during Integrated engineering validation of plasma diagnostics have established the Timing System capability of Multiple Clock & Trigger distribution. Machine Control System (MCS) connectivity with DAQ & Front End Electronics for communication of Shot No, Trigger time-stamp & Status monitoring has also been tested successfully. A data storage system depending on the volumes of data expected to be received from various status monitoring subsystems and diagnostics are in the process of being fully commissioned. An e-log book has also been opened for logging the experimental activities.

A.1.2.3 Diagnostics Developments

Filter polychromator for Thomson scattering Diagnostics : SST-1 Thomson scattering diagnostics uses five channel interference filter polychromator for the spectral dispersion and detection. The filter polychromator is tested for its complete performance and optical ray tracing is performed and the parameters are matched. Figure1 shows the ray tracing and 3D layout of fabricated Filter polychromator. More number of polychromator are required for improving the spatial resolution of the temperature and density profiles. With minor modifications new design is finalized and fabrication process is carrying out presently.

Effect of pressure gradients on laser beam propagation through an optical window for tokamak plasma diagnostics : Experimental investigations are carried out on the effect of pressure gradient on the optical properties of a rectangular fused silica window used in optical diagnostics of plasma. Effects of surface deformations due to pressure gradient at vacuum interface on the laser beam propagation through the window are discussed in the context of optical diagnostics. Ultra High Vacuum (UHV) sealing of a large size rectangular glass window with metal assembly using a Helicoflex seal is also discussed. It has been shown that vacuum induced deformation in optical window surface may not significantly affect diagnostics, which are dependent on intensity /relative intensity measurements. However, wavefront distortions introduced in the laser beam by window deformation could have a significant effect on the plasma diagnostics, which depend on wavefront-based techniques.

Defect detection and quantification of defect size using Infrared thermography for Plasma Facing Components : Plasma Facing components (PFCs) are the first wall components which directly comes into contact with high temperature plasma inside the tokamak and hence subjected to the bombardments of Energetic Particle Flux and High Heat Flux of plasma radiation during operation. PFCs being multilayer brazed component consist of Plasma Facing Material (PFM) brazed on heat sink of copper alloy having a cooling channel through it for active cooling. Efficient heat transfer through the brazing layer in actively cooled PFC is required in order to obtain its optimum service life. If the brazing integrity of PFM to heat sink is not good, then it will result in shortening service life of the PFCs. To test and evaluate the brazing quality of the PFCs, Non-Destructive Testing & Evaluation (NDT&E) have been carried out using active Infrared Thermography (IRT) Method. In active IRT a Hot and Cold thermal stimulation is provided using the water loop facility called "Facility for Infrared Non-destructive Examination (FINE)" was developed at IPR. Using FINE, few PFC mock-ups were tested for their brazing quality. By analyzing transient temperature evolution data of each tile, different Thermal Response Quantities (TRQs) were obtained. Based on these TRQs value, tiles were qualitatively classified as good brazed and poor brazed tiles. To quantify IRT results, Finite Element Method analysis (FEM) were carried out. Using FEM, temperature evolution curves were obtained for deferent defect sizes (different percentage thermal contact area) which have been (artificially) created at brazing interface. From the simulated temperature evolution curves corresponding to different size of the defect, the values of each TRQ were obtained for different defect sizes. Characterization curves for different TRQs vs. Defect size were obtained. Thereby comparing the experimental TRQs with the TRQs those obtained through the FEM analysis, quality of the brazing for each tile is quantitatively obtained.

Active infrared thermography of brazed cooling tubes of prototype bolometer camera housing : Active infrared thermography (IRT) technique is a widely used technique for the non destructive testing (NDT) of materials and welds for sub-surface defects and anomalies. It is also emerging as a widely used technique in non-destructive testing of plasma facing components in tokamaks and other fusion devices. The IRT method is safe and no physical contact with the specimen under test is required. The thermographs obtained from the IR camera are easy to read and the defects can be identified visibly by looking at the thermographs without any post-processing of the data. We have used this method to investigate the brazing of the cooling tubes of the prototype bolometer camera housing that is being developed for Steady state Superconducting Tokamak (SST-1). Figure A.1.1.2.1. shows isometric diagram of bolometer camera housing and the part where cooling tubes are welded, were studied by active IRT. A verification of IR thermograph has been presented herewith the conventional method of x-ray radiography for the NDT of a part of brazed cooling tube. The radiograph has been taken using X-rays of energy 160 kV and exposure of 8 mA-Min. Figure A.1.1.2.2. shows the radiograph and the thermograph of one of the sections. The two straight white portions in the radiograph are two cooling tubes, whose corresponding thermograph is also shown alongside. The darker portions in the radiograph show the presence of material and the lighter portions indicate the absence of material between the tube and the pipe. As seen from the figure, the thermograph compares well with the radiograph. The temperature is higher at the places where the brazing material is present (referred as good brazed region) and remains low at the places where it is absent (referred as poor brazed). Since silver

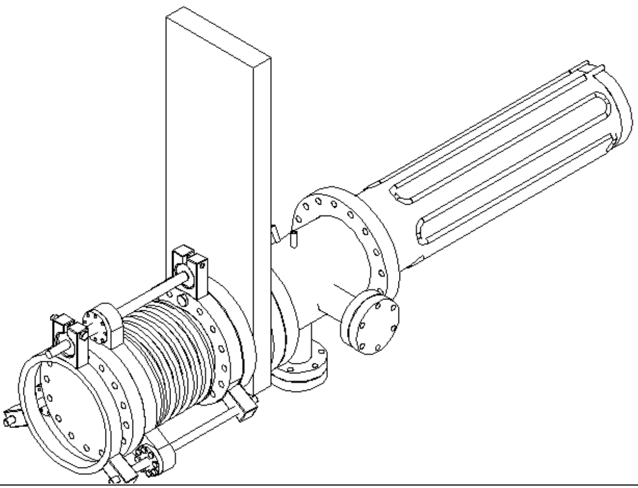

Figure A.1.1.2.1 Isometric view of the complete bolometer diagnostics. The part with cooling tubes were studied with active IRT.

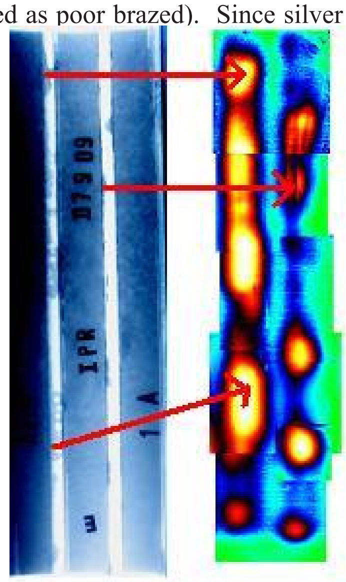

Figure A.1.1.2.2 Comparison of the thermograph (right) with the radiograph (left). Surface temperature (see thermograph) of the tube is high at the places where brazing material is present (see radiograph) whereas it remains low at places where the brazing material is absent. The third vertical tube seen in the radiograph is not visible in the thermograph because of the viewing line of the mirror.

(brazing material) has high heat conductivity and air has low heat conductivity, as soon as the hot water is flown in the tubes, it transfers heat to the inner surface at places where silver is present, whereas the absence of silver leads to gaps that restrict the transfer of heat and results in delayed temperature response. Thus the brazing quality may be described as "good" or "poor" by comparing the thermograph with the X-ray radiograph. All the bright areas in the thermograph correspond to the location in the radiograph where brazing material is present.

A.1.2.4 Heating and Current Drive Systems

Ion-Cyclotron Resonance Heating (ICRH) Sysem

ICRH system is getting ready for first phase operation of SST-1 at 1.5 T Toroidal magnetic field for which 1.5 MW rf system is required to operate at 45.6 MHz. Low power amplifiers, 2 kW and 20 kW stages are already made ready and 100 kW stage is being fabricated which will be used as a driver to 1.5 MW system which is already developed and partially tested up to 350 kW power. Integrated power supplies with all the interlocks will reach IPR soon. Automatic matching network is already tested to get a response time of 80 ms to have online antenna plasma matching. Fast ferrite tuner is also designed and is tested using VNA as well as 1 kW RF power to have on-line automatic matching which will be used on SST-1 in second phase. The high power test set up to test fast ferrite tuner at 500 kW is being made ready. The Vacuum transmission line (VTL) section of SST-1-ICRH system consists of a large number of RF components like 8 inch transmission line sections, reducers, edge welded bellows, movable finger joints, ceramic supports, vacuum windows with ceramic as dielectric, torque ring etc. The complete VTL section is actively water cooled from inner conductor and this necessitates a stringent water leak tightness of cooling tubes and vacuum leak tightness of inner conductor joints & outer conductors. Here are four such VTL lines for two ICRF launching structures 180 degrees toroidally apart. Due to involvement of large number of components and criticality in integrating them onto SST-1 vacuum vessel, a mock up assembly outside the machine is being carried out. All the functional tests like leak testing, ultra high vacuum, low power test and rf conditioning is initiated. A mobile Ultra High Vacuum (UHV) test stand is made ready for leak qualifying and UHV testing of VTL components. This T-shaped test stand is a turbo molecular pump based and also backed by a rotary pump. Suitable baking arrangement along with temperature indicator and controls are made. An ultimate vacuum of $2X10^{-10}$ Torr is achieved after 3 baking cycles at $100^{o}C$.

Generalized Test Facility for high power RF Devices : A variable 0-70 kV, 22 A power supply is being developed to test high power rf sources at different power levels. It consists of 11 kV to 1 kV step down transformer, 1 kV variable inductor system, step up transformer, 70 kV HVDC power supply and 70 kV solid state crow bar system. The voltage variation system and HVDC system is commissioned and solid state crow bar system is accepted at factory which will soon be commissioned at IPR.

Other Activites : The up-gradation of antenna test facility in terms of new magnetic field coils, better vacuum system and new magnet power supply completed. In order to produce plasma by different means, initially it was produced using two inclined electrodes and perpendicular magnetic field. It was observed that the plasma exists only in upper half of the electrodes and novel type of striations are observed in presence of magnetic field and electric field gradients. Further experiments are in progress. For future reactors one need to have higher MW transmission line and antenna and hence one needs to develop a combiner to combine the RF power and prototype of combiner upto 180 kW power level is designed and developed. RF characterization using VNA shows encouraging results and soon it will be tested for high power.

Lower Hybrid Current Drive System

The activities related to up gradation of the LHCD/SST-1 system is in progress. The two earlier klystrons have been interfaced with the auxiliary systems like electromagnet, klystron tank, cooling system, power supply system, data acquisition and control system and rf drive system. The tanks for the new klystrons have been fabricated, tested and installed on the new support structure. The filament transformer to be placed inside the tank is procured, tested and would be installed inside the tank. The special oil for the tank has been procured and would be filled into the tank once electrical and control components are integrated inside the tanks. The interlock and control card based on FPGA is being designed. The high voltage power supply (HVPS) (70kVDC, 20A) has been integrated with 11 kV input regulator and has been successfully tested. The solid state crow bar unit has been delivered to IPR and preparation work for its installation and commissioning is underway and is expected to complete soon. Routine testing and maintenance of diagnostics, klystrons, rf system and components is done regularly. The on-going computational studies employing LUKE and CRONOS code for SST1 is being carried out in collaboration with CEA, France. Experimental activities are also carried out on Tore Supra tokamak in collaboration with CEA, France. Contribution is also made in ITER LHCD system through CEA EFDA task and by participating in LH4IT working group. Collaboration activity in developing window material through NFP project is also undergoing.

Neutral Bean Injection (NBI)Heating for SST-1

For the hydrogen Positive Ion Neutral Injector source (PINI) mounted on the SST1-Neutral Beam Injector test stand consistent operations were carried out up to an acceleration voltage of 30 KeV with ion currents ~ 10 ampere. The attention of this group is now focused on enhancing the ion beam current to greater than 20 ampere. In order to meet these objectives the following tasks have been taken up: (a) Improvements in the discharge currents to values greater than 1000 ampere (b) Operation of the cryo-condensation pumps to handle the required hydrogen gas feed of ~ 60 torr-lit/sec (c) Establishment of active cooling for all the internal components along with the calorimetry. For executing these tasks certain important steps have been taken up, namely, ensuring a reliable high vacuum operation, providing the necessary safety for hydrogen operation, and implementing a test-run of the cryo-system. A major portion of the efforts were given to test the performance of cryo-distribution system, cryo-electrical isolators and flow controls. A leak proof operation of the LN2 system was achieved. Currently the system is being tested for LHe circulation and is being prepared for establishing the 'hydrogen-pumping' and controlling the residual hydrogen gas pressure. Also, measures are being implemented for reducing the time lag between the two phases of cryo operation i.e. regeneration and restart.

Activities related to the upgrading of ion source's filament power supplies (AC/AC converters) have been taken up, this step is necessary for increasing the discharge current in the plasma box of the ion source. New electrical diagnostics such as the high voltage measurements for the acceleration grid and the suppressor grid have been added. These diagnostics are useful in controlling the characteristics (ex. the divergence and back streaming secondary electrons) of the ion beam. Experiments are also being carried out to measure the plasma parameters for the ion source.

In the diagnostics, a new observation channel has been added to the Doppler shift spectroscopy. While the existing channel continues to provide data along the horizontal dimension, the new channel is capable of providing the data of the vertical dimension. This observation channel will improve the 'signal-to-noise ratio' of this diagnostic. Similarly, steps were undertaken for improving the signal-to –noise ratio of the calorimetric diagnostics (thermocouples). Specific experiments are in progress for examining these aspects.

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A.2. Fusion Technologies Development under X1th Five Year Plan

A.2.1. Fusion Relevant Prototype Magnet Development

Magnets (of intermediate sizes) realization along with establishment of an appropriate test facility towards testing these magnets had made significant progresses. More variants of the high current carrying high field Nb3Sn based superconducting strands in `Internal Tin' route of fabrication had been tried out successfully. Superconducting filaments of ~ 5 microns were targeted and were realized in green form. Simultaneously, the heat treatment (HT) schedules for these strands have been carried out in a parametric fashion towards their optimization from metallurgical characteristics. Bobbins of these HT strands have been prepared for their I-V characterizations. In parallel, the facilities for cabling up to 800 strands in four stages have been developed successfully. The conduiting of the cabled conductors and the swaging of these cabled conductors have been done successfully meeting the tolerance criteria. A special purpose winding machine for fabricating a 30 kA Cable-in-Conduit-Conductor (CICC) based winding pack had made significant technological progresses. This set-up will be fully realized by Oct 2011. As a validation of this important facility, a two turn double pancake shall be wound using this facility using indigenously developed NbTi based 30000 A CICC by Dec 2011. A deep hole drilling facility for producing Nb3Sn based strands on `internal tin' route has also been established.

Cynate Ester & Bisphenol-F FRP based radiation resistant insulation system has been developed for the prototype winding packs after several chemical and process characterizations. A medium sized laboratory scale vacuum pressure impregnation system has also been fully commissioned as a functional facility in IPR. During this period, the 30 kA pow-

Figure A.2.1.1. 30000 A CICC final stage wrapping.

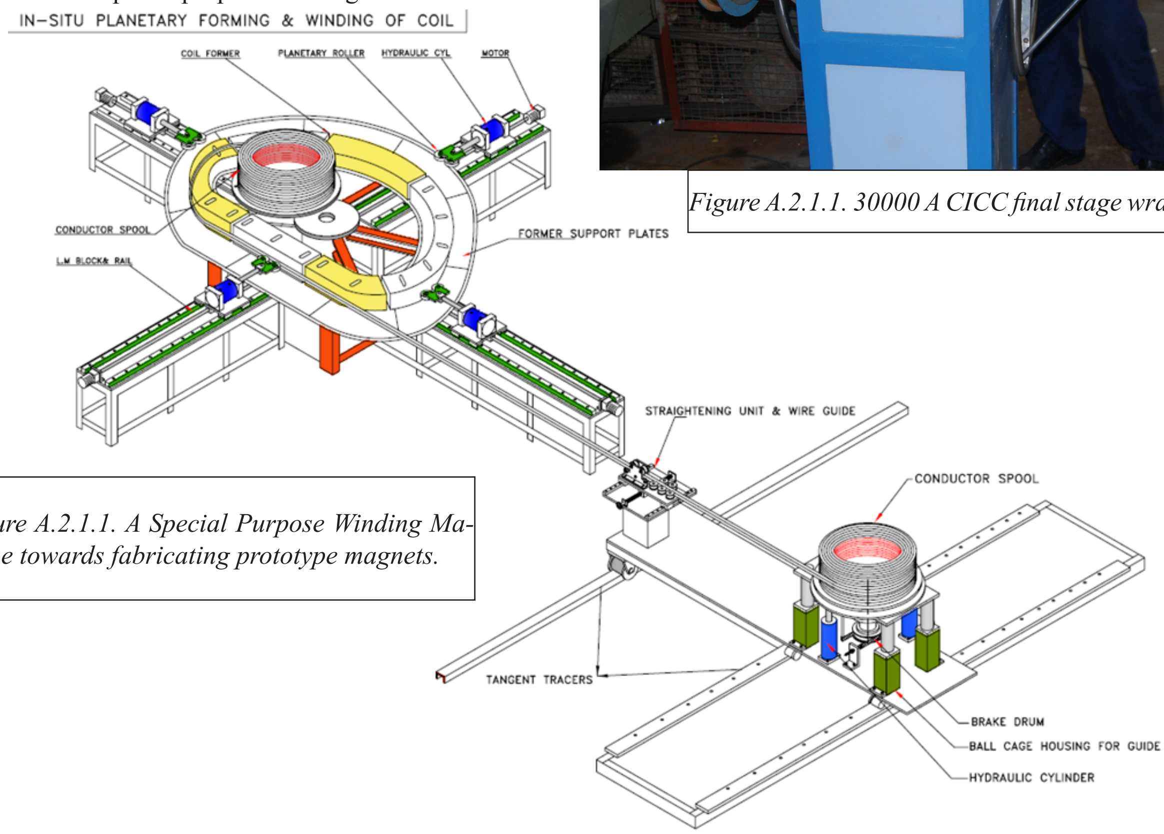

Figure A.2.1.1. A Special Purpose Winding Machine towards fabricating prototype magnets.

er supply meant for testing the fabricated magnets has been contracted to an Indian industry. Presently, the conceptual design of such a power supply is being reviewed. The bubble type thermal shield for testing the prototype winding packs in the prototype cryostat has been engineering designed. This thermal shield will be completely fabricated by Sep 2011. A joint helium cryogenic facility capable of providing 600 W with supercritical helium at 6 bar up to a mass flow rate of 40 g/s has been indented also.

A.2.2. Prototype Divertor Cassette Development for Fusion Grade Tokamaks

Prototype Divertors Division (PDD) of IPR deals with design and development of divertors for fusion grade tokamaks. During 2010-11, the division continued with work related to fabrication of divertor cassette body, developing fabrication technologies for divertor targets & dome, development of new tungsten based materials, procurement of high power electron beam system & ultrasonic flaw detection system, high heat flux testing of brazed test mock-ups.

Divertor target development : Divertor target test-mock-up is fabricated using high pressure high temperature sinterbonding process to join tungsten alloy mono-blocks with copper-alloy straight-tube. Physical and mechanical characterization of the tungsten-copper joint is done. Efforts are in progress at NFTDC (Hyderabad) for development of tungsten mono-block test mock-ups with curved-tube of copper-alloy and establish high heat flux test facility for thermal load testing of test mock-ups.

Divertor Cassette Body Development : Quotation received from Indian fabricator for fabrication of ITER-like Divertor Cassette Body and Support Structures for Divertor Vertical targets and Dome. Further techno-commercial discussions are in progress

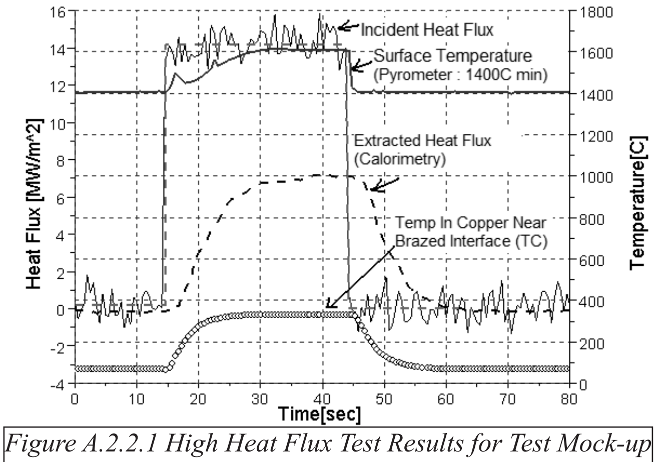

Figure A.2.2.1 High Heat Flux Test Results for Test Mock-up with Tungsten Tiles Brazed To Copper Alloy .

Tungsten Material Development: Indigeneous development of tungsten based materials i.e tungsten alloys and tungsten-copper functionaly graded materials for Divertor plasma facing material applications are in progress at IIT-Kanpur.

High Heat Flux Testing of test mock-ups: Brazed test mock-ups developed by NAL (Bangalore) with Graphite and Tungsten tiles thermally attached to surface of a copper-alloy block are tested for their thermal performance under high heat flux conditions. The experiments were performed at Plasma Materials Test Facility of Sandia National Laboratories (Albuquerque, USA) using EB-60 electron beam. Both graphite and tungsten test mock-ups could withstand several cycles of incident heat flux higher than $10MW/m^2$. Calorimetric measurements performed on the water cooled test mock-ups indicated extracted (absorbed) heat-flux of $7.5MW/m^2$ at highest incident power for graphite as well as tungsten test mock-ups.

Development of high heat flux test facility using electron beam:
(a)High Power Electron Beam System : Letter of Intent submitted to the selected party for supply of 200kW electron beam system ; (b) Vacuum Chamber and target handling facility: Tender documents released for fabrication of the vaccum chamber and target handling facility. Quotations are awaited from the parties. ; (c) High Pressure High Temperature Water Supply Loop : Portable (100 lpm, 20 bar, 80^oC) system is ready. Preliminary design for bigger system (300 lpm, 60bar, 150^oC) is prepapred, enquiry sent to parties for developing engineering design, quotations are awaited. (d) High Pressure High Temperature Helium Loop System : Preliminary design is made and enquiry sent to parties for engineering design and fabrication, quotations are awaited ; (e) Vacuum pumping system : Purchase order placed ; (f) Thermal diagnostics : Purchase order placed for IR-Camera ;

Brazing Studies and Brazing Experiments: Brazed joints are studied for their microstructural properties (using SEM-EDX) and temperature dependence of thermal diffusivity (using Laser Flash Technique). Computational studies performed to correlate thermal diffusivity measurements with temperatures observed on test mock-ups during high heat flux tests. Non-Destructive Testing using Infra-Red ther-

Figure A.2.2.2 Portable Water Circulation System (100 LPM, 80C, 20 bar) assembly prior to thermal insulation.

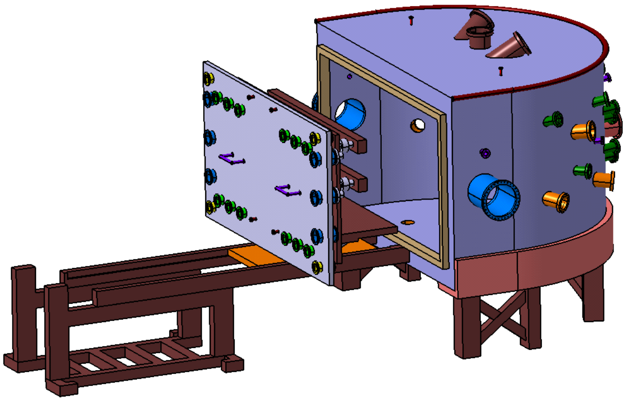

Figure A.2.2.3 Preliminary design of vacuum chamber for high heat flux test facility to be set-up using 200kW Electron Beam source

mography set-up is carried out to study quality of the brazed joints for various brazed test mock-ups. Experimental studies and Computational Analysis done to study the effectiveness of attaching fins to the test mock-ups in improving gas-quenching rates during cool-down cycle of brazing process. Brazing technology developed so far is being utilized for in-house development of brazed test mock-ups. Brazing fixtures with new design are developed and made ready for brazing experiments;

Divertor Test Stand for Remote Handling studies: Structual, thermal & thermo-structural analsysis of locking system between Divertor cassette body structure and test stand was carried out. Based on the structural results, a test stand design was proposed which was later optimized to obtain considerable material saving. Documentation on required studies to be done on locking mechanism & consequent product design of Divertor test platform from conceptual design was prepared.

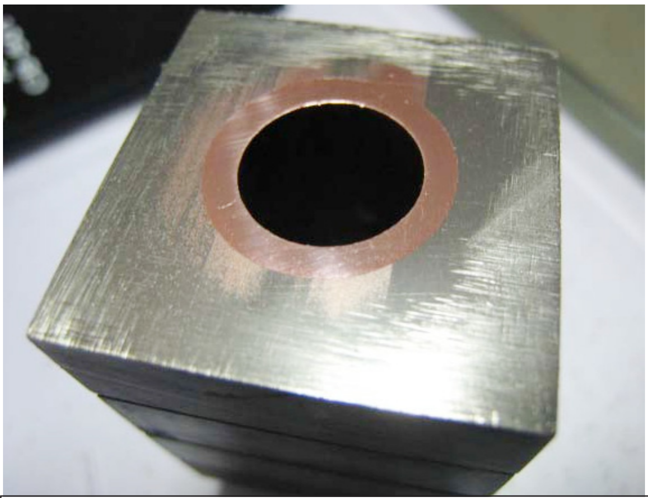

Figure A.2.2.3 Tungsten Mono-block fabricated by NFTDC using High Pressure High Temperature Joining Process

Other technology developments : Visits and/or discussions with various organizations/industries are in progress for development of other technologies of interest such as : (a) Development of Carbon-Fibre-Composite mono-block for divertor target ; (b) Tungsten and copper coatings for Divertor and Dome applications ; (c) Laser assisted powder coating/ cladding of materials for dissimilar material joining studies ; (d) Welding of dissimilar matels such as SS316LN to XM19 ; (e) Non-destructive testing of materials and joints ;

Procurement of various items: (a)Thermo-Mechanical Simulator: Interacted with SAIL (Ranchi), Quotation received from DSI (USA), techno-commercial discussions are in progress; (b) Ultrasonic Flaw Detection System: Quotations received, test samples with known defects sent to parties, flaw detection reports received from parties, party selected for further techno-commercial discussions; (c) Procurement of Infra-Red Pyrometers and IR-Camera are in progress; (d) Procurement of software for simulation of ultrasonic flaw detection and material property database are in progress;(e) Quotations received for Laser Flash Thermal Diffusivity measuring equipment, techno-commercial discussions are in progress; (f) Metallographic optical microscope procured;

A.2.3. Test Blanket Module (TBM)

Indian team is developing Lead-Lithium cooled Ceramic Breeder (LLCB) (half-port size) which has the characteristics of both Solid Breeder and Liquid breeder blanket concepts. The Research and development oriented towards this concept covers major technologies development required for the future DEMO blanket system. This blanket module will be tested in the one half of the ITER Radial Port no-2. The interface requirements between the TBM and the ITER machine are being worked out jointly with ITER organization, Cadarache France. The scientists and engineers from Institute for Plasma Research (IPR) are collaborating with DAE units (BARC, Mumbai and IGCAR Kalpakkam) through Memorandum of Understandings and are actively involved in the design and development of blanket modules and their associated technologies such as, Blanket Neutronics, Engineering Design, TBM Safety, Liquid metal technologies, Thermofluid MHD, Helium cooling systems, Lithium Ceramics, Beryllium pebbles, Structural Materials, Fabrication Technologies and Tritium Technologies specific to TBM program.

LLCB TBM Description : The typical dimensions of the LLCB TBM module are 1.66 m (h) x 0.484 m (w) x 0.57 m (t) in terms of poloidal, toroidal, and radial thickness respectively in tokamak environment (Refer Figure A.2.3.1). The LLCB TBM consists of ceramic breeder zones, which are cooled by the Pb-Li eutectic alloy. The flow velocity of the Pb-Li is moderate in order to remove the heat efficiently, which develops the MHD pressure drop. The ceramic breeder beds, which are filled with lithium titanate pebbles, act as partition for coolant and essentially become a part of structure. The ceramic pebble zones will be purged by a low-pressure helium flow for tritium extraction. The tritium produced in Pb-Li and ceramic breeder zones will be extracted by separate external ancillary systems. Preliminary engineering design of the LLCB TBM concept has been done. Thermal-hydraulic and flow analyses for LLCB TBM have been carried out in details to optimize the flow for keeping the PbLi, FMS and CB zones within their temperature limits. Further 3-D thermal-hydraulic and CFD analyses are required in order to final optimization of the LLCB TBM design. Structural design of the TBM, various other R&D activities such as High pressure He loop, PbLi loop technologies, and manufacturing feasibility studies of the LLCB TBM are under progress. LLCB TBM process systems such as Helium Cooling Systems, Lead-Lithium cooling system, Helium Purge system and coolant purification systems design are under progress. LLCB TBM Preliminary Safety Report (RPrS) to ITER is being prepared jointly by IPR and BARC.

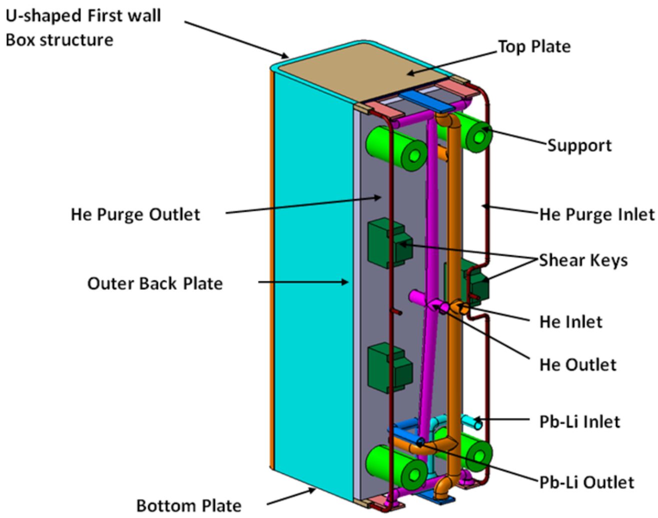

Figure A.2.3.1 Indian LLCB TBM Module

Progress in this financial year : Thermo-fluid MHD studies for LLCB TBM is under progress at IPR along with the experts from BARC, Mumbai and CPP, Guwahati. 2-D MHD code has been developed for rectangular straight channel and has been successfully validated with the available analytical results. Prediction of flow parameters at very high Hartmann number has also been successfully tested. Efforts are being made to capture the flow profile in circular pipes and flow transition regions, such as bends; expansion etc. The development of 3-D MHD code is also under progress. An experimental loop (mercury) is being set-up in IPR for MHD experiments to validate the code. The conceptual design of the loop has been completed. Currently the mechanical design of the loop assembly is going on along with the procurement of various diagnostics. Some of the critical components such as Mechanical pump, heat exchanger, piping are under fabrication at vendor site. The conceptual design of the process loops such as Helium Cooling System, Lead-Lithium Cooling System and Tritium Extraction Systems has been completed. Process flow diagrams for HCS, LLCS and TES have been prepared. The equipment layout in TCWS, tritium building and port cell are in progress. Number of pipes between IN-LLCB TBM (inside port plug) passing through pipe forest and bio-shield has been finalized. The pipe routing inside the pipe forest and AEU is a joint activity between CN-IN-IO which is under progress.

Indian LLCB TBS Process systems : IN-LLCB TBS requires interface with process system such as First wall Helium cooling system, Lead-Lithium cooling systems, Lead-Lithium Helium cooling system, Tritium Extraction system and coolant purification system. Following is the list of process systems provided for IN-LLCB TBM.

(i)First Wall Helium Cooling System (FWHCS): FWHCS is a high-pressure high-temperature system used for cooling TBM First Wall, top plate, bottom plates and back plates. The FWHCS is located in TCWS vault annex and it supplies the helium to the inlet of the TBM. The helium outlet from TBM is routed back to the TCWS. Depending on the tritium concentration in circulating helium the bleed line is opened to coolant purification system for purification and recirculation of helium gas.

(ii) Lead Lithium Cooling System (LLCS): LLCS provides required flow of liquid lead-lithium for cooling the TBM. The lead-lithium flows through the internal channels surrounding ceramic breeder compartments of TBM. The LLCS system consists of dump tank, mechanical pump, lead-lithium to helium heat exchanger and detritiation system all located in port cell. Trace heaters keep the complete loop at high temperature to avoid freezing of Pb-Li.

(iii)Lead Lithium Helium Cooling System (LLHCS) : LLHCS extracts the heat from circulating Lead-Lithium to helium and transferred to helium to helium heat exchanger located in TCWS vault. This system is independent from FWHCS. The Process parameters for both FWHCS and LLHCS are similar. However, separation of two systems increases the availability of FWHCS.

(iv) Coolant Purification System (CPS) : During the high temperature operation, there is possibility of tritium permeation from TBM and from vacuum vessel into the flowing first wall helium and getting contaminated. Apart from tritium there are other possibility of impurities from channels contaminates the helium. Such impurities are removed by the CPS gradually by connecting a bleed line from FWHCS to CPS. The CPS removes both gaseous and solid impurities present in the system fluid.

(v) Tritium Extraction System (TES) : TES is combination of helium purge gas system and tritium extraction system. The system uses low-pressure helium with 0.1% hydrogen as purge gas in order to sweep the tritium from the ceramic pebbles. Tritium extraction system extracts tritium from helium purge gas from ceramic breeder and tritiated helium gas from lead-lithium detritaition system. The TES is located in tritium building. as well as in de-tritiation column.

LLCB TBS equipment layout : Each process systems have various types of equipments. The equipments belonging to specific systems are arranged in designated area. Equipments layouts are worked out with following major considerations, which are challenging in the limited space environment:

Identical Equipments are grouped together to help in making the layout compact and to give a adequate excess from considerations of maintenance.

- Equipments are also arranged to help for easily connecting the pipes.
- Layout also takes in considerations the arrangement of electrical supply cables and cable trace.
- The present layout is not analyzed in detail, this will need more iterations. It is felt that based on flexibility analysis of piping and need from considerations of reducing Pb-Li inventory in the pipes; the equipment layout may change to a small extent. The same shall be presented during the next stage of review.
- Routine requirement from considerations of industrial safety are also considered during working out the layout of process system components and piping.

The Figure A.2.3.2. shows the Preliminary layout of Indian LLCB TBM process systems in ITER-Port cell no-2. This area consists of equipments primarily of Lead-Lithium cooling systems and some systems form Helium cooling systems and tritium extraction systems with piping.

LLCB TBS Process Control System : The LLCB TBS I&C system includes a variety of equipments viz. sensors, actuators, controllers, network switches, local display terminal intended to perform display, monitoring, control, protection and safety functions. The LLCB TBS I&C system is designed to meet all the functional requirements. Monitoring of parameters in the system (LLCB TBS) like temperature, pressure, flow, level, tritium measurement and leakage is done remotely. Local indication is considered in field instruments where human access is possible. Alarms are integral part of the control system that shall recognize and report alarm event and condition to the operator in an organized, unambiguous, and convenient manner. Alarms shall be generated when in case of any abnormality during operations or on exceeding preset limits for measured parameters. Port cell area primarily houses components for Pb-Li cooling system. Typi-

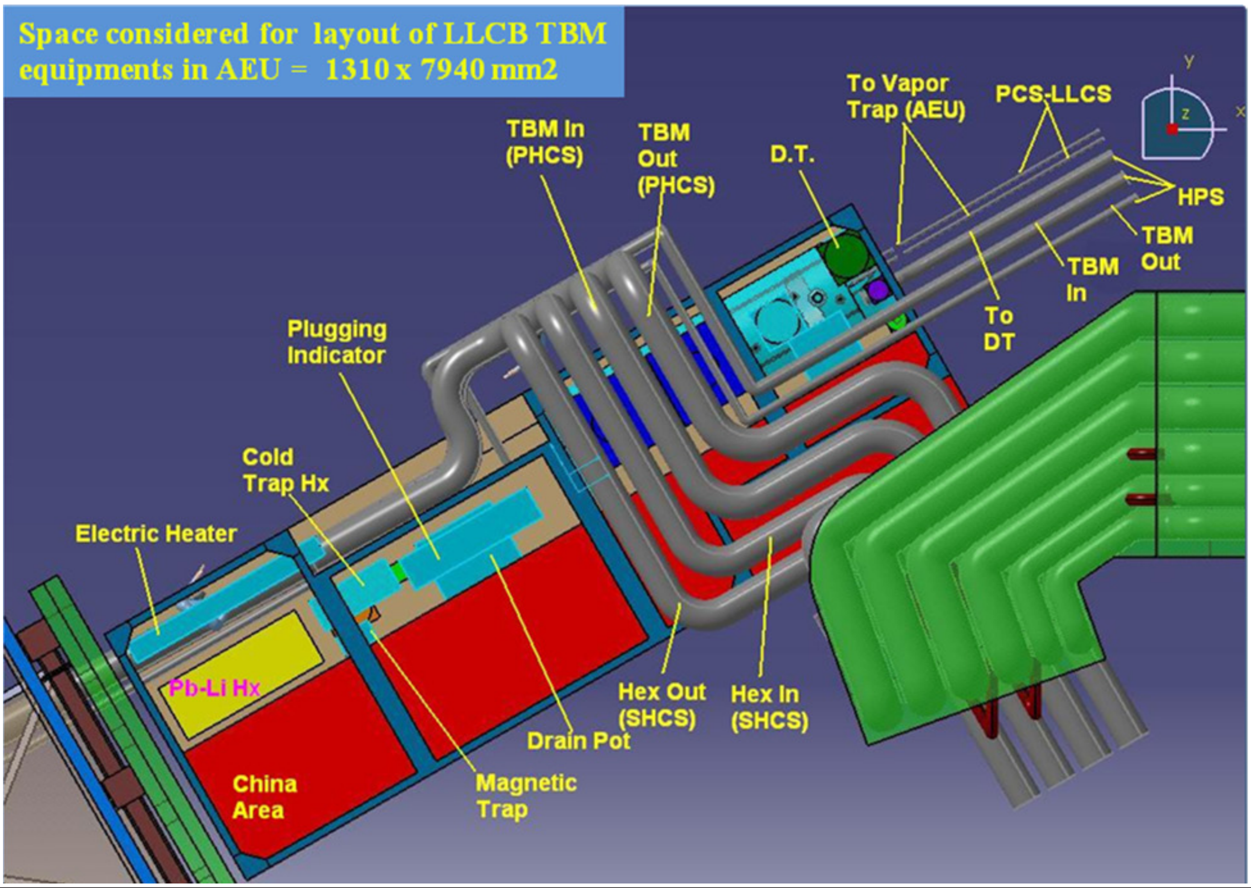

Figure A.2.3.2 Preliminary layout of Indian LLCB TBM process systems in ITER-Port cell no-2

cal equipments are pump, heat exchanger, electrical heater, cold trap, detritiation column etc. It has independent cover gas system for filling of Pb-Li in the loop, draining of Pb-Li to the dump tank and to absorb the volumetric expansion of liquid metal in the stand-by sump tank. The systems have additional active components in form of control valves. The systems have necessary instrumentation for measurement of process parameters. The major maintenance activity envisaged in the port cell area has been worked out. Safety analysis for LLCB TBS is under progress. The RPrS for LLCB TBS is under preparation. Regarding the layout in AEU, Pipe forest and bio-shield the joint activity with IO and CN has been initiated. Indian TBM team will participate in the preparation of proposals for ITER interface in port-2.

TBM related R&D Activities : An MoU has recently been signed between Institute for Plasma Research (IPR), India and Institute of Physics, University of Latvia (IPUL), Latvia to jointly carry out MHD and corrosion experiments with hot Pb-Li (~350 ^{o}C) as the working fluid. MHD experiments have been planned to simulate flow profile in LLCB TBM like geometries in the presence of 4T magnetic field. First experiment has been performed in a simple rectangular channel having two L-type bends. The results from these experiments will be useful in the final design and performance analysis of LLCB TBM and also for MHD code validation. In parallel, technologies for the development of critical equipments/diagnostics related to Pb-Li loop operation are being explored.

Development of buoyancy loop with molten lead-lithium is under progress at IPR. This will be achieved by maintaining the cold and hot legs of the loop at 450 and 550^{o}C. The loop is expected to have flow velocity of ~6 cm/sec and its commissioning is expected in May 2011.

A pump driven loop was set up at IPUL, institute of Physics, University of Latvia, as a part of collaboration between IPR and IPUL, to study the corrosion of Ferritic Martensitic steel samples, P91 (9 Cr, 1 Mo) in flowing Lead Lithium, at a temperature of 550^{o}C, in the presence of magnetic field. Flat and Tensile samples, made out of P91 material were used for corrosion studies. The initial corrosion experiments are carried out for 1000 hours. The corrosion samples were P-91 specimens. The samples were characterized at various labs within India and database is generated.

An experiment is being setup in IPR to study the corrosion of coated samples with static Lead Lithium initially at 500^{o}C. At a later stage the same system will be upgraded to rotate the samples in Lead Lithium at required velocity to simulate the flowing Lead Lithium case.

Graphical User Interface (GUI) was developed for calculation of the atom densities of the nuclides present in a mixture of materials. This program has a capability of taking a user defined gram density and the volume fraction of a material in the given mixture and it is very handy tool for the Monte Carlo transport calculations. A 1-D neutronic analysis was carried out for HCSB EU DEMO to understand the optimal geometric configuration of Beryllium and Ceramic Breeder. A neutronic analysis of the LLCB TBM first wall was carried to obtain the power density in the first wall. The ITER neutronic model Alite-4 was used for the Monte Carlo calculations.

Reduced Activation Ferritic Martensitic steel is a structural material, which is under development at MIDHANI, under the guidance of IGCAR experts. Detailed investigations are under progress in the tensile, creep and ductile-brittle transition behavior of this steel. The initial studies have confirmed that the Indian RAFM steel possesses the required microstructure, creep rupture strength, elevated temperature tensile strength as well as very low ductile-to-brittle transition temperature. Systematic investigations are being carried out to optimize the steel development, fabricability of the material and characterization of Indian RAFM steels for ITER-TBM program. Structural material mechanical properties testing facilities are being set-up at IPR. Dedicated metallurgists, mechanical engineers and chemical engineers from IPR are working towards the blanket materials R&D program.

In parallel, various critical technologies such as tritium extraction systems, corrosion studies, ceramic pebble development, TBM safety, Beryllium pebbles manufacturing, full scale TBM fabrication techniques, Robotics, Instrumentation & Control systems for TBM are under progress at BARC and IPR.

The LLCB TBM will have both tritium extraction from helium purge gas of ceramic breeder and tritium extraction from the Pb-Li loop. The gas-liquid contactor is under proposal for the Pb-Li system whose design is underway. The main objective of the Tritium Extraction System (TES) is to extract as much tritium as possible (>97%) from the breeder zones and purify the circulating streams to maximum possible extent (up to ppb level). The equipment of Tritium Extraction System (TES), such as Atmospheric Molecular sieve Bed (AMSB) and Cryo Molecular Sieve Adsorber Bed (CMSB) and helium-water shell & tube heat exchanger have been designed. An experiment to study permeation of hydrogen isotopes through structural materials of IN-LLCB TBM is conceived. Design of the experimental set up is complete.

Recently, an MOU on “Technical program of cooperation between Institute for Plasma Research (IPR), India and Russian Federation institutes: NIKIET, Efremov and Kurchatov Institutes” was signed on 14 January, 2011. This MOU defines areas of scientific and technical collaboration in joint development of Indian Lead Lithium Ceramic Breeder (LLCB) Test Blanket Module. IN and RF shall exchange the results of R&D and design work performed on Indian LLCB TBM concept and discuss them at joint workshops.

IPR scientists and engineers visited Institute of Physics, University of Latvia, Riga for three months duration in two batches for working in Liquid Metal loop experiments.

Regular meetings with ITER Organization such as PMG-2 meetings, TBM-PC meetings are attended by Indian delegation consisting of IPR members and experts from DAE units.

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A.2.4 Negative ion Beam Source

Consolidation of procurement activities to ensure realization of the objectives of the ROBIN experiment, commissioning of hardware, experiments on characterization of Cs distribution and experiments on production of RF plasma formed the core activities under the –ve ion source & technology program. A summary of the activities are presented below:

Procurement & Commissioning:

A)Power supplies:

Procurement contract for extraction and acceleration power supplies : The procurement contract for the High voltage power supply (HVPS) system for the –ve ion source has been awarded to Gandhinagar based power supply manufacturer M/s Veeral Control Pvt. Ltd. The power supply system includes Extraction (11kV, 35A DC) and Acceleration (-35kV, 15A) HVPS along with the incomer LT panels, high voltage cables, Earthing and isolator switches, remote monitoring and control units, oil cooled resistive dummy load and all other accessories to make the system complete and operational. A modular topology is adopted for the power supply with fiber-optic based signal interface. The system is presently under the engineering design phase. Manufacturing and demonstration of the first modular unit is expected shortly. Meanwhile, the infrastructure development activities to house the power supplies are already going in consultation with Ahmedabad based architect M/s HCP Design Pvt. Ltd. The architectural layout plan of the HVPS building has already been finalized and tender for construction is expected to be released shortly.

Procurement of 2MVA distribution system for the HVPS system

(a) 2MVA 11/0.433kV transformer : In order to cater the AC incomer requirements of the HVPS system and other experimental needs, a 2MVA 11/0.433kV distribution system has been designed and is presently under procurement phase. The AC power from the 11kV grid system of IPR will be stepped down to 433V for LT distribution through a 2MVA, 11/0.433kV distribution transformer. This ONAN cooled transformer will be equipped with all necessary protections and all the routine and type tests shall be performed for the conformity of performance. The contract for design and manufacturing of the transformer has been awarded to M/s PETE Transformers Pvt. Ltd. Hyderabad.

(b) 3200A LT distribution panel : In order to distribute the power available from the 2MVA transformer, an AC LT panel distribution system has been designed. The panel will receive the power of the transformer through a 3200A, TPN copper bus duct. The incomer feed a 3200A ACB, which then distributes the power in four outgoing feeders rated for 1250A and 800A. All the feeders are protected with ACBs provided with overload, short-circuit and earth fault protection. In addition to UV/OV protection is also in the incomer breaker. The contract for the design and manufacturing of the panel has been awarded to M/s Laxmi Engineering Pvt. Ltd. Ahmedabad.

Optimization of RF matching circuit : The RF matching circuit, which is used for matching the plasma impedance with the generator impedance, has been optimized for reducing the inductive effects. The matching circuit has been re-assembled in a stacked manner with Shunt capacitor circuit at the bottom, 100kVA 1MHz RF isolation transformer in the middle and Series capacitor circuit on the top (Refer figure A.2.4.1). In addition to this, a compact centrifugal blower has been added over the RF matching transformer in order to provide additional cooling of the circuit. The complete matching circuit has been supplemented with a local shielding in order to avoid radiation propagation. In addition to this, a stepper motor based, PLC controlled, remote capacitor tuning system has been designed and procured. The remote tuning system is presently under commissioning phase.

Figure A.2.4.1 A view of the optimized RF matching circuit

Installation of grid heating and grid-bias power supplies : For heating and biasing the grids of the ion source for the extraction phase of operation, the heating and bias power supply rack has been upgraded with Grid heating and bias power supplies. The SMPS based power supplies rated for 33V, 66A and 60V, 10A DC (for Grid bias and Grid heating respectively) have been procured from Xantrax USA. The power supplies are equipped with sophisticated features like remote turn on/off, remote programmability etc. The power supplies have been interface to the data acquisition and control system of –ve ion lab and have been tested successfully for full rating (over dummy loads) both in CV and CC modes. It is planned to interface the power supplies with the grids, once the grid-assembly of the ion source is delivered.

Commissioning of 3 Nos. (5 KVA) UPS for DACS system : For uninterrupted and efficient operation of the source all the DACS hardware i.e PXI system rack, PLC system rack ,FO module rack and spectroscopy rack are required to be supplied with UPS. For this purpose three UPS of 5KVA(each) capacity have been installed in the lab for all the DACS hardware .

B)Development of DACS

In house Design, development and testing of Prototypes of different types of Fiber optics links required for front- end signal conditioning in DACS system of the negative ion source :

Prototypes of the following mention fiber optics links that contains transmitter modules, receiver modules, power supply and fiber cables are designed, developed and successfully tested for following required specifications and distance up to 300 meter with HCS cable, 30 meter with Plastic cable. Based on the prototype testing, developments of final circuit layouts and PCBs of all the modules of links are started.

(a) 1 channel Fast fiber optics link for Analog signal
(b) 1 channel slow fiber optics link for Analog signal
(c) 8 channel slow receiver card for Analog signal
(d) 1 channel Fast fiber optics link for digital signals
(e) 8 channel fast fiber optics link for digital signal
(f) Power Supply with 500 VDC isolation

Integration and testing of following mentioned upgraded/new sub-systems with DACS (Data Acquisition and Control System) (i.e interface hardware installation, GUI and control program development and data acquisition program development etc.)

(1) Water cooling system
(2) MFS based Gas fed system
(3) PG bias an PG heating power supply systems
(4) Spectroscopy system

Data acquisition software is upgraded and tested for reports generation facility and memo (master excel) file generation of every shot. User can generate report of every shots in four different templates depending upon the operating mode. One report of only RF mode generated from the DAQ software is shown in the figure A.2.4.2

C)Experiments & Diagnostics

RF Compensated Langmuir Probe: A RF compensated Langmuir Probe that have been designed and fabricated for use in the 1MHz,100kW RF ion source of the negative ion lab of IPR, was tested on table top (bread board) by giving power from a signal generator and the LC filter used there was shown to work properly for the first three harmonics of the RF signal(up to -20dB). Its use in ROBIN (practically) will be tested shortly. Based on the same principle, another RF compensated probe is tested in an 1kW 13.56 MHz inductively coupled RF plasma at IPR. The parallel LC filter in the probe was tuned in such a way that the ratio of output to the input impedance of the probe was nearly 100 at the resonant condition and so nearly 1% of the RF voltage drop was appeared across the probe-plasma sheath. The plasma parameters were calculated from the characteristics of the compensated probe as well as an uncompensated probe. It was found that the temperature measured from the compensated probe was less than that of the uncompensated one, which is in good agreement with the findings of other researchers doing research in similar plasma.

Commissioning of subsystems:

Cooling water system: Different components of the negative ion source and RF generator need to be cooled by flowing low conductivity cold water (<1 μS/cm, 20^{o}C) during beam extraction. For this purpose, a cooling water system of 500 LPM capacity has been installed in negative ion lab. The cooling water system has multiple lines to supply water in each component. Each line is equipped with flow meter (rotameter

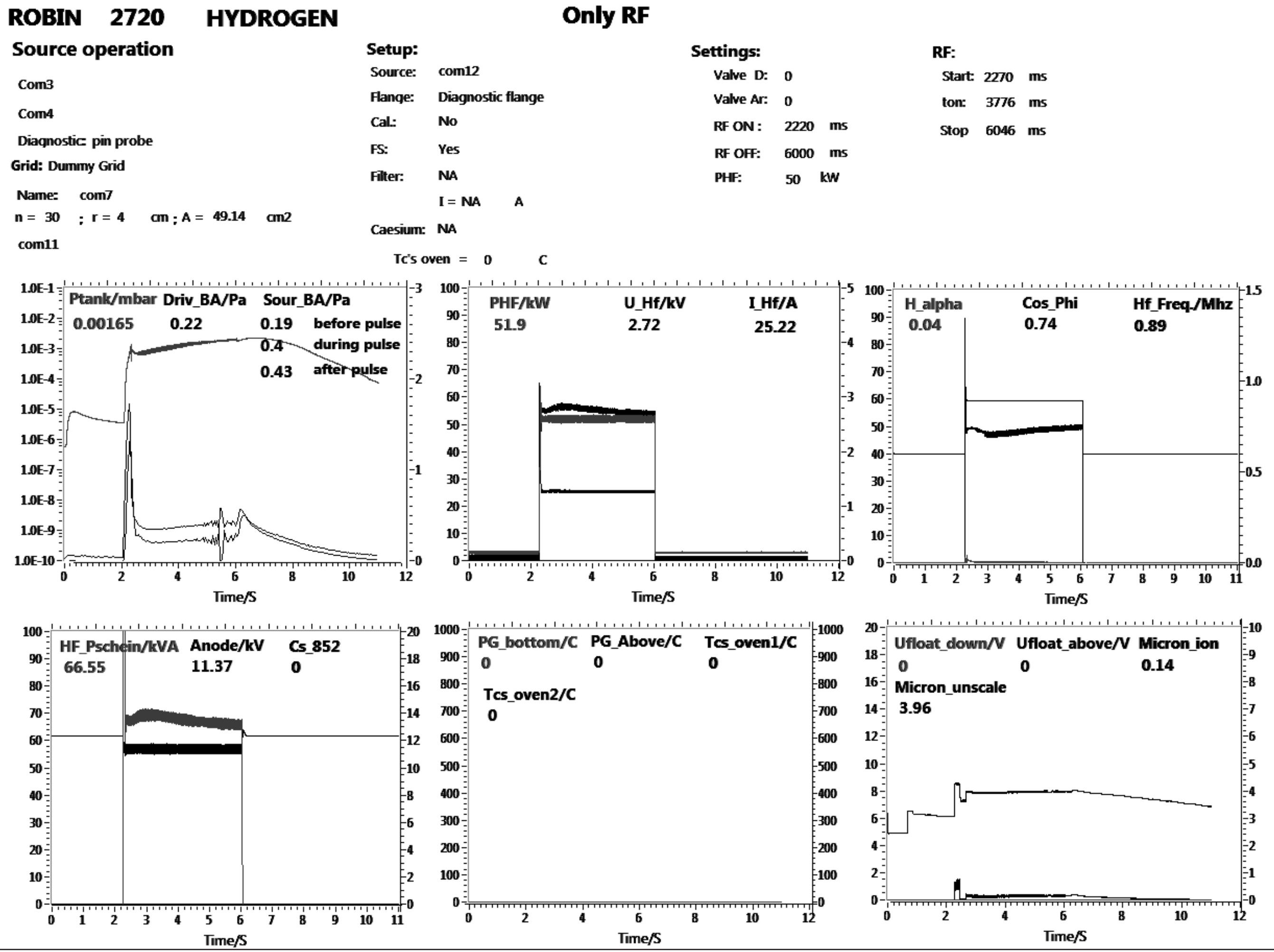


Figure A.2.4.2 A typical screen of the DAQ software in the RF mode

and turbine flow meter) and ball valves at the inlet and outlet to control the flow rates. Temperature transmitters are also installed in the return lines for calorimetric measurements during the source operation. The conductivity of the supplied water is checked by conductivity meter installed in the supply line. The water is supplied into the source components at a pressure of 7 – 10 bar whereas in RF generator components it is 4 – 6 bar which is achieved by a pressure reducing valve in the line. The safety relief valves have been installed at appropriate locations to avoid any accidents. The cooling water system has been interlocked with source operation using PLC to avoid any accidental operation of the source in the absence of proper cooling. The cooling water system is already being used successfully for ion source experiments. The heating water system has been procured which will be used to cool specific components of the source during beam extraction operation with cesium. The typical supply temperature from this system would be 400^{o}C to avoid any Cs accumulation on the source walls. The heating water system will be commissioned with cooling water system soon.

Gas feed system :A new gas feed system based on mass flow controller (MFC) has been installed to achieve a constant pressure inside the source during the pulse length. Using this gas feed system, different operational pressures of the source are achieved quite easily. The MFC is operated/controlled by PLC to setup the desired source operation pressure and puff pressure when the plasma is ignited. To avoid the RF induced errors in the MFC, the MFC is shielded properly. The typical operation pressure of the source is 0.4 – 0.8 Pa and the puff pressure is 1.4 – 2.0 Pa.

Vacuum Vessel: The vacuum vessel (~2.5 m long, 1.0 m diameter) of stainless steel with support structure is in the final stage of fabrication and will be installed/commissioned soon in the negative ion lab. The negative ion source with extraction system will be installed on this vessel which will be evacuated using a TMP of 5000 l/s capacity and cryopump of 15000 l/s capacity. The base pressure in the vacuum vessel and ion source would be ~1×10^{-6} mbar. One specially made ISO500 gate valve will isolate the ion source from vacuum vessel.

The vacuum vessel has many ports for the diagnostics such as Doppler shift spectroscopy, vessel pressure, quadrupole mass analyzer, calorimeter temperature and flow meters.
The operation/control of various gate valves, pneumatic valves, vessel pressure have been interlocked using PLC system for safe operation of the ion source.

Cryopump: One adsorption cryopump of 15000 l/s capacity has been procured to be used during the beam extraction experiments. The cryopump has been successfully tested in the lab. The pumping speed of this pump has been found in excess of 30000 l/s for hydrogen.

Compressor system:
One air compressor has been installed for the operation of different pneumatic valves during the ion source experiments. The compressor is equipped with 300 L capacity air tank, air filter and refrigerated air dryer. It can deliver compressed air of 30 cfm at a maximum pressure of 12 kg/cm^2.

Figure A.2.4.3 Adsorption cryopump for negative ion source experiments

Experiments:
Caesium oven system:
A caesium oven has been designed, fabricated and operated for characterization of the performance of the oven and distribution profile. The flow rate and angular distribution of cesium flux coming out of the oven have been measured with a specially fabricated surface ionization detector (SID) probe. This qualifies the Cs oven that needs to be deployed for the ROBIN/BATMAN experiments. The experiment shall be further advanced to carry out measurements using a multi-nozzle based distributor, to assess the feasibility of deploying a single oven for large area source.

TWIN RF Driver Negative ion source design activity : Under Indian program, experiments initiated with the objective of understanding the physics and technology of RF based negative Neutral Beam systems for ITER, INTF-DNB and future fusion machines. In this voyage, experimentation on a single RF driver based negative hydrogen ion source (ROBIN) has already been started as a maiden step. The intermediate step between single driver ROBIN and eight-driver INTF-DNB, an experimental system consisting of a two driver based source powered by a single 1 MHz, 180 kW RF generator is designed.

Plasma of density ~ 10^{18} m^{-3}, in a volume of ~ 0.5 m^3 chamber shall be produced in this experiment from which, extraction of ~ 8 A of negative hydrogen ion current @ 50 kV, is

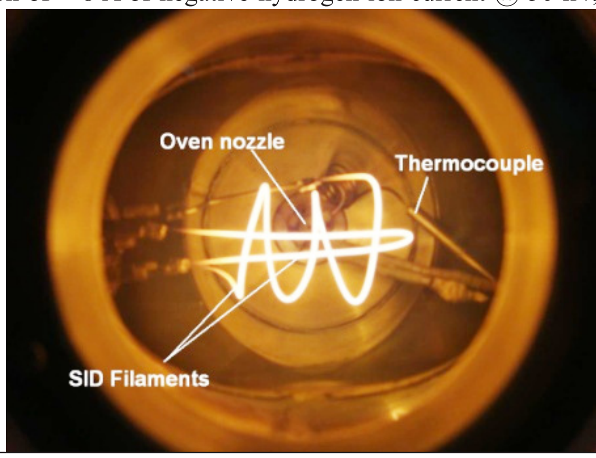


Figure A.2.4.4 Cs oven experimental setup

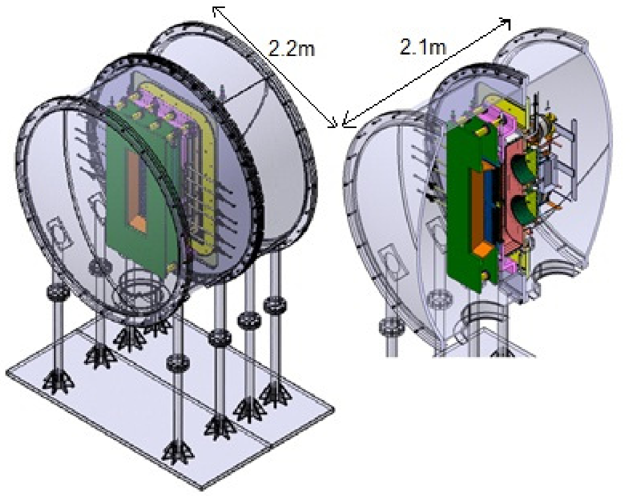


Figure A.2.4.5 Isometric view and vertical cross-sectional view of the two-driver ion source setup.

foreseen. Power is launched though an actively cooled coil mounted on each of the driver. Adequate flexibility has been incorporated in the system configuration to test configurations of the coupling under atmospheric conditions, or inside a vacuum chamber. The primary or immediate objectives of the two driver source experimental program are, (1) two RF drivers are driven by single RF Generator, (2) remote tuning of matching circuits kept under vacuum through control system, (3) to understand the mutual influence of the RF coil antennas on the source operation, (4) Modulated operation (5Hz, 3s ON-20s OFF) with two driver and (5) ITER type plasma grid (PG) current filter field operation and its influence on plasma production (in beginning phase) and on beam extraction (in the following phase).An isometric picture and a vertical cross-sectional view of the two-driver source is shown in figure A.2.4.5.

Progress in manufacturing of accelerator system of ROBIN ion source: At the works of M/s PVA, Germany, the manufacturing of the accelerator system of ROBIN ion source has progressed quite considerably. In next few weeks the accelerator assembly will be ready for the final acceptance tests as per requirements. First level of acceptance tests have already been carried out on the accelerator assembly in March 2011, however, some modifications were required related to the interfaces of the cooling water hoses which will be tested during final acceptance tests in June 2011(figure A.2.4.6).

Figure A.2.4.6 Accelerator assembly of ROBIN ion source under pressure testing at the works of M/S Tepla

A.2.5 Neutronics

Neutronics studies related to fusion blankets using 14-MeV neutrons are underway at the Institute for Plasma Research. The neutrons are generated using the T (d, n) 4He reaction. A sealed neutron generator of 1010 n/s yield and a pulsed neutron generator are available for carrying out the experiments. In addition, an accelerator based 14-MeV neutron generator is under development where 1 mA deuterium beam acceler-

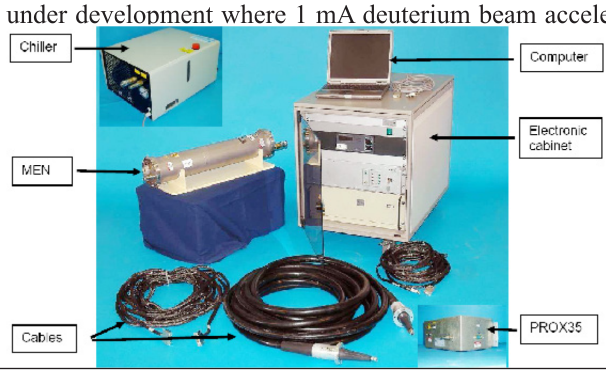


Figure A.2.5.1 The 14 MeV Neutron generator (GENIE35) with subassemblies ated up to 300 keV impinging on a 20 Curie tritiated target would produce nearly isotropic 14-MeV neutrons. The expected neutron yield is 10^{11} n/s.

A.Sealed 14-MeV neutrons generator.

Specifications

Neutron Energy: 14 MeV (DT)
Neutron Yield: >1010 /s
Neutron tube life time: >2000hrs
Pulse rate: 10Hz to 10KHz
Minimum pulse width: 30 us
Power Supply: 230 V, 3 kW
Size (D, L): 150X 800mm

B.Pulsed Neutron Generator.

Specifications

Neutron Energy: 14 MeV(DT)
Neutron yield: 10^{10} /s
Neutron tube life: >400 Hrs
Pulse rate: 1 to 100 Hz
Duty factor: 1% to 100%
Pulse width: 0.8 us
Power supply: 230V, 500 Watts
Size (D, L): 130X 1000 mm

C.Accelerator Based 14-MeV neutron Generator.

Specifications

Beam Energy maximum: 300KeV

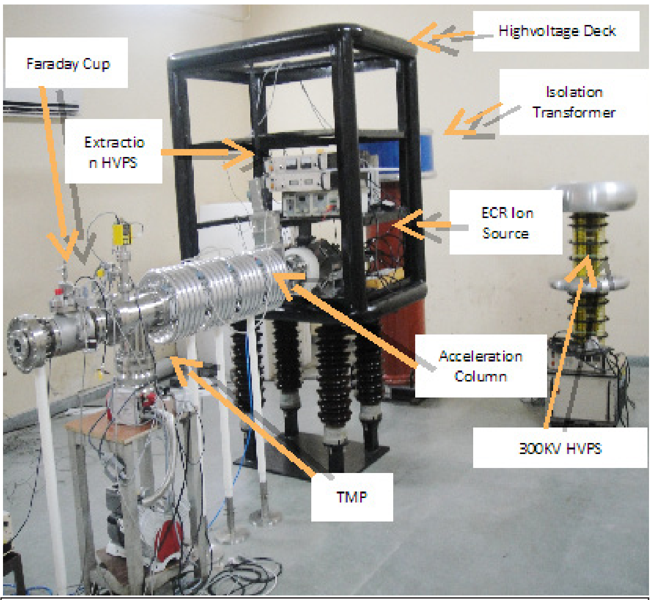


Figure A.2.5.2 Partly Assembled 14-MeV Neutron Generator

Type of Ion Source: ECR Ion source
Beam Current at the target: 1 mA
Beam Spot size: 15mm
Tritium Target Activity: 20 Ci
Target Diameter: 35mm
Neutron yield : 10^{11} n/s

The neutron sources have been used for the neutronics design experiments for the International Thermonuclear Experimental Reactor (ITER) blanket. The planned experiments include the neutron shielding for the ITER TBM (Test Blanket Module), Tritium production measurement in blanket breeder materials (Li2TiO3-BeO and Li4SiO4), Decay heat experiments, neutron induced γ-activity studies in blanket materials, neutron-induced reaction cross-section measurement in fusion materials etc. The sources will also be used for the 14 MeV neutron and Tritium diagnostics development.

D.Facilities for Neutron Induced Activation Analysis

1.High Purity Germanium Detectors(HPGe)(figure A.2.5.3 a)

- HPGe detector of 20% efficiency are being used for prompt gamma, neutron induced gamma measurement.
- High energy resolution
- Wide Energy range

2. Gamma scintillation detectors (figure A.2.5.3 f)

- BGO and NaI Detectors proved good signal to noise ratio.
- High Energy resolution
- Short decay time
- High absorption efficiency

E.Facilities for Neutrons detection

1.Neutron Detectors (figure A.2.5.3 d)

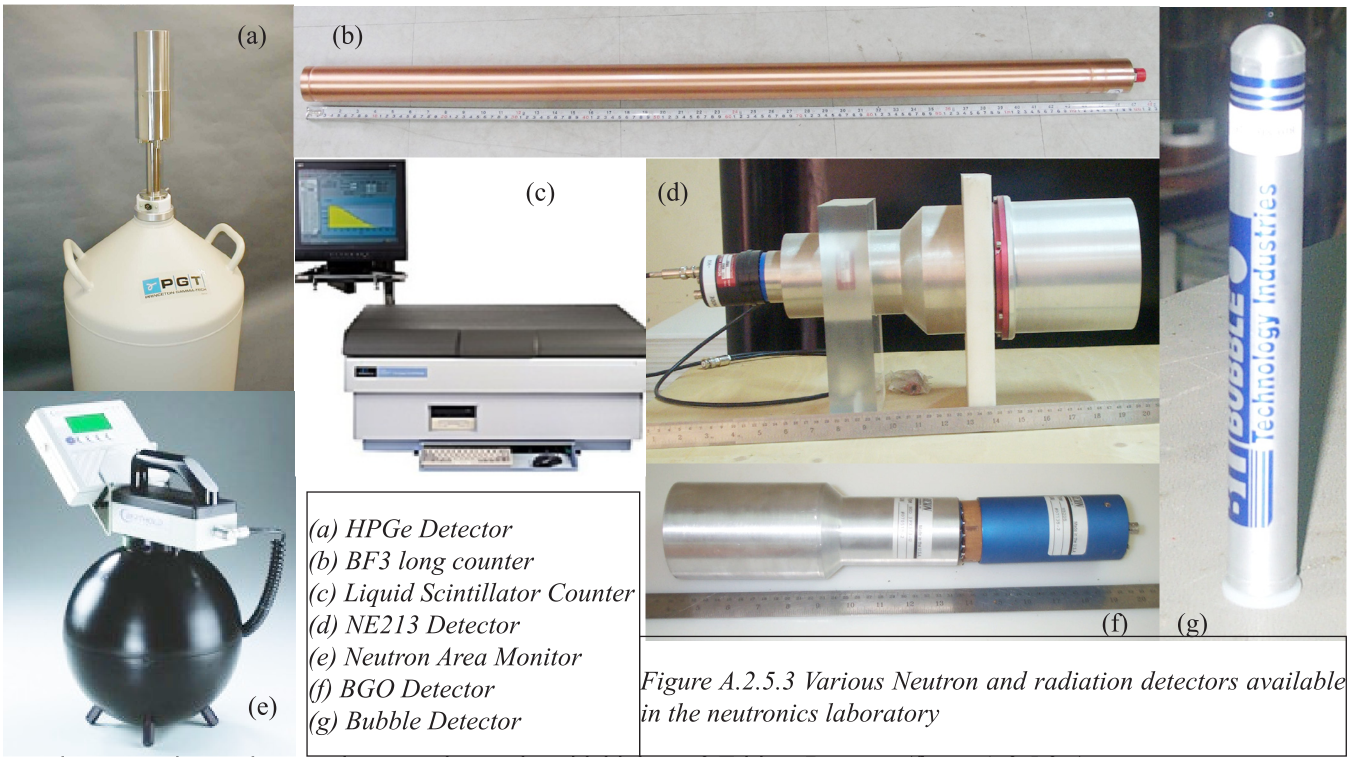
- NE213 Liquid scintillation detectors are used for neutron-gamma discrimination measurement

2.BF3 Detector (figure A.2.5.3 b)

- Gas filled BF3 detector is used for thermal neutron measurement.

F.Radiation Monitoring facilities

Ionising radiations cannot be seen, felt or sensed by human body in any way but excessive exposure to them may have adverse health effects. In order to avoid excessive exposure, appropriate and efficient radiation-measuring instruments are needed. It is not only important to measure (monitor) the radiation exposure at a place where there is a potential of radiation exposure but also the instrument used for monitoring



(a) HPGe Detector
(b) BF3 long counter
(c) Liquid Scintillator Counter
(d) NE213 Detector
(e) Neutron Area Monitor
(f) BGO Detector
(g) Bubble Detector

Figure A.2.5.3 Various Neutron and radiation detectors available in the neutronics laboratory

must be appropriate and easy to interpret the results with high degree of accuracy. Following radiation monitoring instruments are available in Fusion Neutronics Laboratory.

1.Bubble Detectors (figure A.2.5.3 g);
2.Neutron Area Monitor (figure A.2.5.3 e);

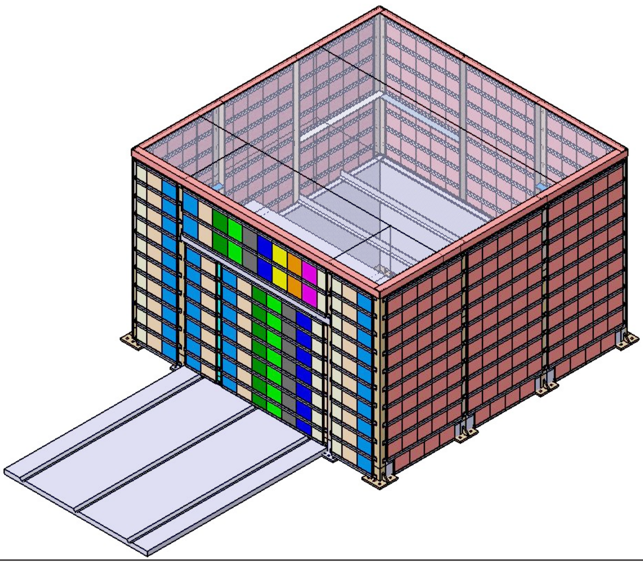


Figure A.2.5.4 Local Shielding for sealed Neutron source

3.Tritium Detector (figure A.2.5.3 c).

G.Local Shielding Design for sealed Neutron Source.

IPR has procured a 14 MeV neutron generator of strength $1x10^{10}$ n/s. It has to be shielded against the neutron and gamma radiation to protect the people working in the facility and the shielding design has to be evaluated and approved for the mechanical integrity. The shielding parameters have been estimated using the monte-carlo code MCNP and has been approved by AERB. All the volume except the neutron generator cavity has to filled with shielding in such a way that there should not be any scope streaming. Thickness of HDPE (High Density Polythene) in five sides is 1.05 m and 20 mm thick Lead sheet is to be added on the 1.05 m HDPE in four sides excluding top. In one side of the local shield, a movable door is to be designed either on rails or wheels. The joints should be designed in such a way that direct neutron streaming can't take place. The support structure can be made of MS with minimum thickness possible. It is difficult to handle the 4mx2.5mx2cm single lead sheet so some modular structure is required to add the lead shield at the four outer surfaces. The dimension of one lead sheet can be taken as 25cmX25cmX2cm (thickness). The mass of each lead module will be around 15 kg so that it can be easily handled.

Experiments in the laboratory

Measurement of Tritium production rate distribution : A neutronics experiment has been performed to measure the tritium production rate (TPR) profile in the breeder assembly with LiAlO2 as breeder and high density polyethylene (HDPE) as neutron reflector. The breeder assembly was irradiated with 14-MeV neutrons from the sealed D-T neutron generator. The objective of the experiment was to check the tritium production prediction capability of the monte-carlo code MCNP with FENDL2.1 cross section data library. The tritium production rate profile in the breeding assembly was measured by irradiating the Li2CO3 pellets kept at various locations and then counting using liquid scintillation technique.

Fast Neutron Radiography: A new method for the neutron radiography of the hydrogenous material was tested in collaboration with VSSC, ISRO Trivandrum. In this method, D-T neutrons were moderated using high density polythene (HDPE) and the moderated neutrons were allowed through a collimator to fall on the Dysprosium screen through samples. The radiographic images of the samples were recorded on x-ray films. The obtained images were good but L/D ratio has to be increased to improve the sharpness of the images.

Performance of metallic mirrors under experimental situation of high radiation damage relevant to ITER machine : Reflectivity is measured of the pulsed laser deposited (PLD) mirrors of tungsten on polished SS substrate in the presence of Helium gas environment. The PLD films were irradiated by 8 keV proton beam to produce a radiation damage of 0.4dpa. The effect of back ground gas pressure of He on FIR and UV-Visible reflectivity of these mirrors before and after radiation damage has been studied.

Absolute measurement of neutron yield for D-T neutron generator using water activation technique : In a Burning Plasma Experiment (BPE) like ITER, fusion power is continuously monitored by measuring the neutron flux Neutron activation method using the conventional solid metal foils results in poor time resolution. The activation of water by 14-MeV neutrons where 16O (n, p) N16 nuclear reaction takes place is the most promising candidate for this purpose. The short half-life of N16 radio nuclide produced in this reaction (T1/2 ~7.13sec) and the threshold energy being high enough (~ 10.4 MeV) makes it a preferred technique. In order to check the feasibility of this technique, an experimental set-up was designed. The experimental set-up consisted of a water pipeline running between the neutron generator and a detector. The detector was a fully shielded and collimated NaI(Tl) spectrometer. The water column was irradiated with the 14-MeV neutrons produced in a sealed neutron generator. Water when irradiated with 14-MeV neutrons produces gamma photons of energies 6.128 MeV (67.06%) and 7.115 MeV (4.94%) from the N16 nucleus which is measured with NaI(Tl) spectrometer. From the measured gamma intensity, the D-T neutron yield is estimated.

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A.3. Basic Experiments

A.3.1. Large Volume Plasma Device (LVPD)

In this, experimental and theoretical efforts were focused mainly on two fronts namely, 1) developing a mechanism for scavenging of energetic electrons, producing a control on Electron Temperature Gradient (ETG) and finally exploring in detail the electron temperature gradient driven turbulence and 2) studying characteristics of extremely low beta plasma ($\beta \sim 10^{-3}$) sandwiched between high beta plasmas ($\beta \sim 1$).

ETG Turbulence : An understanding of electron heat transport across magnetic field lines in a fusion device is critical since in an ignited D-T fusion reactor, the fusion alphas primarily heat electrons and typically, for reactor parameters, electrons and ions tend to be thermally equilibrated in general. Numerical simulations and theoretical models predict that electron temperature gradient driven ETG turbulence may be the main source for the observed anomalous electron thermal transport. ETG turbulence is a small-scale turbulence in magnetized plasma having a short wavelength, $k_{perp}\rho_e \leq 1 \leq k_{perp}\rho_i$ and low frequency, ω in the range $\Omega_i < 2\pi\nu < \Omega_e$, where k_{perp} is the perpendicular wave vector, ρ_e / Ω_e and ρ_i / Ω_i are the Larmor radii/ gyro frequencies of electrons/ions. Calculations reveal that the ETG mode, which is responsible for the turbulence, is a fast growing instability driven by electron temperature gradient satisfying threshold condition $\eta_e = L_n / L_{Te} > 2/3$, here L_n and L_{Te} are the density and temperature scale lengths. Direct investigation of this instability in fusion devices is extremely difficult as the small-scale length of the instability becomes very small in presence of strong magnetic field and extreme temperature conditions. This is where the role of devices like LVPD becomes important as they produce high-density plasma at low magnetic fields and thereby modify the scale length of ETG instability to measurable limit. In basic plasma devices, the plasma is contaminated by the presence of ionising hot and non-thermal electrons. Each of them is a potential source of instabilities. This renders making a case for ETG difficult. A good experimental bed for studies on ETG therefore should have no non-thermal electrons, a flat density profile and a gradient in electron temperature. This ensures that instabilities driven by gradients in density and energetic electrons are not excited. In the past, attempts to produce such plasmas in LVPD have not been successful. Establishing an independent control over density and temperature profiles has proved to be a difficult assignment. For example, heating electrons by injected electron beams have not yielded a convincing case for having experimentally observed ETG because beam electrons themselves are a potential source of instabilities. It is briefly reported here the first unambiguous laboratory observation of ETG turbulence in the plasma of LVPD, devoid of non-thermal electrons. In this plasma, a suitable Electron Energy Filter (EEF) as shown in figure A.3.1.1, filters out energetic electrons and allows imposition of a gradient in electron temperature keeping plasma density radially uniform. The LVPD is a large double walled vacuum chamber (2m diameter, 3m length). The source of primary ionizing electrons is a set of thirty-six filaments (emission area ~ 75cm^2), deployed on 45cm X 65cm water-cooled rectangular plate with continous line cusp arrangement made with 4kG Samarium-Cobalt magnets. Another multi-cusped plate is kept on the other end of the device to provide axial confinement of the plasma particles. The radial confinement of the plasma is provided by a uniform axial magnetic field of 6.2G contributed by a set of 10 coils garlanded on to the device. The discharge plasma is generated by pulsing a discharge power supply (V_d~ -70 V, I_d ~ 200 A) at fill pressure of 10^{-4} torr, Argon) with Δt_{dis} ~9.2 ms. A highly transparent (82%), 1mX2m cross-section of 4cm width solenoid acting as magnetic EEF is placed in the middle of LVPD. It provides transverse magnetic field ≤160G over an axial width of 4cm and divides LVPD plasma into source, target and filter plasmas. Plasma is produced in the source. It contains both hot and cold electron plasma. The EEF allows transport of cold electron plasma from the source to the target and inhibits energetic electrons from traversing to the target plasma. The result is that the target plasma (n_{ec}~ 3 X 10^{11}cm^{-3}, T_e~ 1.8 eV and plasma beta, β ~ 0.2- 0.4) is devoid of energetic primary ionising and non-thermal electrons [figure A.3.1.2]. Different combinations of radial profiles of the plasma parameters can be secured by resorting to different activation schemes of the EEF consisting of adjusting the physical size and magnitude and spatial variation of

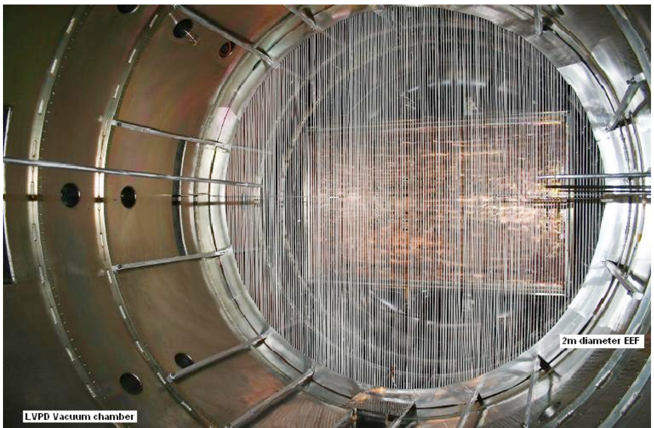


Figure A.3.1. The photograph showing cross-sectional view of vacuum vessel and the Electron Energy Filter (EEF) .The magnetic EEF is placed in the middle of the device.

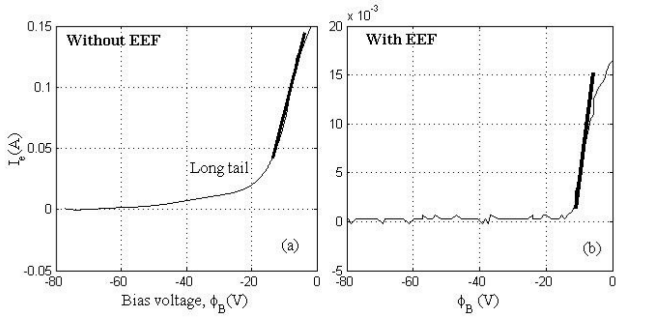


Figure A.3.1.2. I-V characteristics of Langmuir probe (a) plasma without EEF and (b) with EEF. Note a long tail of non-thermal electrons in (a) and their absence in (b).T_e reduces from 7 eV to 1.8 eV, radially at centre of the device.

the excitation current in the solenoid of EEF. Figure A.3.1.3 shows the radial profiles of the n_e, φ_p and T_e for the selected two schemes used for experimental investigations of ETG. In the first scheme, the plasma is electric field free with flat plasma density and gradient in electron temperature (Fn_eGT_e) with typical scale length L_{Te} ~50cm. In the second scheme, the plasma with hollow plasma density and no gradient in electron temperature (Hn_eFT_e) is embedded in a weak electric field with a reversal in the direction of the field at the point where gradient in plasma density changes sign. We define r ≤ 45cm as the core region and remaining as the outer region with focus on the former. A consequence of gradient in electron temperature of the plasma is reflected in figure A.3.1.4. In the Fn_eGT_e , about 2-3% of fluctuations in plasma density ($\delta n_e/n_e$) and magnetic field ($\delta B_z/B_z$)are excited in addition to 13% of temperature fluctuations(δTe/Te). The temperature fluctuations are observed only in the core region of Fn_eGT_e , the scheme where finite electron temperature gradient exists and are conspicuously absent in the case of Hn_eFT_e. The observed turbulence exhibits broadband spectra with significant power between $\nu \leq$ 1-15 kHz and a power law of $1/\nu^{1.8}$ for $\nu \leq$ 10-80 kHz [Figure A.3.1.5(a)]. The observed mode frequency lies in the lower hybrid range of frequency ($\Omega_i < 2\pi\nu < \Omega_e$), indicating that the basic instability driving the turbulence is that associated with ETG mode. Strong evidence in favor of ETG mode identification is seen from cross-correlation functions between different fluctuating quantities, as shown in figure A.3.1.5(b). Strong anti-correlation is observed between the normalized density fluctuations with both the potential and magnetic field fluctuations. The correlation coefficients are –0.8 and –0.6 respectively. The cross-correlation functions of the same fluctuating quantities measured at spatially dispersed probes exhibit a clear phase shift correspond-

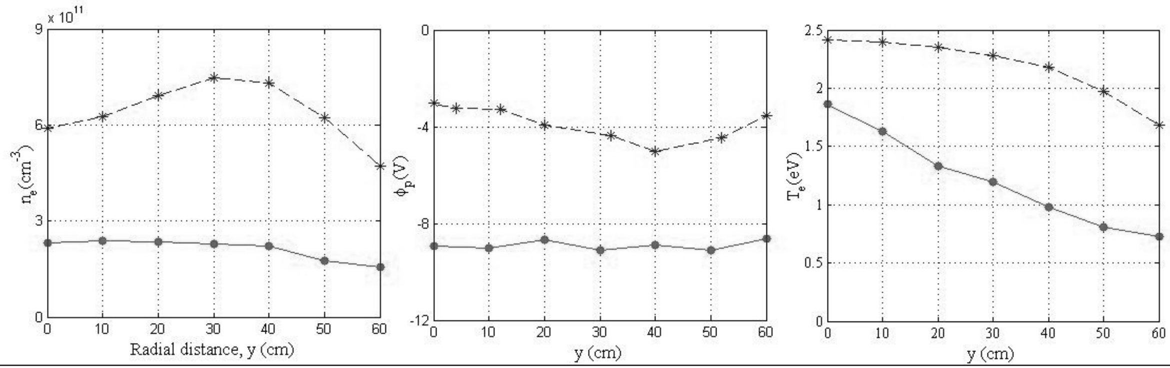


Figure A.3.1.3. Radial profiles of n_e, φ_p and T_e, for scheme (1) flat density and gradient in temperature, Fn_eGT_e (solid line) and (2) hollow density and flat temperature, Hn_eFT_e (dashed line).

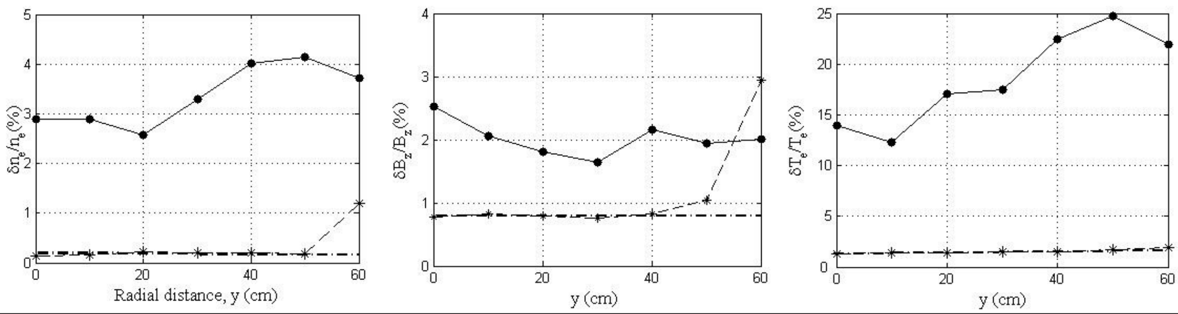


Figure A.3.1.4. Radial profiles of normalized δn_e, δB_z and δT_e. (Solid lines) are for Fn_eGT_e and (dashed lines) for Hn_eFT_e . The noise level is shown by dot-dashed curves. Note that the fluctuation in all the quantities are absent in Hn_eFT_e plasma.

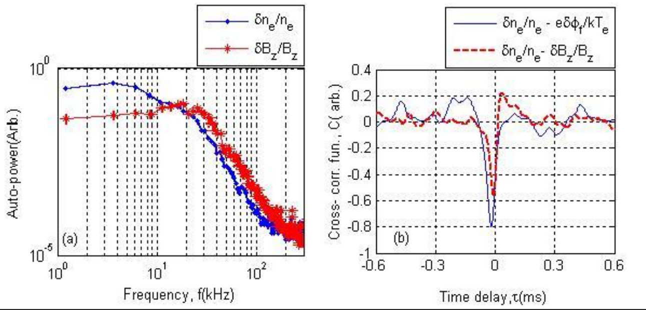


Figure A.3.1.5.(a) Frequency power spectrum of density (blue) and magnetic field (red) fluctuations, and (b) the cross-correlation function between the normalized density and potential (blue) and density and field (red) fluctuations.

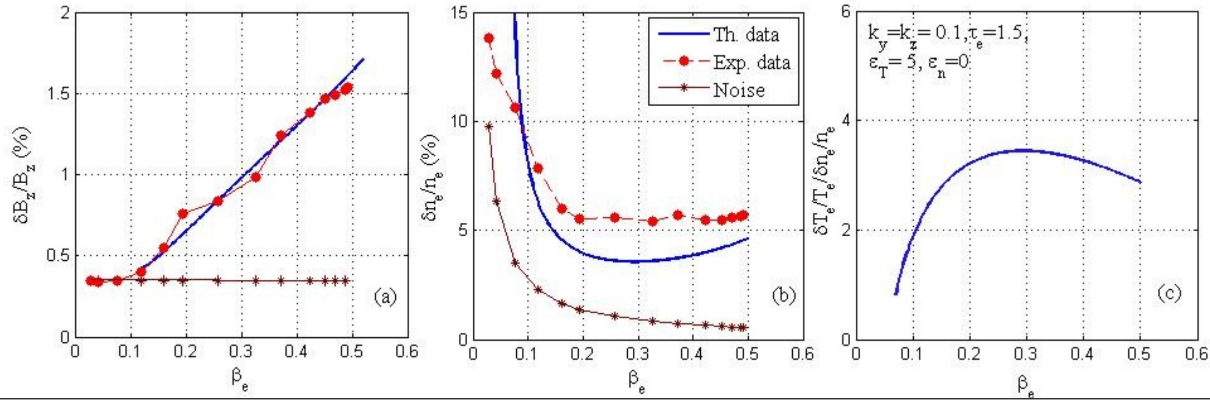
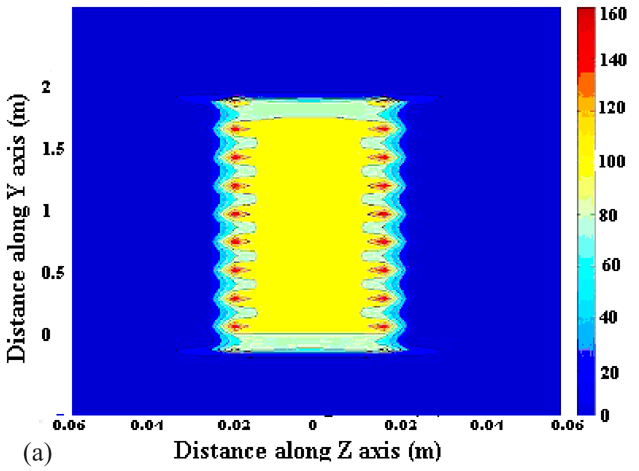


Figure A.3.1.6. A comparison of the theoretically estimated and experimentally observed normalized fluctuations in magnetic field and plasma density along with noise is shown in (a) and (b) and the ratio of normalized δn_e and δT_e versus β_e is shown in (c). This also indicates that δBz are excited when $\beta_e > 0.1$.

ing to the phase velocity ~ 2.8 X 10^3 m/s. The direction of propagation is in the electron diamagnetic drift direction. The wave number-frequency spectrum, S(k,ω) exhibits peak power for both δn_e and δB_z at k_{perp}~ (0.1- 0.3) cm-1 and the corresponding frequency, ν ~ (1- 5) kHz.. The spectrum has width in wave number Δk/k ~ 2 and frequency Δν/ν ~ 2.5. A similar spectrum is seen for δB_z. In summary, it is investigated that ETG plasma turbulence in specially prepared plasma, which is free from any significant component of primary ionizing and non-thermal electrons and gradient in plasma density. This has ensured that energetic electrons and density gradients, having capability of driving low frequency turbulence, do not cause any ambiguity in the interpretation of turbulence driven by grad-T_e. The scheme of investigations described here has provided first successful demonstration that grad-T_e indeed leads to ETG plasma turbulence. Our observations have been calibrated against theoretical predictions. It is shown that there is a fair amount of agreement between theoretical models and experimental observations [Figure A.3.1.6]. These laboratory observations have significant implications for understanding electron transport in fusion plasma; of course, much more work is required to elucidate the nonlinear saturation mechanisms of turbulence in various regions of parameter space. The experiments are also relevant to the physics of negative ion formation and electron extraction in negative ion sources for high energy heating neutral beams and such instability mechanisms, as may be operative in magnetospheric plasma during sub storm activity when plasma beta is very high. Although ETG instability of high beta plasma is not known to exist in present day fusion plasmas, it may be important in alternate magnetic confinement concepts.

Characteristic of Low beta plasma sandwiched between high beta plasmas : The Electron energy filter (EEF) is a device, which embeds transverse magnetic field, localised around the filter region in the plasma. This filter divides the plasma into three regions consisting of source, filter and target plasmas. In LVPD, the electron energy filter is a high aspect ratio solenoid. The source function for primary ionising electrons resides in the source region. The target plasma has no source function and is filled with the plasma that diffuses across the filter region from the source region. Another function of the filter is to make the transport of electrons across the magnetic field dependent upon its energy and also trap or provide loss pathways for energetic electrons. In this report we describe the preliminary results obtained explaining the basic characteristics of the plasma in the filter region. The filter enables to remove bulk of the energetic electrons and helps in setting up gradient in electron temperature in target plasma. The magnetic field pattern when EEF alone is charged and the resultant magnetic field of both the EEF and the axial magnetic field of LVPD are shown in figure A.3.1.7(a-b). Mag-



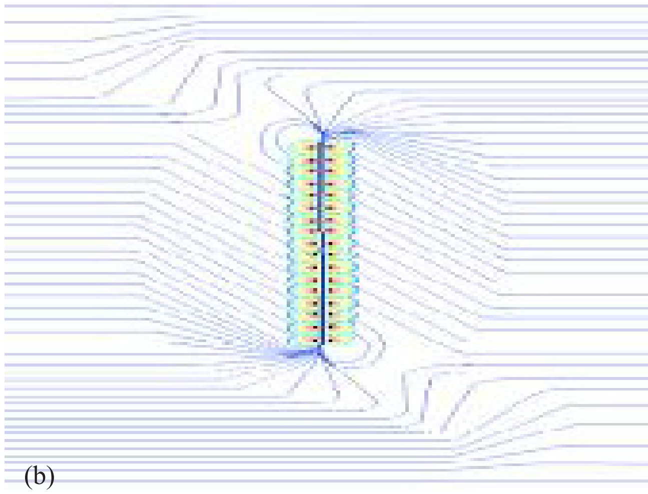
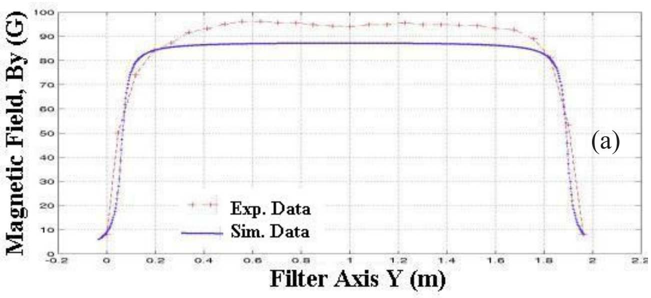


Figure A.3.1.7.The contour plot showing the top view of the formation of field by EEF is shown in (a) and the axial profile for the resultant magnetic field is shown for within EEF and in the near region of the filter (schematic)

netic field of EEF can be divided into three regions. Inner region consists of closed circular field lines around each turn. This region is separated from the outer region by null points between the turns and a separatrix running around the turns of the solenoid. In the outer region, both the closed and open field lines exist. The open field lines encapsulate closed field lines, encircling all the 155 turns of the solenoid. Even when axial magnetic field is as small as 6.2 G, the field pattern undergoes a radical transformation. First, closed field lines encircling all the turns of the solenoid disappear. Secondly, open field lines run all across the device from the source to target regions via EEF. The field lines enter EEF solenoid by bending at some angle and exit out by taking another bend through another angle. Thirdly, two oppositely positioned neutral lines appear just outside the entrance and exit of the EEF. Measured leaked field, mostly perpendicular, to the axial magnetic field of LVPD is less than 1 G at 30 cm from the EEF[figure A.3.1.8(a) and (b)].The axial magnetic field confines the electrons radially ($\rho_e \approx$ 1.2 cm and $\rho_i \approx$ 35 cm). In the filter region as the magnetic field is stronger (~150 G), gyro radii of electrons and ions ($\rho_e \approx$ 0.01 cm and $\rho_i \approx$ 2 cm) are much smaller. An extreme variation in plasma beta is seen for the three regions. Since there is no confinement provided along the axis of the EEF solenoid, ions and electrons can be transported out along those magnetic field lines that are intercepted by the end and back plates [figure A.3.1.9(a) and (b)]. The pulsed (t = 9.2 ms) Argon plasma is produced in the source region. The Argon pressure is maintained at 4 X 10^{-4} mbar and is quickly ionized by the primary electrons (V_d = 70 V, I_d ~ 160 A). The pulsed discharge plasma fills the entire chamber consisting all the three regions in < 300 µs. EEF solenoid divides the whole plasma into source, filter (region in and around the solenoid) and target plasmas. Plasmas in the filter and target regions are diffused from the source region. Only when solenoid is not activated there is local plasma production in the target region by energetic primary electrons



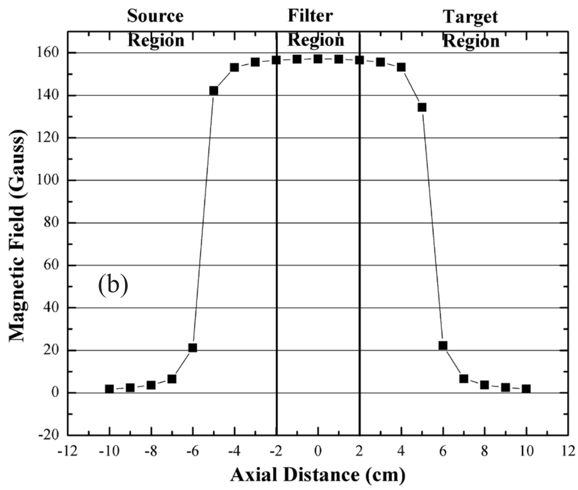


Figure A.3.1.8.The calculated magnetic field profile is shown in (a) inside the filter and (b) across the axis of the EEF.

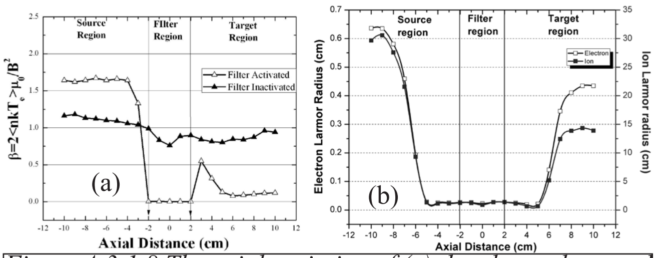


Figure A.3.1.8.The axial variation of (a) the plasma beta and (b) the gyro radii for both ions and electrons is shown for both, filter charged and uncharged cases.

transported from the source region. The plasma parameters are measured with Langmuir probes and magnetic loops. Figure A.3.1.10(a) shows axial profile of plasma density from the source region to the target region. Activation of the filter causes plasma density to increase by 50% in the source and decrease by 300 % in the target. Over all density decrease from the source to the target is by more than an order of magnitude. The decrease is not monotonic as there is a visible indication for two steps of decrement connected by a 1 cm plateau in the filter region shifted towards the target region. Figure A.3.1.10(c), show that the floating potential, a measure of energetic electrons, has axial variation only when the filter is activated. Comparing figures A.3.1. 10(b) and (c), the plasma potential is most positive in the source region where floating potential is the most negative. This implies that the source region entirely contains ionising and non-thermal electrons. These electrons are scavenged out of plasma by transport processes much ahead of the target as evidenced by decrease in the floating potential by about 12 V. Although two connected Potential Gradients (PG) are located in low plasma

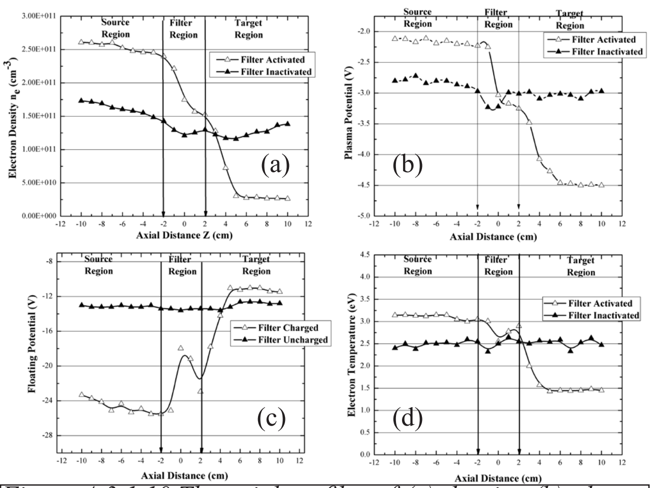


Figure A.3.1.10.The axial profiles of (a) density, (b) plasma potential, (c) floating potential and (d) the electron temperature are shown in EEF active and inactive conditions.

beta region supporting purely electrostatic turbulence, preliminary investigation shows that there exists EMHD turbulence both at the beginning of PG in the source region and at the end in the target. Localization of electrostatic turbulence in this region is also correlated with a significant drop of electron temperature in Figure A.3.1.10(d) from 3 eV in the source region to 1.5 eV in the target. No such change in electron temperature is seen when the filter is not activated. The potential drop of the PG is of the order of the electron temperature drop. However, this temperature drop is not due to self-consistent separation of the two electron species of the plasma. It is clear then that reduction in electron temperature is a consequence of transport processes of cold electron plasma and formation of PG due to large plasma density ratio between the source and target plasma greater than a factor of 8 and not as a consequence of separation of two components of electrons. What we know till now is that the EEF renders the service of decontaminating the laboratory plasma from undesirable components of energetic primary ionizing and non-thermal electrons, but we still do not have a grasp of how it works although end-point entity seems to be the enhanced plasma turbulence which selectively transports cold electron plasma with a price of loss of plasma density by a factor of 8. It is not known what role high beta plasma boundaries have played in the working of the EEF We need to manipulate this interface region in order to clarify the role of high beta plasma in determining the characteristics of EEF plasma and it's functioning as electron energy filter.The detailed study of excited turbulence and subsequently the plasma transport is a subject matter of current experimental plan of LVPD.

A.3.2. Interaction of Low Energy Ion and Neutral Beams with Surfaces

A mini surface characterization facility consisting of a micro-hardness tester, an optical microscope, a precision diamond saw, a mounting press and a grinder polisher has become operational (figure A.3.2.1). With all the equipment necessary for an investigation including the mini surface characterization facility being in place, a surface treatment experiment was carried out with a sample of SS201 material. The high density microwave plasma beam was used to treat the sample at 400oC for one hour using a mixture of nitrogen and hydrogen (ratio = 1:2) at a pressure of 2x10-3 mbar. The density of the plasma beam is 1.1x1012 cm-3 at the center and falls off to 2 X 10^{11} cm^{-3} at 8 mm from the center (radius of the sample is 8mm while the radius of the plasma beam is about 13mm). Even with high density of the plasma (current density ~30mA/cm^2) it does not lead to heating of the

Figure A.3.2.1. A mini surface characterization facility

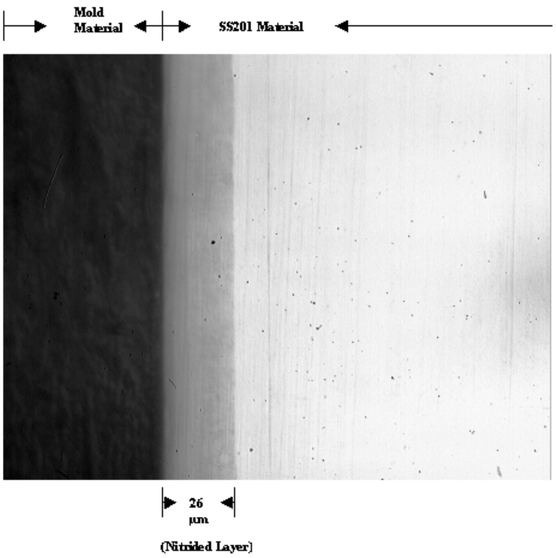


Figure A.3.2.2 Surface clearly showed a nitrided layer

sample with low bias voltage and hence the bias voltage had to be increased to –380V to obtain the process temperature of 400°C. The treated sample was then cut with precision diamond cutter, mounted in a mold material with the help of the mounting press and then surface smoothed with the grinder / polisher. After that the surface was examined under optical microscope. The nital etched surface clearly showed a nitrided layer of 26 microns (figure A.3.2.2.).

After that the surface was examined by a microhardness tester. Microhardness measurements show a hardness of 1900 HV near the surface compared to a core hardness of 334 HV (figure A.3.2.3). This is more than five fold increase in surface hardness. Hardness at 26 micron depth from the surface is about 1000 HV. Fig. 4 shows glancing incidence XRD pattern of the nitrided surface which suggest efficient conversion of chromium to chromium nitride even at a low process temperature of 400°C. High density plasma sources such as ECR and PSII have been used successfully (reported in the literature) in nitriding at low temperatures of 350-450°C. However hardness increase for similar type of material was up to 1500 HV and only a shallow case depth of less than 10 microns was obtained. The present plasma source which has a plasma density of one order higher has provided a very high surface hardness of 1990 HV never reported before in any nitridng experiments. Also the case depth is rather high for only one hour treatment. In conclusion the present experiment strongly suggests that the nitriding process is related to

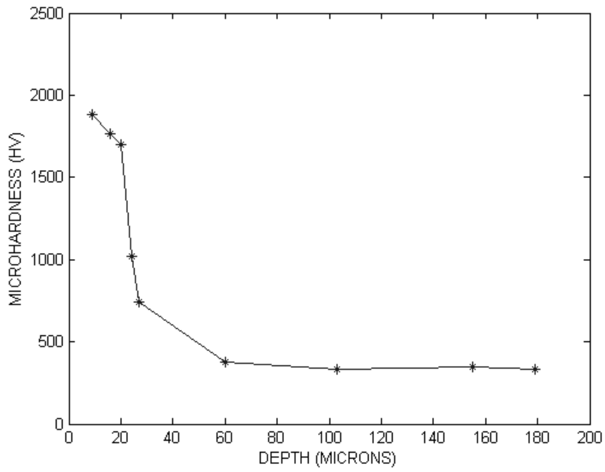


Figure A.3.2.3 Higher hardness near the surface layer

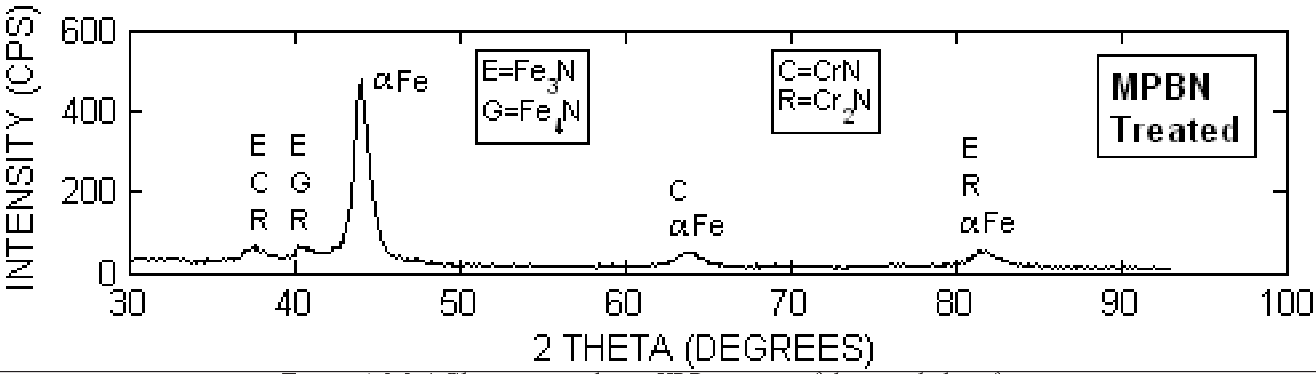


Figure A.3.2.4 Glancing incidence XRD pattern of the nitrided surface

the plasma density (hence the current density), i.e. more the plasma density more efficient the nitriding process is. Future work will involve up-gradation of the electromagnet from present 450 Gauss to more than 1 KGauss and more experiments involving surface treatments for nitriding with ions as well as neutrals will be carried out.

A.3.3 Plasma Wake-field Acceleration Experiment

The temperature calibration of the heat pipe oven has been completed without lithium and the calibration verified using ANSYS simulation. The heater design was also modified and the new Kanthal element heater and insulation is smaller in size and also has better temperature stability. Cera-wool insulation was also added to the system to reduce heat loss from the oven. External temperature probes to monitor the oven temperature profile have been added. The ArF excimer laser has been installed and the laser tube passivation has been carried for energy stabilization and is now ready for experiments. The layout of the laboratory is shown in the figure A.3.3.1. The measured temperature profile of the oven system as compared to simulation results from Ansys is given in Fig.2. The photograph of the improved heater with the external temperature probes is shown in Fig.3. This system has been tested up to 800°C for 4 hours with a temperature stability of ± 1°C using the new PLD temperature controller. Work plan in the immediate future is to introduce lithium into the oven and measure the vapor density and vapour column length which is an important parameter in forthcoming ex-

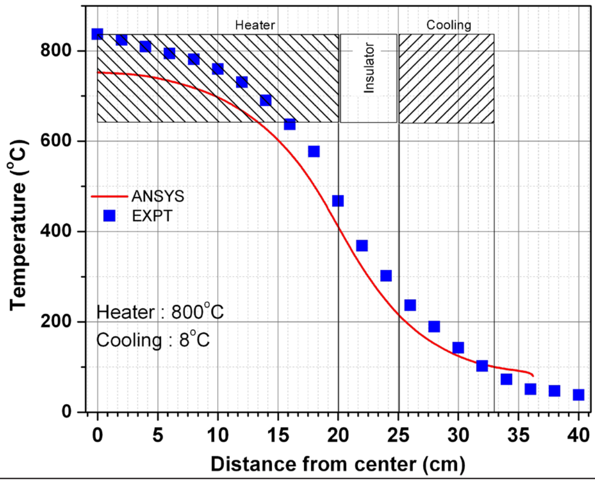


Figure A.3.2.3 Temperature profile of the heat pipe oven without lithium

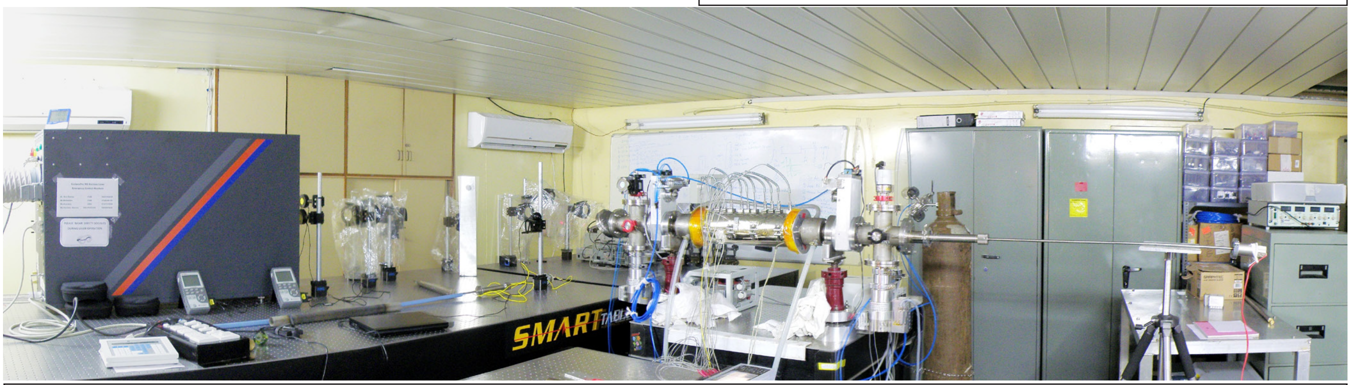


Figure A.3.3.1 View of the plasma accelerator laboratory showing the ArF laser and the plasma chamber.

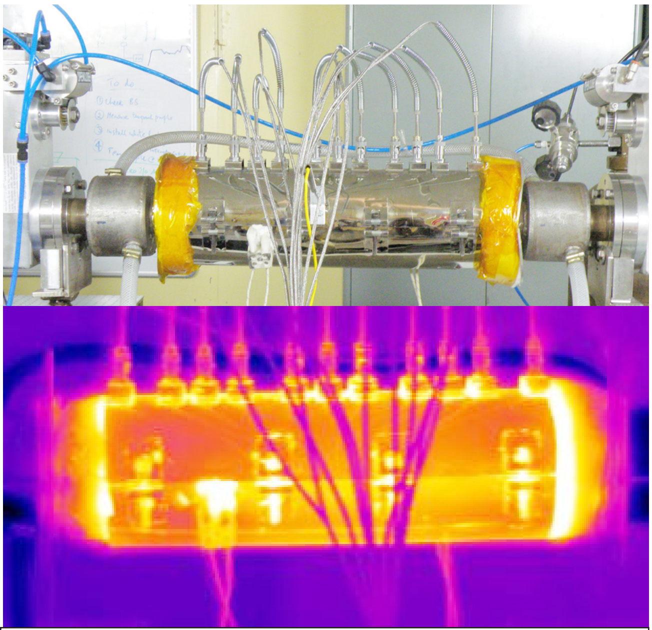


Figure A.3.3.4 The heat-pipe oven (Plasma chamber) showing the new compact heater and the external temperature sensors. The IR image of the system at 800°C.

periments. The purchase of the optical multi channel analyzer system for plasma diagnostics is currently underway.

A.3.4 System for Microwave Plasma Experiments (SYMPLE)

Progress has been made with regard to the development of both the plasma source as well as the high power microwave (HPM) source, using VIRCATOR (Virtual Cathode Oscillator). Figure A.3.4.1(a) shows the temporal profiles of density acquired simultaneously by an array of probes. and (b) shows the axial density profiles generated at different temporal regimes, from the snap shots. The dark dotted curve corresponds to a profile in the post pulse regime, having a uniform extent in the axial direction, followed by a steep gradient.

The Plasma Source : Expanding the earlier work on development of the plasma source, we have characterized the washer gun plasma, optimizing various parameters such as the ambient pressure, Ar flow, magnetic field, discharge voltage, pulse duration etc. The objective has been to attain the prerequisites such as high density (~10^{12}/cm^3), axial uniformity of about 1m, radial uniformity ~ 10 cm and an axial steep gradient (~$\lambda_{microwave}$) that is required to carry out the proposed investigations on microwave absorption in plasma. In the main pulse regime of ~ 100 μs (Figure A.3.4.1), the plasma density close to the gun is ~ 1X10^{12}/cm^3, followed by an axial

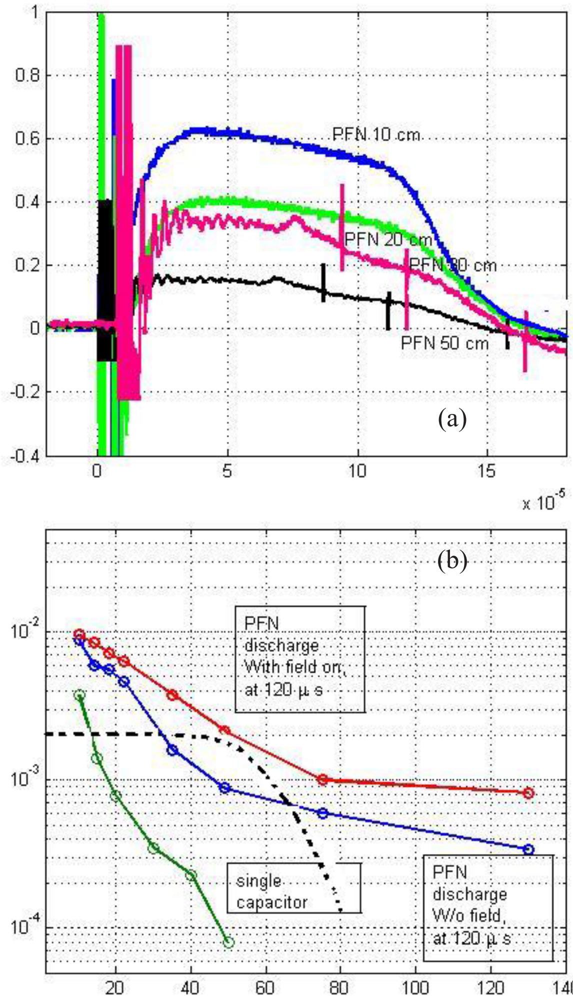


Figure A.3.4.1.(a) temporal profiles of density acquired simultaneously by an array of probes (b) (b) The axial density profiles generated at different temporal regimes, from the snap shots.

gradient. Thus there is no regime of axially uniform plasma. However, in the post pulse plasma, a parametric regime, has been identified that gives required axial uniformity and a sharp gradient. The density at this point is reduced considerably. Further enhancement towards attaining the right density profile has been to install a multi-gun structure to enhance the radial uniformity and to enhance the power level to increase the density. A 4-gun source has been developed accordingly, as shown in Figure A.3.4.2 and is installed in the device. Successful plasma shots have been produced using this new source. Detailed characterization to understand the performance of this source, and with increased power levels, is under way.

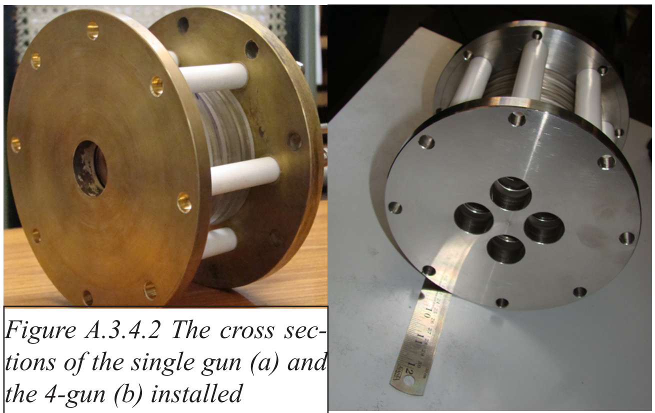


Figure A.3.4.2 The cross sections of the single gun (a) and the 4-gun (b) installed

The VIRCATOR source :A compact generator has been developed. Overall dimension of this system is 6 feet by 4 feet. This system is designed to operate with up to 350 kV on water pulsed forming line to generate 75 kA , 40 ns pulse, which further will be compressed in time with the help of plasma opening switch. The equivalent electrical circuit of the complete generator, including the POS and the load, is given in Figure A.3.4.3. Schematics of the generator and a complete overview of the system arrangement in the laboratory are both presented in Figure A.3.4.4.

TheTeslaTransformer :With reference to Figure A.3.4.3, the power source for the system is a capacitor bank Cb=1.92 µF, made from three parallel connected capacitors, which can in principle be charged to 40 kV.A repetitive spark-gap (s1), operating in nitrogen, closes the primary circuit, with the rest of the bank circuit data being inductance Lb=125 nH and resistance Rb=30mΩ. The single-turn primary winding of the Tesla transformer is made from a thin copper sheet encapsulated between few layers of polyethylene with a resulting self-inductance Lp=164 nH. The secondary winding is made from a round enamelled copper wire wound onto a conical dielectric former resulting in a self-inductance Ls=64.5 µH.

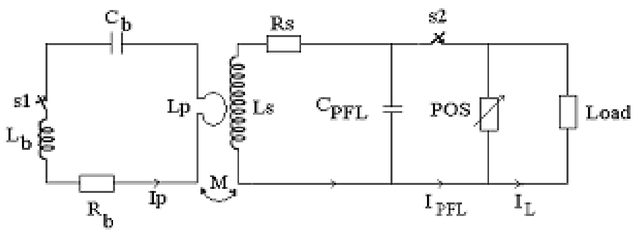


Figure A.3.4.3 Equivalent electrical circuit of the generator including the POS and a load. Subscripts: b is for the capacitor bank, p and s are for transformer primary and secondary and L is for load. s1 and s2 are closing switches and CPFL is for the pulse forming line capacitance during Tesla transformer charging.

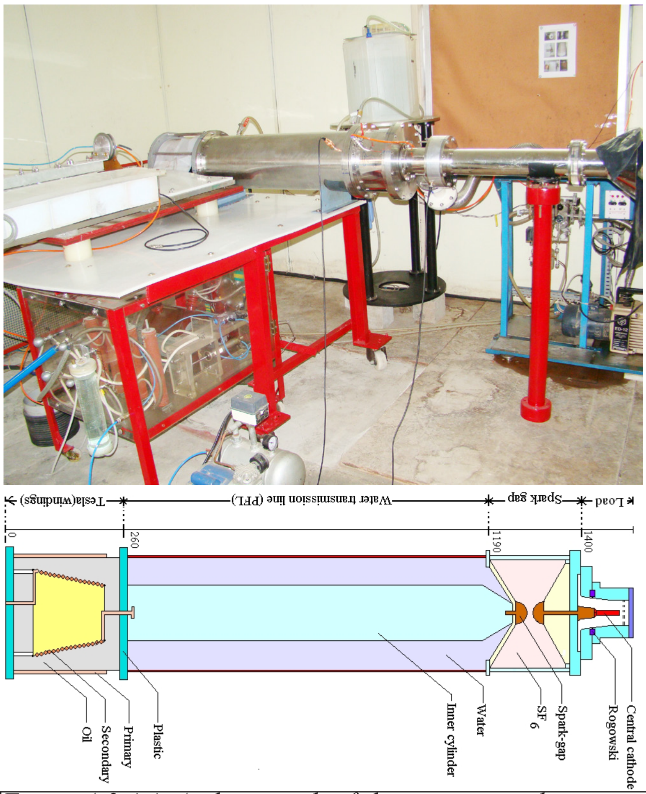


Figure A.3.4.4. A photograph of the experimental arrangement (a) and the schematic (b) of the system.

The relatively high resistance Rs=2 Ω is due to skin and proximity effects both generated during the fast bank discharge. The mutual inductance of the high-voltage transformer, operated in oil, is M=2.1 µH.

Pulse forming line : A 3.8 Ω / 50 ns coaxial water filled pulse forming line is attached to the Tesla transformer output. The line capacitance during charging is 6 nF and the maximum charging voltage allowed can attain 400 kV when the water has a resistivity (permanently controlled) in excess of 15 MΩcm.

Spark-gap :A self-breaking high-voltage fast spark-gap operating under pressurised SF6 gas (30 psi required for 300 kV operation) is made from two hemispheres mounted 5 mm apart using polyethylene supports. The switch has a very high closing voltage reproducibility.

Diagnostics development :In the secondary circuit, the Tesla output voltage is monitored with a V-dot voltage sensor as described in installed in the metal wall of the water pulsed forming line very near its output. Current in the diode (load)

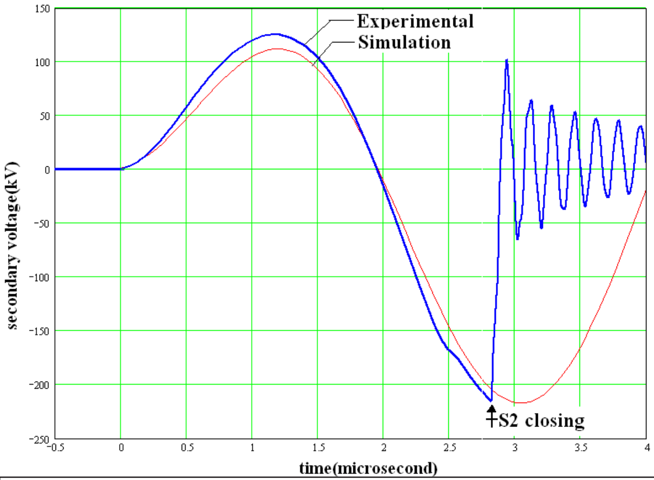


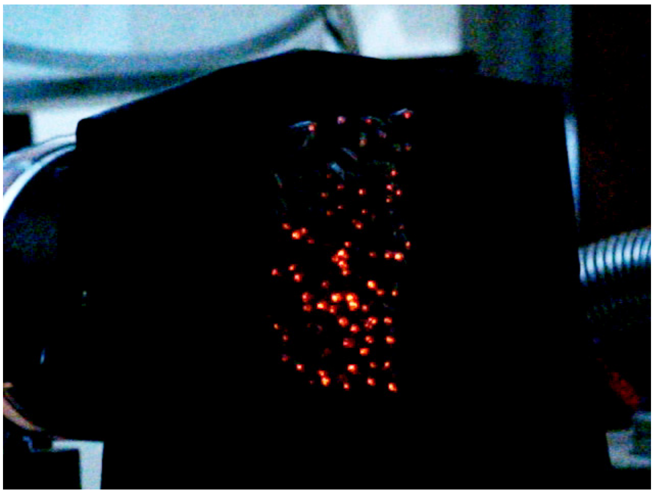
Figure A.3.4.5 (a): The o/p voltage from the HV source. (b) current in the diode, when VIRCATOR is in operation.

is measured with the aid of a Rogowski coil havinga rise time of 1 ns and a droop time of 2 µs.

Results and discussion: The voltage at the end of transmission is produced in the figure A.3.4.5(a) and the current in the load is presented at A.3.4.5.(b). A VIRCATOR system is attached to this system as a load to study dynamic behavior. It is producing enough power of microwave to glow the neon lamp (figure A.3.5.6a). The FFT of the microwave output is being shown on figure (A.3.5.6 b).

A.3.5. Flowing Plasma Experiment

Double layer is a localized structure of plasma potential in plasma extended over tens of Debye length. Researchers have observed DL in various experiments over last few decades. Some of the DLs are current free (CFDL) some are not.



Recently (2003) CFDL have been observed in helicon plasma with diverging magnetic field configuration. In the same configuration unexpected absorption of power at relatively low magnetic field is also observed. These observations are yet to be explained fully. These observations on CFDL in helicon plasma in diverging magnetic field has led to the set up of a new experiment at IPR. Designing and fabrication of the experimental set up had started few years back. During last one year regular experiment is ongoing on this device. Plasma has already been characterized. Few observations related to DL and low magnetic field abnormal absorption have already been made. Detail study is ongoing. The experimental set up as shown in figure A.3.5.1 is a linear machine consists of two sections. The first part is a cylindrical glass tube of 5 cm radius and 70 cm length. Plasma is produced in this chamber, so it is called the source chamber. The second part is a cylindrical SS chamber of 21.5 cm diameter and 50 cm length. The total system has 18 KF 40 diagnostics ports out of which 15 are radial ports. The total system is Helium leak

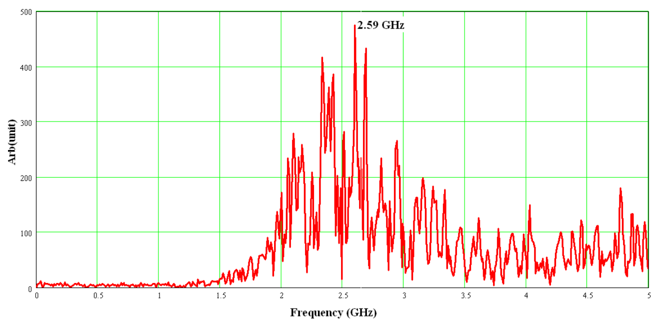


Figure A.3.4.6 (a) neon glow due to microwave and (left) (b) The FFT of the microwave(above)

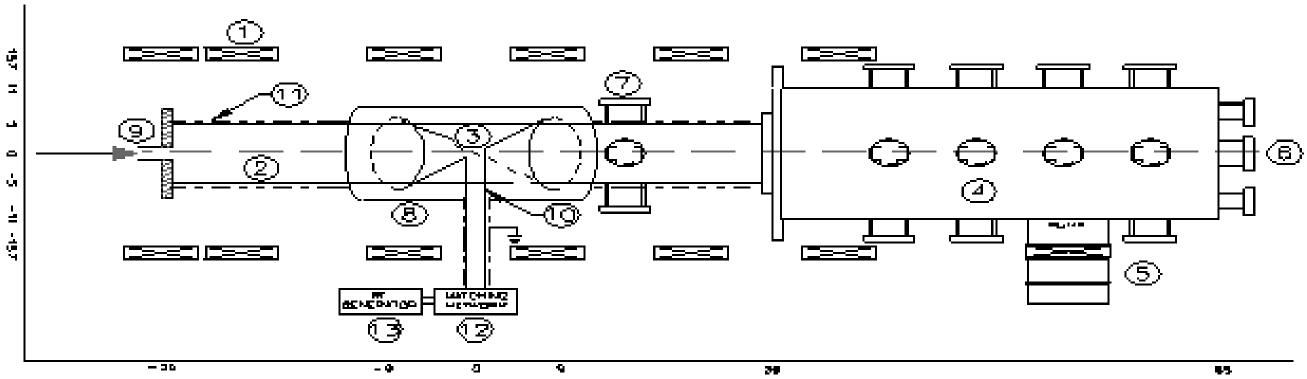


Figure A.3.5.1 Schematics of the flowing plasma experimental set up and the different parts are: 1.Electromagnets 2.Borosilicate Glass tube 3.Half-wavelength Helicon m=+1 antenna 4.Diffusion chamber 5.Diffusion pump 6.Axial 40KF diagnostics port 7.Radial 40KF diagnostic port 8.Antenna shield 9.Perspex source tube end flange 10.Transmission line 11.Brass mesh shielding12. Matching network 13.RF generator

tested upto 1e-7 mbar-lit/sec. The vacuum system consists of a 2000 liter/s diffusion pump backed by a 360-litre/min speed Rotary pump. After a base pressure of 2e-6 mbar is reached, plasma is produced in 2e-4 mbar – 6e-3 mbar fill pressure of Ar and He gas. Plasma is produced by feeding RF power from a 2.5 kW RF generator at source frequency of 13.56 MHz to the helicon m= +1 antenna through a matching network. Existing operating parameters are: RF power: 20-1500 watts, Gas: Argon or Helium, Magnetic field: 0 –150 gauss, Pressure: 2e-4 mbar – 6e-3 mbar. Diagnostics used are as follows: single Langmuir probe, double Langmuir probe, triple Langmuir probe, emissive probe, Rogowski coil, B-dot probe, Mach probe and retarding field energy analyzer. Impedance matching between 50 Ohms to 0.5-10 Ohms + 220 nH of antenna+ 100 nH of transmission line + Stray Capacitance 80pF. The matching network is L type with two capacitor arms. The schematic is given in figure 2. Existing nnormal operation is CL = 700-800 pF, CT = 100 pF, LT = 2

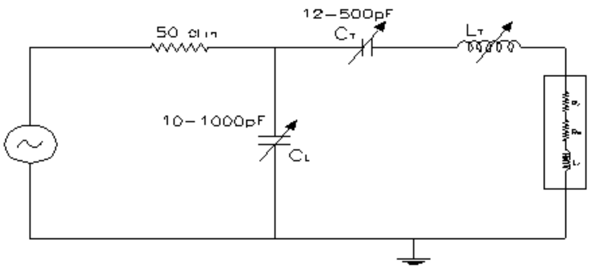


Figure A.3.5.2 Schematics of the Matching network with the tuning capacitor CT and load capacitor CL. Antenna resistance RA is in series with antenna inductance LA and Plasma resistance RP. LT is the tune inductor to increase the value of CT.

turn inductor (we have 2,4,6,8,10 turn inductors). Plasma can be produced even with RF power as less as 1 watt without any reflection. Figure A.3.5.3 shows that in vacuum with no plasma the current flowing to the antenna is more than the current when there is plasma. The current to the antenna is measured with a rogowski coil near the transmission line for zero reflection. The plasma resistance can be calculated from the power coupled. The calculated value of the antenna vacuum resistance is nearly 0.34 Ohm and with plasma the resistance can go up to 1 Ohm. The antenna vacuum resistance is loss through the resistive heating of the antenna, the losses in the vacuum variable capacitors in the matching network

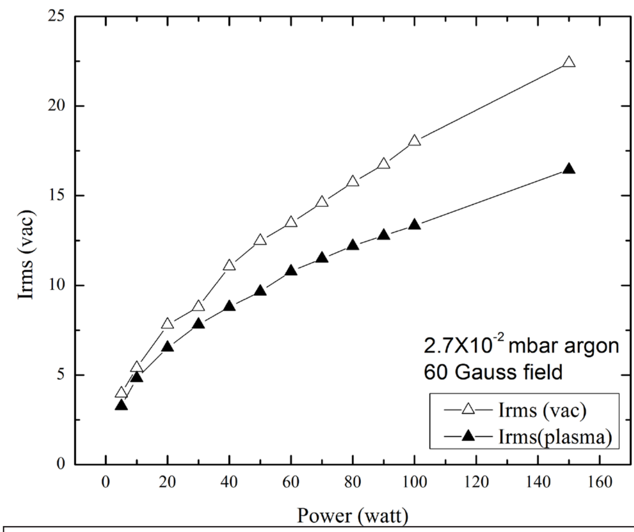


Figure A.3.5.3. RMS current to the antenna with plasma (Solid Triangle) and without plasma (hollow triangle)

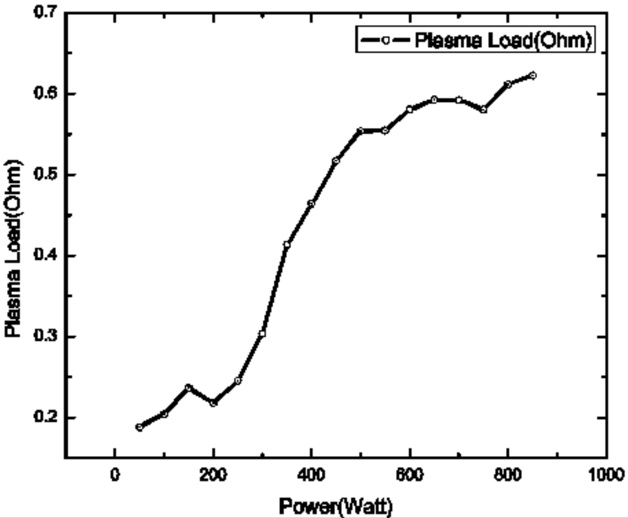


Figure A.3.5.4. Plasma load is deduced from the antenna current measured with a Pearson current transformer at different powers ranging from 50-1000 watt at 60 gauss field and 5X10^{-3} mbar of Argon. Plasma load is obtained by deducting the vacuum (no plasma) load.

and the loss in the transmission line. FigureA.3.5.4 shows the measured values of antenna resistance after the vacuum resistance is deducted. The axial plasma potential is measured with an emissive probe. We observed a potential fall of nearly 25 volts with high potential side towards the source plasma and low potential side towards the diffusion chamber plasma. The thickness of this CFDL is nearly 250 Debye lengths for Argon plasma produced with 115 Gauss field and 400 Watt RF power at 7X10^{-4} mbar. The electric filed is centered on 40cm from the antenna. The local density and temperature are measured with Langmuir probe. Future experiments are planned for looking at the position of this CFDL at different pressures and gas.

A.3.6. Laser Blow-off Plasma Experiment

Experiments on characterization of Laser-Blow-Off plasma plume: Experiments related to the characterization of laser induced plasma (for the both film ablation and solid ablation) are continuing in this period with improved experimental and detection system. Based on the spatio-temporal high resolution spectral and image analysis of expanding plasma plume, we have identified various atomic processes during free expansion, plume-ambient gas interaction and plume-magnetic field interaction. Various physical processes, associated in kinetic distribution of plume species, geometrical formation, hydrodynamic instability and validity of different expansion

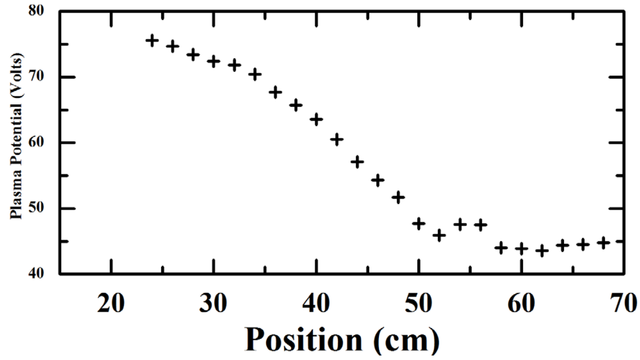


Figure A.3.5.5. A current free double layer of nearly 270 Debye lengths and a potential drop of 25 Volts measured with an emissive probe. Pressure 4.7X10-2 mbar of argon and 400 Watt RF power with 100 Gauss field near antenna.

models are briefly addressed and reported in various journals. It is observed that in presence of background gas, magnetic field or combination of both, structures are developed at edge and also inside the plasma plume which are help to understand the formation and dynamics of laser induced plasma. A combination of Principle Component Analysis (PCA) and higher order spectral techniques has been performed on the image data to study the internal mode structures (hidden structures) within the plume. Further, the energy density and intensity profile of ablating laser beam play the crucial role in the geometrical aspect of the LBO plume and its dynamics, which are highly relevant in thin film deposition, neutral beam injection in tokomak plasma environment, and other

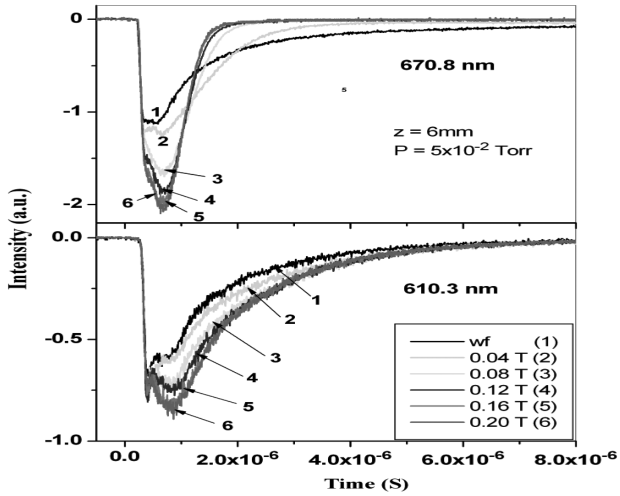


Figure A.3.6.1. Distinct behavior of temporal profiles of Li I 670.8 nm and Li I 610.3 nm lines in 10^{-2} Torr Argon pressure for various magnetic fields. The profiles were recorded at z = 6 mm from the target.

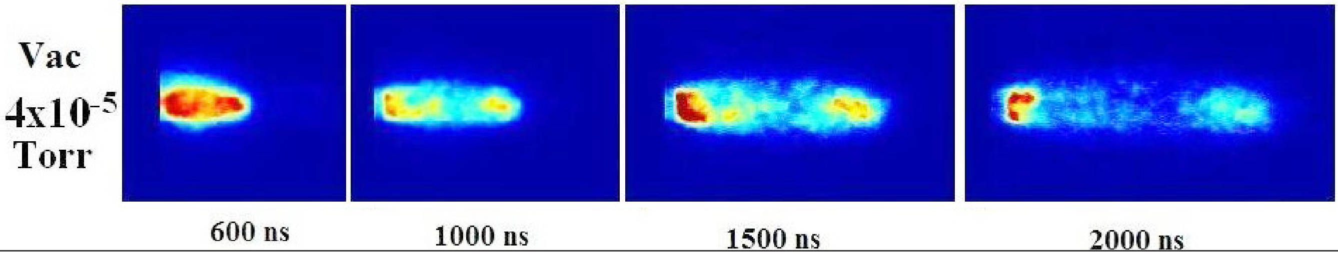


Figure A.3.6.2 Low divergence and long lived LBO plume expansion produced by Gaussian profile laser

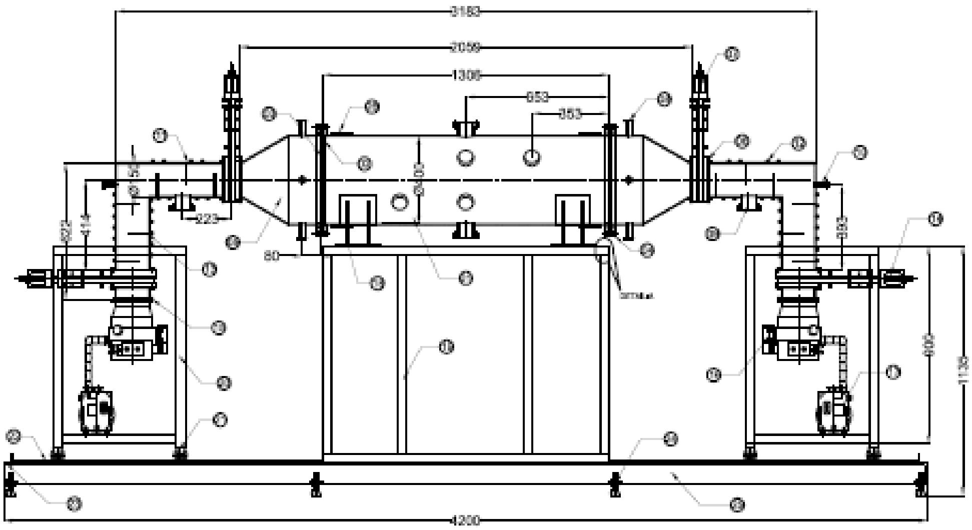
LBO induced beam applications. One of the important finding in the sense that the laser having Gaussian intensity profile produces low divergence and long lived highly collimated plume. The persistence of low divergence for the longer times is highly suitable for producing collimated atomic/ionic beams for the various practical applications. Apart from the continuing the above studies, we are developing experimental facilities to identification and quantitative determination of the elements, chemical composition and clusters present in ablated plume using Crossed Beam Reactive Ablation and Laser-Induced Breakdown Spectroscopy (LIBS) technique.

A.3.7. Multi-Cusp Plasma Experiment

Purchase order for all the procuments have been done with. The engineering design and facbrication drawing of the vacuum chamber has been obtained from the vendor and the thermal analysis is bing done. Figure A.3.7. shows the part of the fabrication drawing submitted by the vendor for ipr approval which was done with. An ANSYS based simulation for the thermal analysis of the chamber with the hot ionizer plate is in progress. The prototype testing and refinement works in the ionizer assembly are also being done. The delicate welding of Tungsten heating filements are being done at Glowtronics, ltd. Bangalore. The welding will be optimized for minimum contact resistance, so that energy loss can be reduced. The integrated design of the Cesium oven assembly with the hot plate is progressing with the prototypes already made. The winding design for the electromagnets with Vacuflux 50 material is being completed. This winding design needed to be redone after finalizing purchase procedure for the procurement of the soft core material. It is expected to have the first plasma by the ehird quarter of this financial year.

A.3.8. Basic Experiments in Toroidal Assembly (BETA)

Experimental study of control of mean profile : This experiment is primarily for understanding fluctuations and transport in simple magnetized currentless toroidal plasma. In the present experiments argon plasma is produced using hot



SLNO	DESCRIPTION
26	MAGNETIC HOLDING PLATE
25	ISMC 100x75 C CHANNEL BASE FRAME
24	SCREW JACK
23	ISA 40x40X5 CHANNEL FOR STOPPER
22	GUIDE TAIL
21	CASTLE WHEEL
20	INVENTORY CHAMBER FRAME
19	MAIN CHAMBER FRAME
18	CHAMBER LEG
17	ROTORY VANE PUMP
16	TURBO MOLECULAR PUMP
15	ISO-K 160 FLANGE
14	UVH GATE VALVE-ISO CF160 VAT
13	INSIDE BAFFLE
12	½"COPPER TUBE
11	6" PIPE LINE
10	ISO-CF16 FLANGE
09	ISO- CF63 FLANGE
08	ISO KF-25 FLANGE
07	UVH GATE VALVE-160CF OERLIKON
06	ISO CF 160-FLANGE
05	INVENTORY CHAMBER Ø400
04	INVENTORY FLANGE ISO-F
03	ANNULAR FLANGE
02	MAIN CHAMBER FLANGE ISO-F
01	MAIN CHAMBER Ø400

Figure A.3.7.1 Assembly drawing of the vacuum chamber for multi-cusp plasma device experiment, submitted by the vendor and duly approved by IPR biased filament with a typical toroidal magnetic fields of 200-900G. Typical profiles of plasma parameters like electron temperature and density are estimated using Langmuir probes. The role of fluctuations and flows in sustaining mean profiles in a current less toroidal plasma is being studied. The flow and fluctuation measurements in a simple magnetized current less toroidal plasma have been conducted. The measured plasma parameter profiles are observed to be accompanied by large fluctuations. The existence of large fluctuations and filling of plasma in the entire radial domain are observed to be closely related to each other. The E×B drift velocities calculated from the gradient of measured mean plasma potential profile have shown significant deviation from the net flow velocity measurements. Interestingly, it is observed that the measured fluctuation driven flow velocity, which is opposite in direction to the mean field driven flow, partially accounts for the observed difference between the net flow and the mean electric field driven flow.

A.3.9.Experiments on Non-Linear Plasma Oscillations

The aim of the experiment is to study phase mixing and wave breaking of non linear plane plasma oscillations. The experimental requirement for studying the above mentioned phenomena has been determined. The target plasma density is ~ 10^8/cc and temperature is 2 – 4 eV. The required length of the uniform plasma having δn/n is ~ 1.4 m. An experimental device consisting of magnet system, plasma source and vacuum vessel is being redesigned in accordance with the experimental requirement. Previous designs have been drastically modified to make the vacuum vessel more economical. The magnet system has been completely redesigned and ripple has been reduced to ~ 0.35%. Ten magnets will be used to produce a uniform axial magnetic field of value 720 G over a distance of 1.4m. The inner diameter of the magnet is 41cm; length along the axis is 10cm. The centre to centre distance between the magnets is 20cm. The distance between the last two magnets is 2cm. The NI of each coil is 12000 amp turns. Filaments mounted on the axial end flange of the source chamber will be used to produce plasma. Filaments will be arranged in columns with separation between the columns being ~ 4cm. The vacuum vessel consists of a cylindrical source chamber having a considerably larger diameter and a cylindrical main chamber of diameter ~ 155mm and total length 2.18m. The main chamber comprises of three cylindrical vessels already existing in the laboratory and two new units of length 359m and 263mm that are being made in the workshop. The dimension of the final source chamber is yet to be finalised. Initial operation will start using a source chamber having diameter 0.5m and length 0.5m.

A.3.10. Experiments on Dusty Plasma

The basic objective of studying dusty plasma is to study the dust rotation in the presence of a magnetic field. Many experiments have observed that the dust particles start rotating in an azimuthal (horizontal) plane in the presence of a vertical magnetic field. As the magnetic field was increased the direction of rotation of dust particles gets reversed. It was found that the rotation is the result of the competition between the ExB drift and the diamagnetic drift acting on the plasma ions. In the present case a radial magnetic field will be applied for getting the dust rotation. The experimental set up consists of the experimental chamber, vacuum system, the rf electrode configuration and diagnostics. Here we are using a stainless steel cylindrical chamber whose inner diameter is 31cm and length approximately equal to 50cm. The chamber is operational and now a dc filament discharge is being regularly obtained. Rf electrode design is completed and in the process of fabrication. Soon a capacitive rf plasma will be produced. Optical camera, optical beam probe and Langmuir probe are the main diagnostics presently planned. One of these axial ports will be used for inserting laser light and another axial port will be used for collecting scattered light from dust particles, with the help of a sCMOS camera. As we know that the light coming from the laser after passing through the cylindrical lens will be scattered by the dust particles. To capture this scattered light we will use a sCMOS camera. It is a very sensitive instrument, works on the principle of photoelectric effect. As the dust plasma frequency can go up to 60 Hz and it is always advisable to use a diagnostic which with speed as high as double the speed of the phenomena to be studied. So the camera should be having a frame rate faster than at least 100 Hz. The resolution of the camera is also a very important parameter. It directly depends upon the number of pixels and the area of each pixel present on the CCD camera chip. More the number of pixels better is the resolution. The camera is in the process of procurement. Radial magnetic field will be produced by permanent as well as electromagnet. By using a configuration of a disc magnet and another ring permanent magnet, a radial magnetic field profile can be generated. This magnet has been designed, fabricated and tested. Four electromagnets will be for producing a radial magnetic field. The inner diameter of inner magnets will be 10 cm and inner diameter of outer magnets will be 20 cm. The width of each magnet is 2 cm and the length along the axis is 6 cm. The total number of turns in each electromagnet will be 12 and the electromagnet spacing will be 5 cm.

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A.4. Theoretical, modeling and Computational Plasma Physics

A.4.1. Laser-Plasma Interaction

Vacuum acceleration of charged particle in a relativistically intense ultrashort laser pulse : Vacuum acceleration of a charged particle is studied in 1D, in the field of a relativistically intense short duration laser pulse whose intensity is chosen to be a slowly varying function of space. In the present study a Gaussian profile is used to model the focusing and de-focusing of a laser pulse. Final energy gain of the particle is obtained numerically as a function of a dimensionless parameter containing intensity of the pulse, its duration and focal length. These numerical results have been explained using a higher order adiabatic theory which is derived using Lie transformation perturbation method.

Multistage acceleration of ions by relativistic laser pulses : Multistage acceleration of ions by ultrarelativistic laser pulses incident on a solid target has been studied using PIC simulations (LPIC++). It is found that the scaling of ion energy (for both the first stage and second stage) with a dimensionless parameter which is the ratio of field energy density of the laser pulse to the rest mass energy density of the target matches well with the steady state model of Robinson et al (2009). Further understanding of the dynamics of the process is in progress.

Excitation of Nonlinear Wakefields by an Intense ultrarelativistic Positron beam : Characterization of wakefields excited by an ultrarelativistic positron beam propagating through an underdense / overdense plasma column, besides being of fundamental academic interest, is also of relevance to plasma wakefield accelerator experiments like plasma based e+ - e- linear collider. In this work, we have analytically investigated, in one dimension, the excitation of nonlinear wakefields by an intense, ultrarelativistic, ultrashort positron beam passing through an underdense / overdense cold homogeneous plasma. Expressions for electric fields and frequency of the excited oscillations both inside and outside the beam are computed and compared with the corresponding expressions for an electron beam. It is found that for the same ratio of beam density to plasma density, frequency of the excited wakefield is higher in case of a positron beam whereas the amplitude of the excited wakefield is weaker than that excited by an electron beam. The adjoining figure A.4.1.1. shows the wake electric field excited by an electron beam (blue) and a positron beam (red), both inside and outside the beam, for $\alpha = 0.45$ (ratio of beam density to plasma density). Further, it is found that the peak decelerating field increases monotonically with beam density whereas the peak accelerating field initially increases with increasing beam density and then it tends to saturate. These conclusions, drawn from an 1D analytical calculation, is found to be consistent with present day 2D and 3D PIC simulations of wakefields excited by an ultrarelativistic positron beam in a cold homogeneous plasma.

Ultrashort hard x-rays from laser irradiated bioplasmas (with TIFR) : Hot plasmas created by intense femto-second lasers are attractive tabletop sources of energetic charge particles as well as photons whose energy can be well extended in the hard x-ray region and beyond. These emissions are of great importance to various scientific, technological and medical applications. Typically, in laboratory experiment one uses nano/micro structured targets to enhance these emissions via local field amplification due to surface irregularities. Such artificial target has limitation during manufacturing process itself. Also one needs very high laser intensity for such targets to produce intense hard x-rays. Recently TIFR group has investigated biological target consisting of a few micron-thick layer of microbe (E. Coli) where the brightness of hard x-ray emissions (up to 300 keV) is increased by 100 fold, at a moderate laser intensity. This increased x-ray yield is attributed to the local enhancement of electric fields around individual microbe and generation of hot electrons. Above experimental results were re-produced by detailed electromagnetic particle-in-cell (EMPIC) simulations at IPR.

Laser plasma interaction with few-cycle ultrashort focused light beam : In laser generated plasmas or direct acceleration of charge particles by ultra-intense lasers it is very important to know the laser beam dynamics to analyze the results. Commonly used slowly varying envelope approximation fails for an ultrashort Gaussian pulses as the pulse duration approaches near one optical period or below. Using complex analytic signal representation (M. Porras et al., PRE, 58, 1086 (1998)) we obtained an accurate Gaussian pulsed beam of focal width down to one wavelength and pulse duration equal to one optical period. The analytical profile is then used as an initial condition for numerical excitation of the laser beam in the electromagnetic particle-in-cell code (EMPIC). Numerically propagated beam was matched with the analytical beam which was extremely important before investigating laser illuminated plasma with few-cycle Gaussian beam. Electron acceleration from a near critical density overdense plasma (steep density gradient) slab is studied by previously mentioned electromagnetic particle-in-cell simulation with normally incident few-cycle Gaussian light beam. Keeping the focal width equal to the wavelength we vary the pulse length. It is seen that in the sub-relativistic regime en-

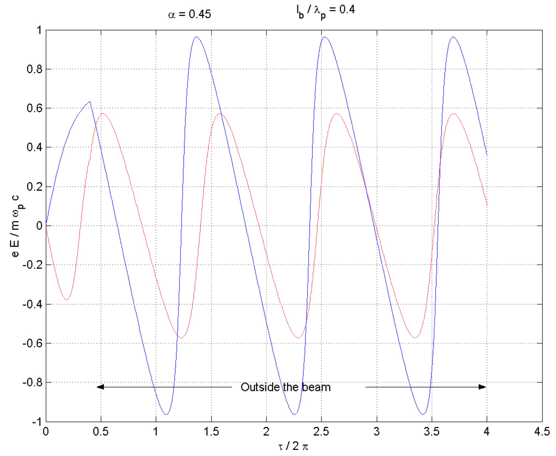

Figure A.4.1.1 showing the wake electric field excited by an electron beam (blue) and a positron beam (red), both inside and outside the beam, for α = 0.45 (ratio of beam density to plasma density

ergy gain by electrons is almost same for single-cycle and five-cycle pulses. For ultra-high intensities five cycle pulse produces more energetic electrons due to its longer penetration and subsequent supply of energy to a larger number of electrons under its envelope. The single-cycle pulse although penetrates deeper at a higher intensity it can only effect less number of electrons under its envelope. Figure A.4.1.2 shows projection of electron density after the interaction of a single cycle pulse of focal intensity 3.5 x 10^{20} W/cm^2 with a slab plasma of density n0 = 2 nc. Further investigation of this results are in progress.

Binary Coulomb collision in plasmas using Monte Carlo method (with PSSI fellowship) : Binary Coulomb collisions are important in some plasma condition, e.g., laser produced high density plasmas. In plasma simulation, most often, physical problem is simplified by ignoring binary collisions in a first attempt. To be more realistic we aimed to include binary collision in the electromagnetic particle-in-cell code which is at present collision-less. We successfully developed the binary Coulomb collision code using the model initially proposed by Takizuka and Abe [J. Comput. Phys. 25, 205 (1977)]. We tested various collision frequencies (slow down frequency, energy transfer frequency) with known text book expressions which are valid for an idealistic case of infinite ion mass. For a second case with ions as Maxwellian distribution at some temperature and electrons as box type initial distribution having zero mean velocity it is seen that electron distribution approaches the desired Maxwellian distribution after a long time. We have integrated this collision code in 1D-3V (one spatial coordinate and three velocity) electro-

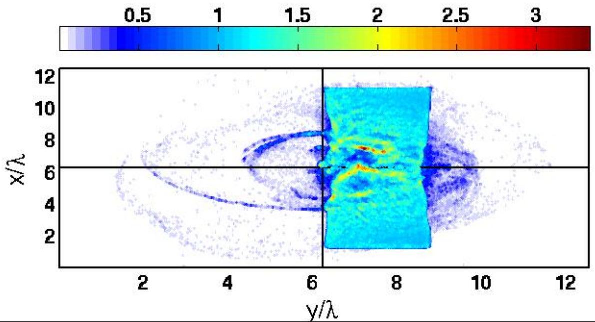

Figure A.4.1.2 Projection of electron density (normalized by background ion density $n_0 = 2\ n_c$) in the x-y plane. The laser (propagating in y and polarized in x) is single-cycle pulse with FWHM = T_0 (laser period), focal width w0 = λ0 = 800 nm, and focal intensity 3.5 x 10^{20} W/cm^2.

magnetic particle-in-cell code and studied collisional absorption of S-polarized light in an underdense plasma slab. Preliminary results are under investigation.

Laser cluster interaction with sub-cycle laser pulses : Atomic clusters, of typical size a few nanometer, have caught significant attention in recent years to produce (i) energetic electrons, (ii) ions, (iii) x-rays after the irradiation with intense femto second laser light. Nuclear fusion also shown possible with laser heated deuterium clusters. Because of its much smaller size than the laser wavelength and solid like plasma density a large fraction of laser energy can be coupled to the cluster. Experimentally this interaction is commonly studied with a pump-probe set up. The pump-pulse ionizes the system leading to the increase in the Mie-plasma frequency much above the laser frequency. Later cluster-plasma expands due to Coulomb expansion, Mie-plasma frequency comes down and then probe pulses are shoot at suitable time delays so that probe frequency matches the Mie-plasma frequency and enhanced absorption of the probe pulse takes place. This linear resonance (LR) process is well-studied in theory and particle-in-cell simulations. One of the drawback of this long pulse LR is that large fraction of ions at the cluster boundary already leave the cluster much earlier than LR is met. In reality cluster plasma is generally inhomogeneous due to multiple charge states and inhomogeneous expansion. Therefore there is no single Mie-plasma frequency to meet LR. For few-cycle short pulses and earlier than LR there is also another collisionless absorption process known as an-harmonic resonance (AHR) [Phys. Rev. Lett. 96, 123401 (2006)]. We have initiated work in this direction by performing simple modeling and three-dimensional PIC simulations with laser pulse duration as short as single optical cycle and below. The wider frequency band of a sub-cycle and near single-cycle pulse provides a few advantage. Some part of the frequency spectrum of the laser pulse may overlap on the wider Mie-plasma frequency spectrum of the ionized inhomogeneous cluster plasma leading to efficient LR. At the same time the off resonant part of the cluster may undergo AHR with some other frequencies of the sub-cycle pulse. The result is that we force both LR and AHR work together to maximize the energy absorption while cluster ions are compact during very short duration of the pulse.

A.4. 2. Non-Linear Physics

An Exactly Solvable Model for Nonlinear Buneman instability using Lagrange variables : Buneman instability is the most elementary cold plasma electrostatic instability involving streaming of electrons with respect to ions. It is associated with novel physical effects like double layer formation, anomalous resistivity etc. Electrons streaming rapidly past the ions excite electrostatic fluctuations which can either lead to anomalous resistivity of plasma by random scattering of electrons or double layer formation by reflection of streaming electrons. Buneman instability is of importance in many laboratory plasma experiments with intense parallel electric fields, such as for example in turbulent Tokamaks and in astrophysical situations with relativistic jets. In this work, we have studied the nonlinear evolution of Buneman instability in the long scale length limit, which is well described by equations for the cold ion fluid with quasineutrality and electron dynamics responsible for giving an ``equation of state'' with negative ratio of specific heats to this fluid. Introducing a transformation for the density variable, the governing equation for the transformed quantity in terms of Lagrange variables turns out exactly to be a linear partial differential equation. This equation has been analyzed in various limits of interest. The linearized density perturbation limit demonstrates the Buneman instability and one recovers an expression for the growth rate. Nonlinear development with a sinusoidal initial disturbance and an initial perturbation in the form of a density void is analytically investigated to see the early development and collapse of double layer like structures which tend to form in such plasmas. Further, governing equations describing Buneman instability including relativistic and dispersive effects have been derived. Analysis and Numerical solution of these equations is in progress.

Nonlinear theory of lower hybrid oscillations in a Cold Plasma : In this work we have a given a nonlinear description of lower hybrid oscillations in a cold magnetized plasma using the method of Lagrange variables. An exact analytical solution with nontrivial space and time dependence is obtained. The solution demonstrates that under well defined initial conditions, in each period, the amplitude of oscillation increases due to nonlinearity and then comes back to its initial state. This represents a class of nonlinear transient structures in a magnetized plasma.

Relativistic effects on nonlinear lower hybrid oscillations in a cold plasma : Here we have further extended the above work, where we have investigated nonlinear lower hybrid oscillations with relativistic electrons, using the method of Lagrange variables. In the weakly relativistic limit, the equation is solved using homotopy perturbation method. It is found that the frequency of oscillation acquires a spatial dependence due to relativistic effects and this results in phase mixing of lower hybrid oscillations.

Nonlinear solutions of the Laser Plasma coupled system : An extensive characterization of nonlinear solutions of the coupled laser and a cold plasma system has been carried out. It has been illustrated that a host of new varieties of solutions appear when the ion dynamics are incorporated. The dynamical studies of these new kinds of solutions in under progress. One particular flat top solutions in the presence of ion dynamical response has been found to exhibit a Brulliouin Scattering instability. The role of temperature in this case is being taken by the quiver velocity of electrons. The analysis is in progress.

A.4.3 Electron Magnetohydrodynamics (EMHD)

G-EMHD simulations : Numerical simulations of Generalized Electron Magneto-hydrodynamic (G-EMHD) equations to study the role of inhomogeneous density on fast electron time scale phenoemena has been carried out in further detail. Some new observations and results are (i) a novel collisionless dissipation of electron currents in a plasma associated with shock formation at the inhomogeneous plasma layer, (ii) The relevance of the collision - less shock to fast ignition, (iii) Observation of Kelvin Helmoltz destabilization of the sharp current layer shocks formed at the inhomogeneity layer, (iv) The formation of a novel state of rotating electron current vortices algned along the narrow plasma density inhomogeneity layer as beads as an aftermath of the KH destabilization (see Fig.A.4.3.1), (v) demonstration of a possible guiding of electron current layers with the help of appropriate inhomogeneous plasma density profile.

1-D simulations of Strongly coupled dusty Plasma : The 1-D GHD model has been simulated using the GHD code in 1-D. The nonlinear phase in 1-D has shown interesting results on the possible wave breaking at high amplitudes in both weak and strong coupling limits. The weak coupling results show formation of stable cusp structure at the wave breaking amplitude of the solitons.

2-D Kelvin Helmholtz studies in a dusty plasma : The shear flow instability in the dusty plasma medium has been studied. The compressibility and sispersion being the prominent effects in this case, their effect have been analyzed in detail on the mode. A numerical simulation code was developed in 2-D to study the nonlinear regime of the instability.

A.4.4 Basic Plasma Studies

Stability of a magnetized multi-component plasma boundary : Plasma sheath is a nonlinear steady-state electrostatic potential structure formed at the boundaries where plasma meets an absorbing surface. A stability of sheath structure which ensures a steady and quiescent bulk plasma state is subject to the boundary flows that need to satisfy the Bohm boundary condition, requiring flow velocity of the plasma at the sheath entrance to exceed the phase velocity of the ion acoustic waves. The generalization of this simple result to magnetized and multispecies plasmas leads to complexities arising from emergence of multiple scales and parameters. In the recent studies, analysis has been carried out for magnetized two ion-species plasmas to investigate the effect of magnetic field on the stability of plasma flow in to a perfectly absorbing plasma boundary.

The existing experiments and theoretical studies in unmagnetized two-species plasma indicate that, the two ion velocities approach a global ion acoustic speed of the system near the sheath-presheath boundary and satisfy a generalized Bohm-Criterion. This behavior is expected to be modified further by the presence of a magnetic field in the cases where the presheath mechanisms scales with the ion-Larmour radius. The present analysis suggests new regions in the parameter space of a two component plasma where the conventional magnetized sheath structure is unstable. The observed effect appears as a consequence of modification of the usual ion-acoustic dispersion relation resulting from the partial magnetization of the two ion species.

Vlasov simulations of finite ion temperature plasmas : Vlasov simulations is effective computational tool to study kinetic and collective processes in plasmas with finite temperature of plasma species. Response of a collisionless finite ion temperature plasma to a compressive density pulse is studied using the Vlasov simulation of a collisionless plasma using the kinetic simulation code KSLab. For small amplitude pulses the simulations show a systematic linear response where regular negative or positive density pulses are generated in the form of counter-propagating structures radiated from an initial square pulse like compressive density perturbation. For large amplitude nonlinear cases the pulse is observed to form undamped stable shock front that propagates time independently for longer duration while reflecting a constant flux of supersonic ions in the upstream

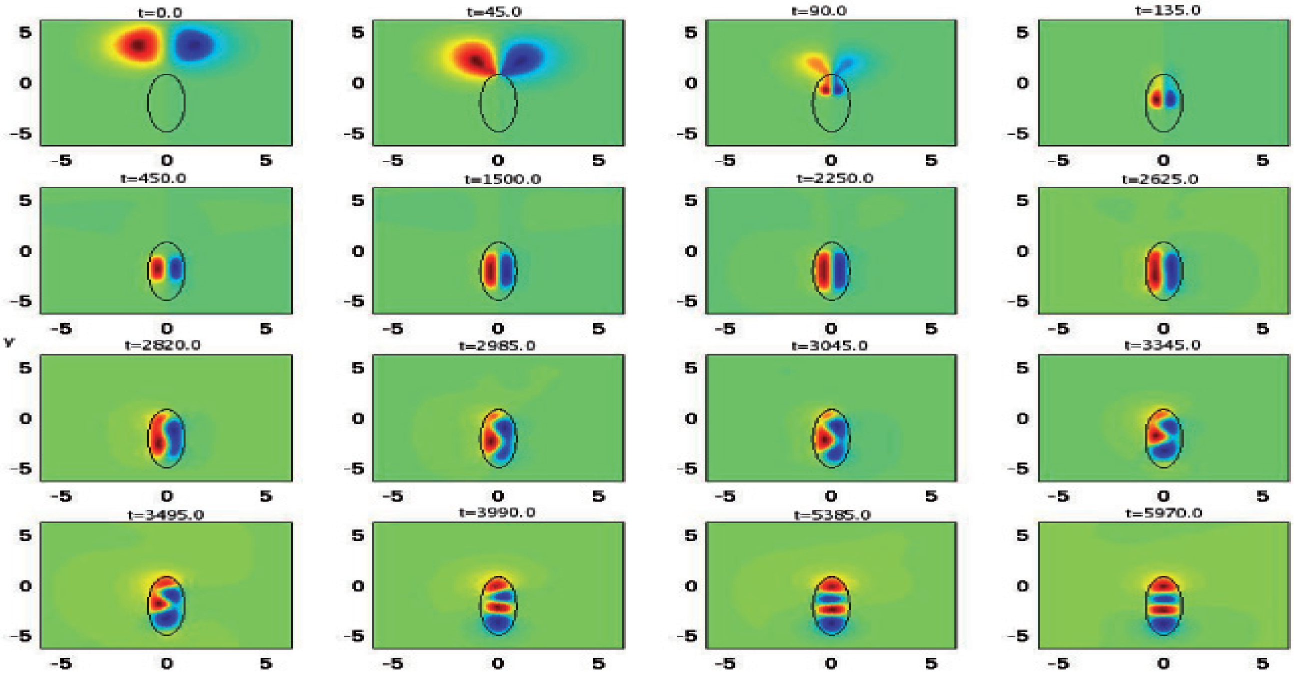

Fig.A.4.3.1 formation of a novel state of rotating electron current vortices algned along the narrow plasma density inhomogeneity layer as beads as an aftermath of the KH destabilization unperturbed plasma. An analytical description is obtained for linear cases where the dispersive properties of the evolution are analyzed using a Fourier-Laplace transform of the initial perturbation explaining the simulation results.

Modeling of plasma as an extended complex dynamical system : Properties of complex nonlinear dynamical systems can be used to describe the behavior of plasma in certain limiting dynamical regimes which may be inaccessible using the conventional collective dynamics of the plasma. For example, reactive processes at time scales slower compared to the fast collective time scales can be suitably analyzed by modeling plasma as a coupled continuum of large number of nonlinear dynamic sub-systems. Such a modeling predicts interesting plasma response to localized perturbations where propagating self organized structures emerge which show critical behavior in the parameter space. The numerical solutions of the model are generated in a 2-dimensional set up illustrating the plasma dynamics in extreme dynamical regimes using the time evolution of the perturbations in a finite range of dynamical parameters.

Fluid simulation of Hall thruster plasma : One-dimensional hydrodynamic simulation of a Hall thruster (HT) plasma in steady state is studied. Our formulation is identical to that proposed by Ahedo et al. (Phys. Plasmas 8, 3058 (2001)). In this model we have included radiative losses (D.E. Post et al., At. Data Nucl. Data Tables 20, 397 (1977)). It is found that the collective effect of radiative atomic processes (e.g., radiative recombination, three-body recombination, charge exchange etc.) is comparable to the well known ionization loss. Radiative effects modify the equilibrium condition of a HT, its performance and may change operating regime from normal to non-sheath regime depending upon the incoming mass-flow rate of the propellant. At a lower mass-flow rate, the effect of radiation shifts the ionization peak further away from the anode than without the consideration of the radiation losses. Radiative effects also reduce the peak electron temperature when the propellant mass-flow rate is increased. A comparative study on the performance of HT with and without anode sheath is also presented in this work.

A.4.5 Global Gyrokinetic Studies

Toroidal universal drift instability -A global gyrokinetic study : An electron density gradient driven instability identified as the toroidal branch of the universal drift instability is studied using a global gyrokinetic model treating both electrons and ions fully nonadiabatically and valid at all orders in the ratio of the Larmor radius to the wavelength. The physics of the magnetic drift resonance, Landau resonance and transit resonance, which are considered to be important for the toroidal universal mode, are kept for both species. A systematic parametric study is carried out for the mode. The toroidal universal drift mode is observed to sustain finite temperature gradient and can thus coexist with the temperature gradient driven modes and may contribute to the observed particle transport along with other drift modes.

Especially at intermediate scales between the ion temperature gradient driven mode and electron temperature gradient driven mode, this branch of the drift instability can also be a plausible candidate for the observed particle loss. The effect of magnetic fluctuations on the mode is also investigated. In contrast to the slab mode, the toroidal branch of the universal drift mode is found to be strongly stabilized by electromagnetic effects at finite plasma. Finally, the effect of trapped electrons on the universal mode is studied and com ared with the other possible modes in the same parameter regime, namely, ion temperature gradient mode in the presence of trapped electrons and pure trapped electron modes.

Size scaling and gradient scale length dependence of hot ion transport by iontemperature gradient driven turbulence : Hot ion transport has been studied using a global gyrokinetic nonlinear simulation in the presence of ion temperature gradient (ITG) driven turbulence. The measured transport tends to saturate as the system size increases exhibiting a continuous transition from a subdiffusive process toward diffusive one. At stronger ITG drive characterized by the temperature gradient of thermal ions hot ions with lower energy remain virtually unaffected, whereas transport of hot ions with higher energy continue to increase with the gradient.

Radial transport of energetic ions in the presence of trapped electron mode turbulence : The nature of transport of hot ions is studied in the presence of microturbulence generated by the trapped electron mode in a tokamak using massively parallel, first principle based global nonlinear gyrokinetic simulation, and with the help of a passive tracer method. Passing and trapped hot ions are observed to exhibit inverse and inverse square scaling with energy, while those with isotropic pitch distribution are found to exhibit inverse dependence on energy. For all types of hot ions, namely, isotropic, passing and trapped, the radial transport appears to be subdiffusive for the parameters considered.

A.4.6 Molecular Dynamics (MD) Simulation

MD Simulation of Yukawa Systems : Parallel shear flow instabilities in strongly coupled Yukawa liquids - A comparison of generalized hydrodynamic model and mo-

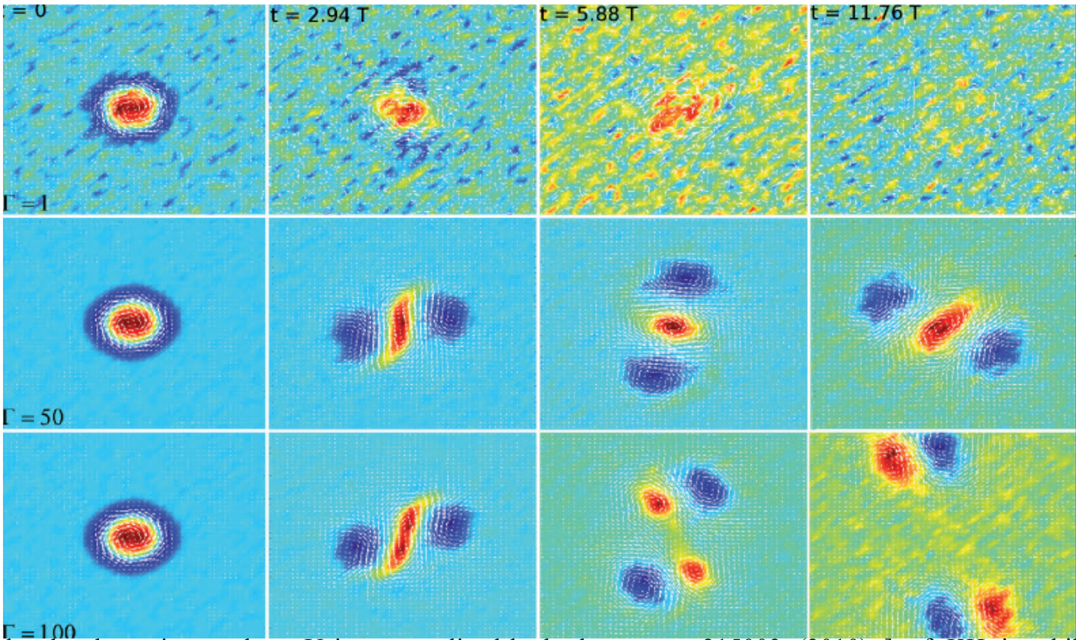

Figure A.4.6.2 Time evolution of the vorticity profile for different values of initial Γ. Rows and columns show snapshots at constant Γ and τ respectively. Blue and red regions correspond to negative and positive vorticity respectively

lecular dynamics results. Using generalized hydrodynamic (GH) model, growth rate spectra of Kelvin-Helmholtz (KH) instability has been obtained analytically for a step shear profile in strongly coupled Yukawa liquids. The class of shear flows studied is assumed to be incompressible in nature. The growth rate spectra calculated exhibit viscous damping at high mode numbers, destabilization at stronger coupling and in the limit viscoelastic relaxation time, τ -> 0, reduce to the regular Navier-Stokes growth rate spectra. A direct comparison is made with previous molecular dynamics (MD) simulations [Phys. Rev. Lett. 104,

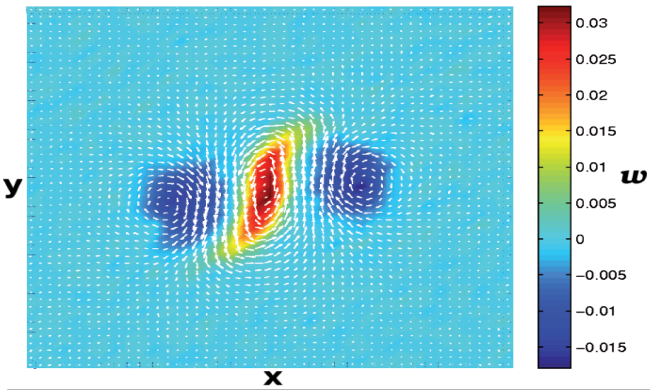

Figure A.4.6.1 Tripole emerging at time τ = 2.82T, starting from an initial Γ = 50. The snapshot shows vorticity plot for only a partial system. Blue and red regions correspond to negative and positive vorticity respectively and the colormap label shows the magnitude of local vorticity. Arrows indicate direction of local velocity

215003 (2010)] of KH instability. We find that for a given value of Reynolds number R and coupling parameter 1 < Γ < 100, the GH and MD growth rates are in a qualitative agreement. Inclusion of the effect of shear heating as an effective coupling parameter Γ appears to improve the quantitative comparison as well.

Coherent vortices in strongly coupled liquids : Strongly coupled liquids are ubiquitous in both nature and laboratory plasma experiments. They are unique in the sense that their average potential energy per particle dominates over the average kinetic energy. Using ``first principles'' molecular dynamics (MD) simulations, we report for the first time, the emergence of isolated coherent tripolar vortices from the evolution of axisymmetric flows in a prototype two-dimensional (2D) strongly coupled liquid, namely the Yukawa liquid [see Figure A.4.6.1]. Linear growth rates directly obtained from MD simulations are compared with a generalized hydrodynamic model. Our MD simulations reveal that the tripolar vortices persist overseveral turn over times [see Figure 2] and hence may be observed in strongly coupled liquids such as complex plasma, liquid metals and astrophysical systems like white dwarfs and giant planetary interiors, thereby making the phenomenon universal.

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B. ACTIVITIES OF OTHER CAMPUSES.

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

FCIPT (http://www.plasmaindia.com) is a division of IPR, and has a mandate to develop plasma based technologies on commercial basis. Further, it also acts as a link between the Institute for Plasma Research (IPR) and Indian industry. In the last one year, at FCIPT, the following activities were undertaken.

B.1.1 PLASMA SURFACE ENGINEERING

Design and development of various basic plasma experimental systems for Delhi University (DU), New Delhi : FCIPT, IPR has taken an initiative to promote the awareness of plasma science among Indian student community. In this direction, FCIPT has received an order from Delhi University, for the design and development of four basic plasma experimental systems. The four systems include, Pulsed Plasma Nitriding system, ExB Cylindrical Drift Velocity measurement system, Washergun based pulsed plasma system, and a Surface Flashover Plasma Source system. The total cost of the project is around 2 crores. These facilities will be used by M. Tech. and Ph.D. students of that region. One of these four systems i.e. Pulsed Plasma Nitriding system has been successfully installed and commissioned at Department of Physics and Astrophysics of DU. The photograph of the installed system is shown in the fugure B.1.1.1. The work on the development of the remaining systems is progressing well.

Figure B.1.1.1. Photograph of the Pulsed Plasma Nitriding System that was installed at Delhi University, New Delhi

Development of alloy/compound coatings using Twin Magnetron system: FCIPT has designed and developed a twin-magnetron sputtering system, in which two different target materials could be simultaneously sputter deposited, and the electrical power to each of these targets could be controlled independently. This system has been used for depositing and studying the Ti-Al alloy coatings. The schematic of the experimental system is shown in figure B.1.1.2. For this study Aluminum (Al) and Titanium (Ti) have been used as the target materials. Efforts were made to tune the operating parameters to deposit the alloy coatings of desired composition by varying the magnetron power to each target. The preliminary results are encouraging and are shown in table 1

Exp. No.	Required composition (atom% Al-Ti)	Aluminium Target power (watt)	Titanium Target power (watt)	Obtained composition (atom% Al-Ti) by EDAX
1	10-90	20	400	8-92
2	20-80	20	200	18-82
3	30-70	20	120	29-71
4	40-60	45	190	36-64
5	50-50	45	80	55-45

Table B.1.1.1: Summary of the experimental details and results

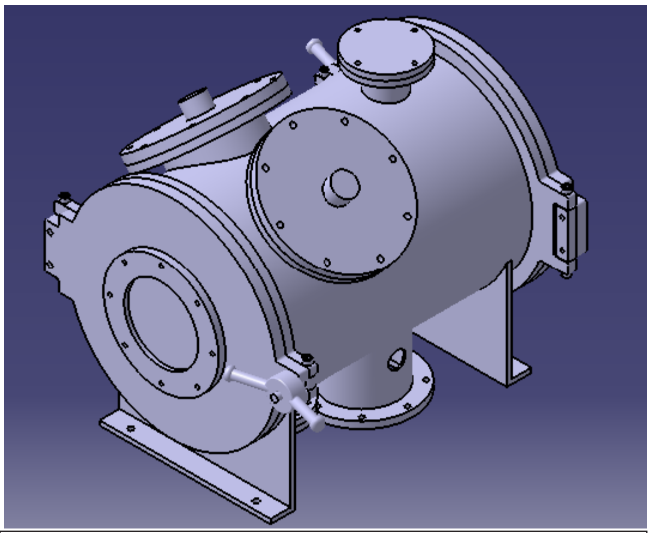


Figure B.1.1.2. 3D rendered view of the experimental twin magnetron system

Installation of Lab Scale Plasma diagnostics Systems for basic plasma study (for Delhi University) : FCIPT has developed two lab scale plasma based experimental systems for Delhi University. These systems are meant for post graduate students, to carry out the experiments on routinely basis and hence they were designed more user-friendly and with safety features. The first system is equipped with such facilities to carry out the following experiments: To study a) Paschen curve, b) various regimes of glow discharge, c) normal-abnormal glow discharge transition characteristics, and d) striations in the glow discharge plasma. In the second system, experiments to measure the plasma properties like electron temperature, plasma density, plasma potential could be carried out using Langmuir probe. Both these systems have been developed and successfully installed at Delhi University (DU), Delhi.

Hot Dip Aluminizing Of 9Cr-1Mo Steels : Hot dip aluminide coatings have been developed on 9Cr-1Mo steels (ASTM A 387 Gr91 Cl.2) so as to generate an insulating top layer of α-Al2O3 followed by ductile aluminide intermetallic phases viz. FeAl and α-Fe(Al). Hot dip aluminized coating with melts of Al-Si alloy with different concentration of silicon (Al with 1%, 3%, 5% and 7% silicon) have been studied with and without heat treatment. Heat treatment of these hot dip aluminized steels have generated the required Al2O3 layer over the FeAl and α-Fe(Al) phases. Aluminide coatings developed from Al-7%Si melts and subsequently heat treated at 900° C for 5 hours have shown the required phases and a diffusion depth of 150 μm. The phases so generated by the heat treatment have been confirmed form the X-ray diffraction analysis. The morphological study of the surface using SEM (figure B.1.1.3) indicates plate type growth of the oxide layer confirming to the transformation of metastable alumina to stable α-Al_2O_3 which is desirable. Further work is being carried out to reduce the case thickness of such aluminide coatings while maintaining the required phases so produced.

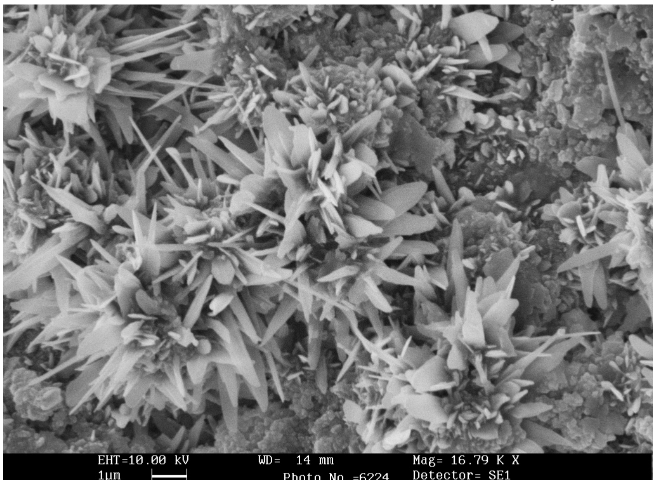


Figure B.1.1.3 Surface morphology of oxidized hot dip aluminized 9Cr-1Mo steels indicating the morphology of Al_2O_3 grown on the surface.

Plasma aluminizing of Inconel 718 alloys under BRNS funded project : A project on under this head had been sanctioned by BRNS, DAE, Mumbai under prospective research funding scheme. The plasma aluminizing system (figure 4) as per design conceptualized by the project team has been installed and commissioned at FCIPT in October 2010. Preliminary work on optimization of Al deposition parameters has been completed and the studies related to the diffusion of Al into inconel 718 samples are being carried out. Processes of deposition and diffusion can be carried out, simultaneously, using the installed plasma aluminizing system. A unipolar high voltage pulsed power supply has been developed under this project to bias the substrate and study the effect of substrate biasing in the diffusion process. Work on interfacing the system with PC using LabviewTM software is in progress.

Achievement of High Growth Rate of Mixed Phase Hydrogenated Silicon (Si:H) thin film by Multi-hole Cathode (MHC) VHF PECVD : Mixed phase Si:H thin films composed of little fraction of crystallites with a large volume portion of amorphous material have attracted much attention in recent years. These films reported the best performance as an active or absorber layer (i-layer) in p-i-n solar cells due to very low light-induce degradation. The effect of multi-hole cathode (MHC) with respect to the total gas pressure

Figure B.1.1.4. Plasma Aluminizing system with unipolar high voltage pulsed power supply for substrate biasing installed in FCIPT.

is investigated to understand its influence on realization of high growth rate of mixed phase Si:H films deposited by Very High Frequency (VHF) Plasma Enhanced Chemical Vapour Deposition (PECVD) technique. Mixed phase Si:H thin films were grown by achieving a very high deposition rate of 3.6 nm/sec at a relatively low substrate temperature of 60°C using MHC VHF PECVD process, under high power density (1.32 watt/cm2) and high operating pressure (2 Torr) conditions. The pressure dependence study of MHC in the pressure range of 0.5 to 9 Torr reveals that the intense plasma spot formation on each hole of cathode surface, at 2 Torr pressure, is responsible for the observed high deposition rates.

B.1.2 PLASMA PYROLYSIS

Disposal and Gasification of Petroleum waste using Plasma Pyrolysis : Safe disposal of petroleum waste, including petroleum residue, pet coke, petroleum sludge, etc., is a serious concern for petroleum refineries. Chemical composition of this waste is generally dominated by carbon and hydrogen, and hence has good calorific value. Plasma pyrolysis/gasification is a state of the art technology for safe disposal and energy recovery from organic waste. This technology converts organic waste into commercially useful by-products. At FCIPT, a MoU was signed with M/s. Bharat Petroleum Corporation Ltd, to convert petroleum waste into useful syn gas using thermal plasma technology. The initial trial experiments have been carried out for disposing and/or gasification of the above mentioned petroleum waste and the results are encouraging. The photograph of the system, used for the pyrolysis/gasification, is shown in figure B.1.1.5. Pyrolysis of this residue, at approximately 800°C, is found to generate mainly Carbon -monoxide, Hydrogen, and Methane; and the composition of gas formed is found to be as follows : Hydrogen: 22-25%, Methane: 18-23% Carbon monoxide: 2-4%, Carbon di-oxide: 2-3%, Oxygen: 1.5-4%, and the rest are hydrocarbons and Nitrogen. These gases thus formed, in the presence of a catalyst, can be converted into methanol/ ethanol. By this way, the amount of carbon released into the atmosphere (in the form of CO2) can be reduced. However, these are the preliminary results and the detailed study is underway.

Figure B.1.1.5 Photo of the plasma pyrolysis system that is used for the pyrolysis/gasification of the petroleum residue

Studies on Thermal Plasma Pyrolysis of Crude Oil Residue and Energy Recovery : DST has sanctioned the above project, which was jointly submitted by Petroleum University (PDPU), Gandhinagar and FCIPT, IPR. In this project the main objectives are as follows: (i)Data generation on plasma pyrolytic disintegration of crude oil residue and energy recovery from the pyrolysis gases; (ii) Understanding the temperature profile in pyrolysis chamber with and without gas flow mechanism in graphite electrode based plasma arc system; (iii) Identification and quantification of various gases formed at different temperatures when crude oil residue is pyrolysed

Installation of a Plasma Pyrolysis system at Doon Hospital, Dehradun : A Plasma Pyrolysis System was installed and commissioned at Doon Hospital, Dehradun. The fabrication and installation of the system was carried out by M/s Bhagwati Pyrotech Pvt. Ltd. Along with FCIPT, IPR. This system is meant for disposing bio-medical waste and has a waste disposal capacity of 20 kg/hour.

B.1.3 RESEARCH AND DEVELOPMENT AND OTHER ACTIVITIES

Development of six laboratory scale glow discharge experimental systems : The Government of India has identified Plasma Physics as one of the important areas of science and technology requiring major research and further academic explorations, keeping in tune with the world-wide advancement in Plasma Physics. Consequently, research and training programs in Plasma Studies are gaining rapid impetus in In-

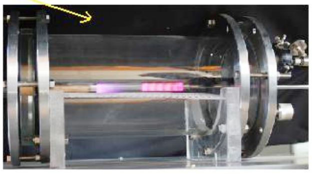


Figure B.1.1.6 Photograph of the system to experiment on Plasma Striations

dia. Plasma physics is being taught in most of the universities, particularly at post graduation (M. Sc.) level, as an elective subject. However, most of the universities are lacking the supportive experimental systems for the students to carry out simple experiments in the lab. In an attempt to popularize plasma physics by supporting Indian academic community, FCIPT has taken the initiative to develop low cost, lab scale compact glow discharge experimental systems. As a first step in this direction, FCIPT has developed six glow-discharge based experimental systems and the working models have been successfully demonstrated at 25th National Symposium on Plasma Science and Technology (Plasma 2010), Guwahati. The developed systems could be used for studying Paschen Curve, Plasma Striations, Plasma diagnostics using single and double Langmuir probes, Ion Acoustic Waves, and to demonstrate one application of the Plasma technologies. This initiative has been financially supported by Board of Research in Fusion Science & Technology (BRFST). Photograph of the Plasma Striations system is shown in the figure B.1.1.6.

Torch development work : Experimental studies on the low power 25 kW plasma torch system were taken forward in the new FCIPT premises. System was operated for various experimental conditions; regimes for stable operation were identified. Based on these studies, torches with better wall, gas & magnetic stabilization have been designed for steady state operation. Plasma torch efficiency was estimated by calorimetric technique. Influence of external applied magnetic field & ratio of primary gas to shroud gas flow on plasma torch efficiency was investigated; more experiments are being carried out presently. A combined experimental-cum-theoretical approach has been adopted to identify dimensionless parameters and build similarity criteria for this class of plasma torches; such an analysis will enable smooth scale-up to high powers. Computational studies based on finite element & fluid dynamic approaches have also been initiated. A 3-year project has been funded by BRFST for numerical simulation of high heat flux on target by thermal plasma impingement method. Experiments will be conducted at low to moderate powers for validating results obtained from numerical work.

Plasma Applications in Textiles

Plasma surface modification of polyester fiber and fabric to enhance dye uptake properties with natural dyes : This is a DST sponsored collaborative project with Institute of Petroleum Technology (IPTG), Gandhinagar. In this project FCIPT has developed atmospheric pressure plasma reactor and studies have been conducted to modify the polyester surface. To understand species formed in plasma an optical emission spectrometer has been connected with the reactor. Attempts are being made to identify the plasma species and correlate role of plasma species with the functional groups formed on the surface of the polymer. In addition the study will help us in understanding the role of graft functional groups for improving dye uptake properties.

Development and Performance Evaluation of an Industrial Scale Atmospheric Pressure Air Plasma System to Treat Angora Wool for Manufacture of 100% Angora Products : This project was sanctioned by DST and the objectives of this project are as follows: (i) To develop and demonstrate industrial scale atmospheric pressure air plasma treatment system to modify the surface properties of 1 m wide Angora web at the processing speed of 3-4 m/min to improve processing of Angora wool. (ii) Setting up of plasma treatment system at Himalayan Institute For Environment, Ecology and Development (HIFEED), to carry out its performance evaluation and manufacture of 100% Angora products from treated fibers. (iii) Treatment of Angora wool on routine basis to provide services to the people of rural areas involved in the development of Angora wool based products. This project has been initiated and a team has visited to HIFEED, Ranichauri, to generate technical data, based on height of carding machine and space available for the plasma system. Further FCIPT, IPR has signed an NDA with InspirOn Engineering Pvt. Ltd. which will help in designing and fabrication of the system for HIFEED.

Plasma Treatment of Brass Valves to Improve Rubber to Brass Bonding : FCIPT has developed a plasma based processing technology to improve rubber to brass bonding by modifying the surface of the brass, some time back. This process was successfully studied for its feasibility on the rubber bonding of TR13 valves used in the auto industry. Based on the success of the feasibility process (600 valves could be treated in one batch) and the willingness of an industrial partner (M/s Triton Valves) to contribute 50% of the system's cost, DST has sanctioned a project to FCIPT, to develop a scaled up version of the experimental system in which 5000 valves could be treated in one batch. The project has been initiated in June 2010. The engineering design of the system is completed, engineering drawings generated, and the execution plan is prepared. Power source and system fabrication is expected to be ready soon

Feasibility Study to recover Phosphorus from Phosphoric acid : Phosphoric acid, in the presence of carbon (reducing agent), reduces into phosphorus and syngas at temperature around 900° C. Phosphorus is highly reactive with oxygen, and it converts into Phosphorus pent-oxide when it comes in contact with oxygen. Hence, recovery of Phosphorus from phosphoric acid not only needs high temperature, but reducing (oxygen starved) environment as well. The chemical reaction is given by,

$$4H_3PO_4 + 16\,C \xrightarrow{900^{O}C} \underset{(g)}{P_4} + \underset{(g)}{16CO} + \underset{(g)}{6H_2}$$

Hence Plasma Pyrolysis may prove to be a suitable technology to provide the necessary reaction condition for the reduction of phosphoric acid into phosphorus. M/s. Excel Industries, Mumbai has sponsored a project of worth Rs. 16.0 Lakhs, for conducting feasibility study experiments to recover phosphorous from phosphoric acid using plasma pyrolysis technology also with the added possibility of recovering energy from the reactions.

Spacecraft Plasma Interaction eXperiments (SPIX-II) : The recent trend towards placing more transponders in a single satellite has led to increased power requirements for Geosynchronous Earth Orbit (GEO) satellites. To fulfill this increased power need, the satellite bus voltage has to be increased beyond the present value of 42 volts. Typically for a satellite rated more than 10 kW of power, the required bus voltage is about 100V. Considering the growing demands of satellite for new applications, this power level is likely to grow further upwards. In any satellite, the solar arrays are the only source of power. Considering the long term goal of Indian space program, ISRO and FCIPT, IPR envisaged to develop an indigenous ground test facility for LEO (Low energy: Te=0.1-10eV, high density: n~10^5–10^{12}cm^{-3}) and GEO (High energy: Te=1-10KeV, low density: n ~ 0.1-1cm^{-3}) environment. The proposed test facility will be capable to experimentally simulate the charging processes of a solar array in both orbits. At FCIPT, during last few years, arcing phenomena on solar arrays has been studied broadly in Low Earth Orbit (LEO) like environment only. The objective of the ongoing study is to design and develop a test facility which can meet the international standards for LEO and GEO like space environment. The photograph of the developed experimental chamber is shown in the figure B.1.1.7

Figure B.1.1.7 Photograph of the SPIX experimental setup

Synthesis of Nano Silver and the study of their anti-microbial properties : For the synthesis of nanosilver particles the electrodes (both cathode and anode) used were commercially obtained silver rods. For cathode a silver rod of 4 -5 mm diameter was used and whereas for anode the diameter was bigger - ~ 30 mm diameter. An arc was initiated and sustained between the electrodes and the DC current applied was approximately 25 A with voltage varying between 30 – 50 V.

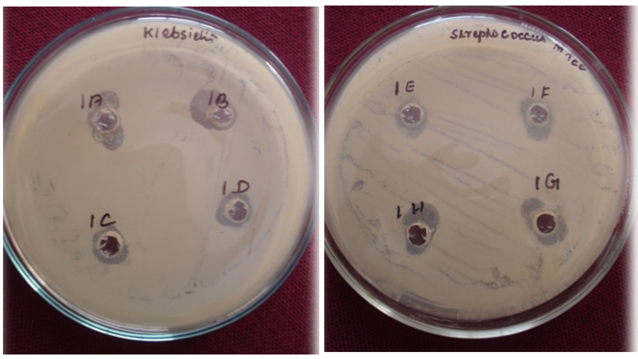


Figure B.1.1.8 Antibacterial activity of solid extract against (a): Klebsiella pneumonia (Gram positive) and (b): Streptococcus pyogenes (Gram negative)

The average particle size of the synthesized nano silver is 170 nm. These nanoparticles were studied for its effectiveness to control the growth of two types of bacteria (i) Streptococcus and (ii) Klebsiella, both of which are pneumonia causing with the first one being Gram negative and the second one being Gram positive.The studies indicated that for Streptococcus bacteria the maximum zone of inhibition of 12 mm was for 100 ppm silver nanoparticle concentration solution with the number of bacteria inhibited being 1 X 10^5 bacteria. For Klebsiella bacteria the maximum zone of inhibition of 11 mm was observed for a concentration of 25 ppm with the number of bacteria inhibited being 9.1 X 10^4. Further studies are to be conducted with reduced silver nanoparticle size.

Creating Worn-out (Fading) Effect in Jeans, using a Non-thermal Plasma Torch : Jeans has been a popular piece of clothing amongst the young and old alike since the late nineteenth century, during which it was invented. Traditionally, denim was colored blue with indigo dye but with changing fashion new trends have emerged. Distressed or worn-out jeans are one such fashion trend that is quite popular nowadays. To give the worn-out look various types of techniques are commonly used. Few of such techniques include stone washing, washing treatment, acid washing, chlorination, ozone bleaching etc. However, all such conventional techniques have certain inherent disadvantages. As a viable alternative to the above techniques, FCIPT has recently developed an environment friendly process for creating the worn-out effect on a fabric using non-thermal plasma flame that was generated using air or oxygen as plasmagen gas and exposing the denim, to this flame, for a few seconds. The distance between the plasma flame and the fabric was properly maintained so that flame would not damage the fabric. The generated plasma comprises of active O radicals and ozone that react with dye-molecules of the fabric for permanently fading the fabric in the pre-defined area, thereby creating the worn-out effect. A pencil plasma torch, connected with an AC power supply (2-10 kV, 100 mA-1 A), was used for generating the necessary plasma. The pencil torch comprises of a live electrode and a ground electrode and the gap between these two could be varied between 0.2 and 6 mm. The plasmagen gas is introduced into the annular gap between the electrodes at a flow rate varying in between 10 and 100 lpm (liters per minute).

B.1.4 SURFACE CHARACTERIZATION LAB ACTIVITIES

The surface characterization lab is engaged in characterizing various materials to aid the internal research & developmental activities and also to the external customers on commercial basis.
Internal Projects, Research and Development : The necessary characterization work associated with the internal activities, both from IPR and FCIPT, is regularly carried out. Some of the important activities with important role of characterization are given below.

Analysis of Carbon-Aluminum bi-layer coatings : Carbon-Aluminum bi-layer coating was developed on glass substrate using magnetron sputter deposition for developmental research of bolometer diagnostics for tokamak plasma. The coatings optimized for the deposition parameters were analyzed using SEM, EDAX and XRD, at every step of variation in parameters such as power, pressure, target-substrate distance, etc. The analysis was used to optimize the microstructure and crystallinity of the film and to evaluate the deposition rate from the thickness. The carbon layer is of amorphous in nature and it could be tailored in transparent to opaque range. Al is highly crystalline but has two distinct microstructures, a uniform layer lying on columnar structure (Figure B.1.1.9).

Analysis of Erbium oxide bi-layer coatings : Er_2O_3 coating development experiments were initiated with an aim to develop and validate tritium permeation barrier and electrically insulating coating for the TBM application to mitigate tritium loss and MHD drag problems. Reactive magnetron sputter deposited, initial coatings were analyzed using XRD, SEM

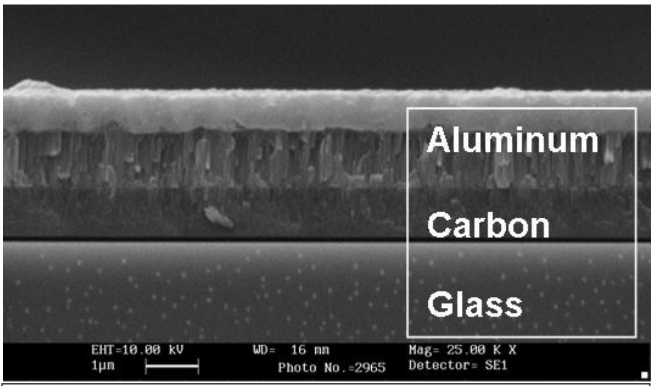


Figure B.1.1.9 SEM image of the C-Al bi-layer

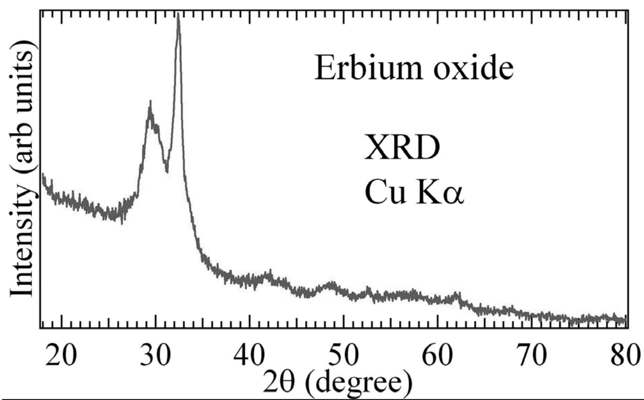


Figure B.1.1.10 Representative XRD pattern of the deposited Erbium Oxide and EDAX and found that the O2 environment effectively converts Erbium into transparent Erbium oxide. However the crystal structure is not cubic, which is the most stable one. XRD results show deposition rate dependent evolution of crystallinity. Figure B.1.1.10 shows a representative pattern of deposited Erbium oxide.

A brief list of other internal research and developments through material characterization :

a) SEM and EDX analysis of cable-in-conduit superconductors - Nb3Sn strands.

b) The crack formation, due to the bend test, in YBCO superconducting tapes was analyzed using SEM.

c) Air plasma treated polyester and polyethylene are analyzed using SEM.

d) Plasma treated textured PU films (artificial skin) were analyzed using SEM.

e) Various plasma nitrided, and plasma carburized steels and Ti based films were analyzed using XRD.

f) Various metallic and oxide coatings and thin films were were analyzed using XRD, SEM and EDAX for phase formation, morphology and diffusion.

g) ZnO and WO3 thin films ion implanted with Fe and Ar respectively at various dose, were analyzed using powder XRD.

h) Arc plasma synthesized nano structures of various materials were analyzed for phase, size, shape and elemental composition using XRD and SEM.

i) Plasma Nitro-Carburizing of 17-4-PH grade steel at various process parameters, was analyzed using powder XRD for phase identification.

j) RAFMS [9Cr,W,Ta,V,Si,C] was analyzed for its microstructure and crystal structure using optical microscope and SEM. The composition was also checked qualitatively. XRD analysis showed single martensitic phase.

k) SEM analysis has been carried out to examine changes/ modification after plasma treating the Marino wool. The treated fiber's surface morphology has been compared to untreated fiber.

l) Pre-solar grains-SiC were observed under SEM in which the shape and size are identified for SiC grains-stardust of SiC compositions.

m) SEM examination was carried out for the microstructural observation of the weld joints (using TIG) of various steels subjected to various treatments.

n) SEM cross-sectional analysis of Tin Oxide films, deposited on Si substrates using thermal evaporation, showed the formation of randomly oriented tin oxide nano-wires.

Activities carried out on Commercial basis : X-ray Diffraction (XRD), Scanning Electron Microscopy (SEM) and Optical microscopy were offered to external parties on commercial basis. A variety of samples, such as drug powders, artery stent, eye lens capsule etc. were characterized.

B.2. ITER-India

In 2010-2011, ITER as well as ITER-India continued to make significant progress towards resolving many of the outstanding design issues. The ITER baseline design, specifically the overall project schedule (OPS) and overall project cost (OPC) was approved by all the ITER Partners in the extraordinary ITER Council meeting in July 2010 held at Cadarache, France. The new ITER Director General, Prof. Osamu Motojima was also appointed on 28 July 2010 replacing Dr. Kaname Ikeda, who retired after leading the ITER Organisation with distinction since November 2005. Prof. Motojima has been formerly the Director of the National Institute of Fusion Studies (NIFS) in Japan and is very well respected in the fusion community. Soon after assuming office, DG Motojima visited ITER-India on 01 September. During his visit, the DG interacted with ITER-India management and employees and also delivered a lecture (Figure B.2.1) on the present status of the ITER project and his plans for project execution. During 2010-11, ITER has made considerable progress in completion of the design and resolving complicated Technical design and Project management related issues. ITER has already signed by the end of March 2011 about 61% of its overall Procurement Packages distributed among its seven partners. The Building construction at the ITER site at Cadarache has progressed on schedule.

There has been good progress also in construction of the ITER-India laboratory building at IPR, Gandhinagar (Figure B.2.2) and is soon to be ready for occupation. Various R&D activities, prototyping and testing of ITER components will be carried out in this laboratory. During 2010-11, ITER-India signed 3 procurement arrangements (PAs) with IO, namely for Torus and Cryostat Cryo-Lines (TCCL), Ion Cyclotron Power Supplies (ICPS) and SPIDER power supply and beam dump. The total kIUA value of these three procurement packages is 11.33kIUA (1kIUA~1.55MEuro). The progress of both the overall ITER project as well as that of ITER-India packages is shown in Figure B.2.4 through the Earned Value progress in 2010 (Jan-Dec) for the In-kind procurements. The progress of specifically ITER-India packages is shown in Table B.2.1. It is to be noted that for both the overall procurements and also for the ITER-INDIA packages, the earned value is falling short of the planned value. As a result, the Schedule Performance Index (SPI) achieved is about 0.6-0.7 in both the cases, indicating a schedule delay. Specifically for the Indian procurement packages, the schedule delay has resulted mainly due to delays in ITER International Organisation (IO) for delivering the Build-to-Print design of the

Figure B.2.1. ITER Director General Prof. Osamu Motojima delivering a lecture on the status of ITER at ITER-India

Figure B.2.2 ITER-India Laboratory building at IPR campus, Gandhinagar

Cryostat package, as the design is still ongoing. As a result, ITER-India could not sign the procurement arrangement of the Cryostat package, which was scheduled in June 2010 in the ITER baseline schedule. Other noticeable delay is in the signing of the ICPS package, which occurred mainly due to disagreements in the package scope and PA documentation. The PA was finally signed in March 2011. Currently, the IO and all the DAs are involved in detailed analysis and formulation of the schedule recovery plan, which will lead to improving the SPI.

ITER-India placed its first industry contracts directly related to procurement for the In-wall shield (IWS) blocks in 2011. While the contract for the IWS manufacture was placed with M/s. Avasarala Technologies Ltd, the contracts for material supplies were placed with M/s. Carpenter Powder Products, USA and M/s. Industeel, France. Following is a brief account of the activities in the different Procurement Package areas of ITER-India in Work Break Structures (WBS):

WBS 1.5 In-Wall Shielding (IWS)

In Wall Shielding blocks (IWS) shall be placed between Outer shell and Inner shell of Vacuum Vessel (VV) to stop escaping the neutrons and to reduce the ripple in toroidal magnetic field. 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.

Activities carried out by IWS group during given period:

Contract Placement: Three major contracts are awarded to execute the IWS PA. (a) Contract for Manufacturing, Pre-Assembly and Supply of IWS to M/s. Avasarala Technologies Limited (ATL), Bangalore (in consortium with M/s. Dynamatic Technologies Limited (on 1st Sept 2010). The Procurement of Fasteners is in the scope of this contract, (b) Contract for Manufacturing and Supply SS 304B7 to M/s. Carpenter

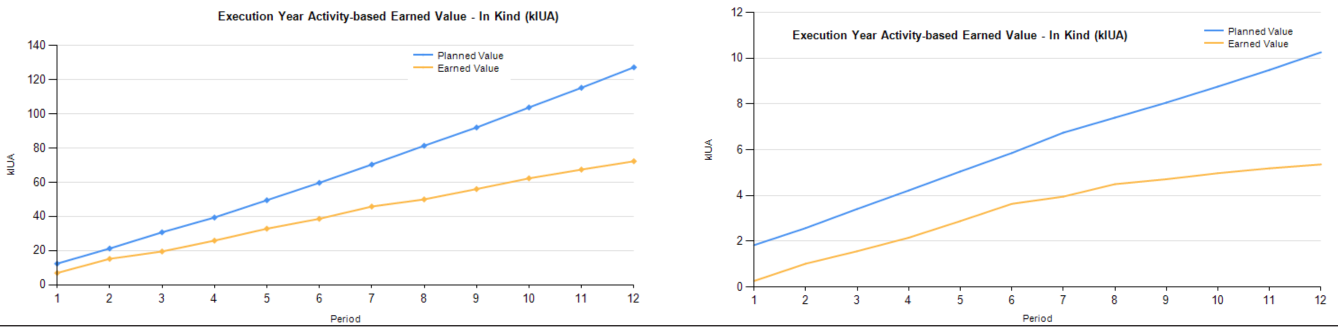


Figure B.2.3. The Progress of the Activity-based Earned Value of the In-Kind procurements of all DAs (top) as also that of ITER-India (bottom) in 2010 (Jan-Dec). Note: 1 kIUA=1.55MEuro.

PA	Description	Planned Value	Earned Value	Schedule Variance (kIUA)	SPI
1.5.P1B.IN.01	n-Wall Shielding (VV-IWS) Block Assemblies	I1.62893	1.10595	-0.52298	0.68
2.4.P1A.IN.01	Cryostat	0.91192	0.00000	-0.91192	▬
2.6.P2A.IN.01	Heat Rejection System (HRS) & Comp Cooling Water (CCWS), Chilled Water System (CHWS)	3.82925	2.67520	-1.15405	0.70
3.4.P2.IN.01	Lower Pipe Chase Cryolines and Later Delivery Cryolines	0.09346	0.07757	-0.01589	0.83
5.1.P3.IN.01	IC RF Power Sources	0.84183	0.46300	-0.37883	0.55
5.1.P4.IN.01	IC RF HV Power Supply	0.46121	0.00000	-0.46121	
5.3.P7A.IN.01	Diagnostic Neutral Beam Power Supply	0.33636	0.23303	-0.10334	0.69
5.3.P7B.IN.01	Diagnostic Neutral Beam Beamline	2.05463	0.79957	-1.25506	0.39
5.3.P9.IN.01	Neutral Beam Test Facility Components	0.08663	0.00038	-0.08625	
5.5.P09.IN	Diagnostic Systems	0.01036	0.00000	-0.01036	

Table B.2.1: Schedule Variance analysis of Indian Procurement packages in ITER for 2011

Powder Products (CPP), USA (on 1st Nov 2010), (c) Contract for Manufacturing and Supply of SS 304B4, SS 430, SS 316L (N)-IG to M/s. Industeel, France (on 9th Nov2010). India has also received credits of 2.3 kIUA for finishing the milestones for the two Contract Awards from ITER – IO.

Mock up – Manufacturing: To validate the machining parameters, two separate mock-up IWS blocks, one having three plates and the other with ten plates were manufactured (Figure B.2.4). Specifications of the three plate blocks are: Material – (a) Plates – SS 304B4, (b) Brackets and Spacers – SS 304, (c) M30 Fasteners – Mild Steel. Specifications of the ten plate blocks are: Material – (a) Plates – Mild Steel, (b) Brackets and Spacers – SS 304, (c) M30 Fasteners – Mild Steel.

Design and Analysis:

(i) Validation of Design for Lifting bolt: Modified M30 bolt (having a tapped hole in the bolt head) and Eye bolt (M12 for Inboard side and M20 for Outboard side) shall be used to handle the IWS blocks during the block assembly at the site of VV Manufacturer. Engineering design of M30 and Eye bolt is completed. Initial test is carried out at ATL for design validation. NDT were carried out to check the formation of cracks during the test. Results are satisfactory.

(ii)Design of Anti rotation Washer: During the ITER operations, anti rotation washers will be use to prevent the rotation of IWS bolts. Since the IWS will be inaccessible after assembly of VV it is necessary that these anti rotation washers having a 100% efficiency. Currently 2 designs have been selected; these designs will first be tested for the maximum torque required opening the bolts and later will be tested under the vibration and thermal loads.

(iii) Design of Mock ups: Based on the engineering drawings given by ITER-India, ATL prepared the manufacturing drawings for Mock ups. Manufacturing drawings are reviewed and approved by ITER-India and IO.

(iv) Analysis: Structural Analysis, Thermo – Structural Analysis and Baking Analysis are carried out (Figure B.2.5) to simulate the actual stresses produced in IWS blocks under various operation conditions. Results are satisfactory. The example shows the results of structural analysis (Category III) of IWS block components.

Outgassing Rate Measurement: To finalize the dimensions of Outgassing Test Coupons, outgassing rate measurement of

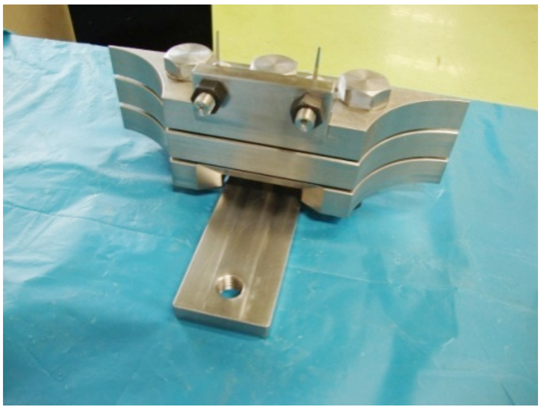
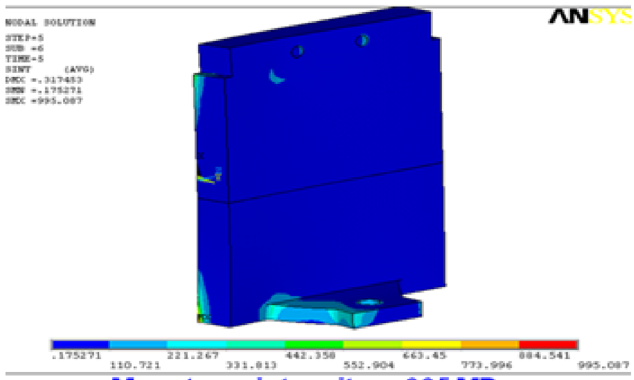


Figure B.2.4 Mock up IWS containing three plates

Stress intensity (MPa) for Rib



Max stress intensity = 995 MPa

IWS materials (SS 430, SS 304B4 and SS 304B7) has been carried out according to "ITER-India Procedure for outgassing system for IWS". This test was performed for above materials having different sizes and 'ratio of as received surface area to cutting surface area' by existing system at vacuum lab of IPR. Thermal Outgassing rates of various size coupons of same material are in acceptable range and are almost equal. Test results are under discussion with IO and dimensions of test coupon for thermal outgassing measurement of IWS materials will be finalized by IO and ITER-India.

Material Production: (a) SS 304B7: CPP completed 3T sample production and test reports are reviewed and approved by ITER-India and IO. CPP also finished 18T production. However acceptance of this material subjected to acceptance of test reports and QA documents. (b) SS 430: IO approved Test Reports of sample plates and bulk production will be started after the approval of necessary process qualification documents. (c) SS 316 L(N)-IG: Product and part qualification reports of Industeel, France are reviewed and approved by ITER-India and IO and bulk production will be started after the approval of necessary process qualification documents. (d) SS 304B4: Sample Production is going on. However up to 28mm is the regular product of contractor. (e) XM-19 and Inconel-625: Contracts are placed by ATL to M/s. Bohler International and M/s.Valbruna s.P.a respectively. Sample production is going on.

WBS 2.4 Cryostat & VVPSS

This group is involved in following activities:

Cryostat Fabrication and Assembly Study: Cryostat is a large vacuum vessel (~29m dia. and ~30 m height), which will be fabricated in three stages: a) Factory fabrication at India. b) Fabrication and assembly in Temporary workshop at France and c) Tokamak Pit assembly at France. Detailed study for Cryostat fabrication and assembly for above three stages is presently ongoing with the help of engineering services provider. Cryostat detailed study involves the following major activities: i) Segmentation study and tolerance planning. ii) Welding study and assembly plan. iii) Transportation study. iv) NDT requirements, inspection and quality plan. A 3D view of the cryostat and its various sections are shown in Figure B.2.6.

Cryostat temporary workshop detail design : The main section of cryostat shall be assembled at the ITER site in France near the Tokamak Building in a Temporary workshop of 50m(w) x 120m(l) x 30m(h). Detailed design of the temporary workshop is presently ongoing with the help of engineering services. Designing involves the layout preparation and structural design as per European code. The conceptual design has been completed and finalization of design is going on.

Cryostat Procurement Arrangement (PA) activity: Preparation and review of PA documents for Cryostat. Identification and review of engineering drawings. Review of interface documents.

Cryostat Procurement/Tendering activity: Preparation of Prequalification document for Cryostat. Preparation of 2D engineering drawings for Cryostat. Expression of interest has been issued for cryostat fabrication.

WBS 2.6: Cooling Water system

The Preliminary design of ITER Component Cooling Water System (CCWS), Chilled Water System (CHWS) and Heat Rejection System (HRS) has been continuing. An interim review of the preliminary design was held. The Process Flow

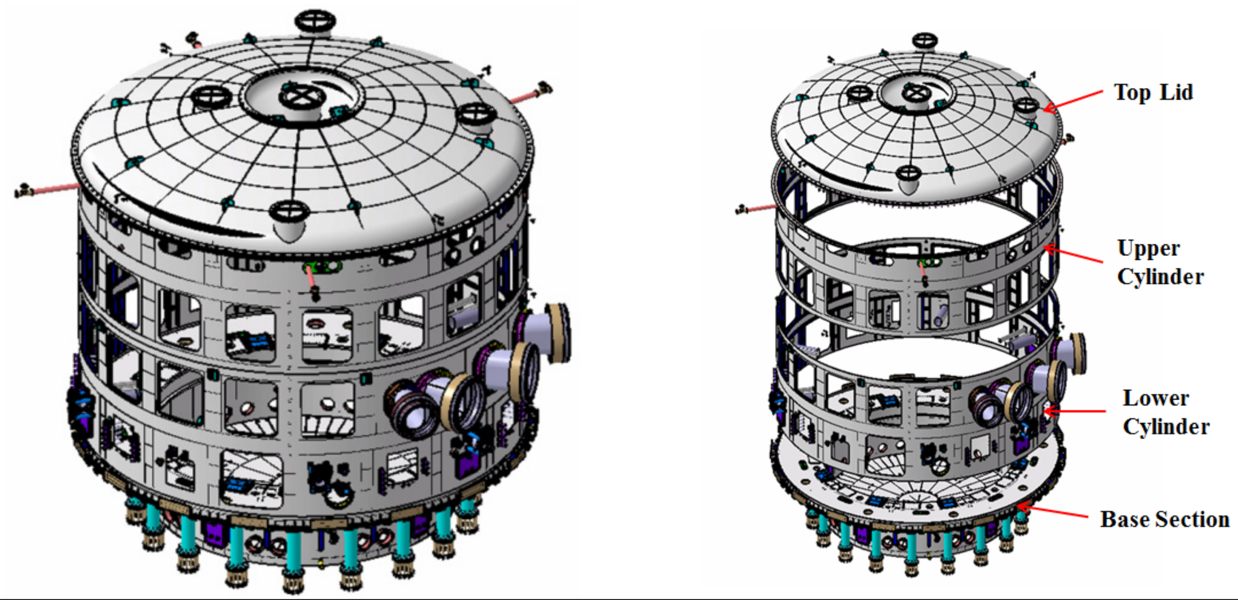


Figure B.2.6. A 3D view of the cryostat and its various sections

Diagrams of CCWS and CHWS have been revised and have been approved by ITER IO. The design and optimization of CCWS and HRS have been completed and the report has been submitted to IO. A new Project Change Request (PCR-336) has been introduced to update the CCWS and HRS based on the optimized scheme. The design basis report of CCWS of has been prepared. The design of water treatment scheme for HRS has been completed. The technical documents like process design basis, piping design basis, electrical design basis, instrumentation & control design basis, equipment design basis, piping material specifications and valve material specification have been prepared. The Piping & Instrumentation Diagrams of CCWS and CHWS have been prepared. The 3-D CATIA models of buildings 67, 68 and 69 have been prepared. The pre-qualification of equipment suppliers has been started. The Expressions Of Interest received from the manufacturers have been scrutinized. Figure B.2.7 shows a schematic of the Cooling towers, heat exchanger building and the pumping stations of the CCWS & HRS systems.

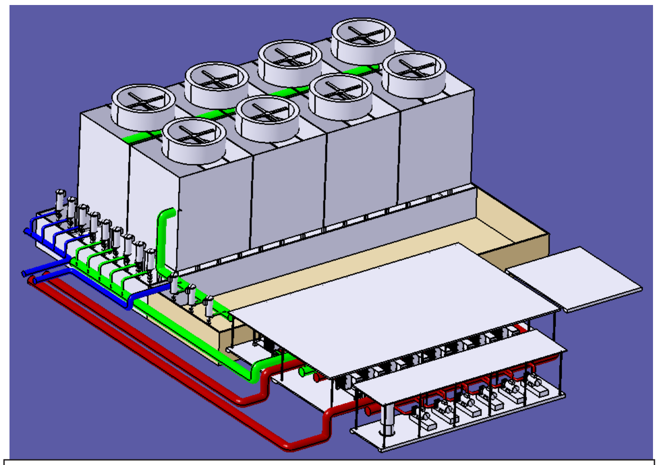


Figure B.2.7: Schematic of the Cooling towers, heat exchanger building and the pumping stations of the CCWS & HRS systems

WBS 3.4 Cryo-distribution & Cryo-line

Cryoline System: Year 2010-11 has been the year for beginning of procurement phase for the ITER cryolines and manifold system with the start of prototype cryoline design. The pre-qualification process for ITER cryolines has been com-

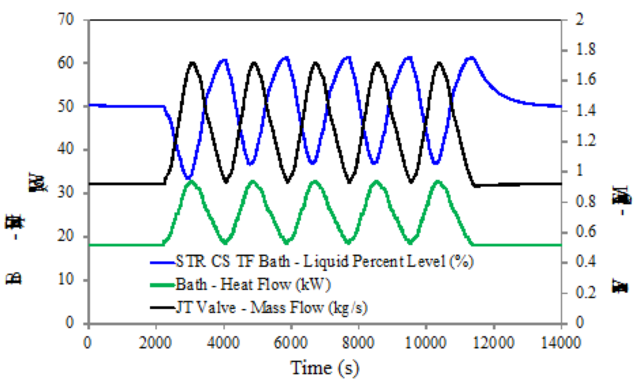


Figure B.2.8 showing the responses due to varying heat load in one of the concepts.

pleted with the pre-qualification of four industries, the first milestone in the procurement process. Another major milestone achieved during this year is the signature of the Procurement Arrangement of Torus and Cryostat cryoline with ITER organization. The design of prototype cryolines has been started with two pre-qualified industries.

Cryogenic Dynamic Simulation : The ITER-India Cryogenic team has extended the capability of simulating the cryogenic process required to support the operation of fusion machines from steady state analysis to dynamic simulation using Aspen HYSYS dynamics. Simplification for the cryo-distribution system is being studied considering the collective distribution concept. Figure B.2.8 shows the responses due to varying heat load in one of the concepts. This unique capability will lead to optimize the ITER Cryo-distribution system as well as to support domestic program.

Conceptual Design Of Auxiliary Cold Box: Conceptual design of Auxiliary Cold Box (ACB) for Cryo Pumps (CP) of ITER has been initiated at ITER-India. A detailed 3D model has been developed based on PFD with following major components: cryogenic valves, heat exchangers, cold-circulating pump, cold compressor and liquid helium bath. Thermo-hydraulic analysis takes in to account the fictional pressure drop, pressure drop through valves, radiation heat load as well as conduction heat load due to valves.

WBS 5.1: Ion Cyclotron Heating and Current Drive Sources

Pre-prototype (R&D) program has been initiated after signing of RFPS PA to mitigate ITER programmatic risk. A specific facility corresponding to single amplifier chains (R&D unit) is being built at ITER-India, IPR, to test critical components/sub-systems and finally to test the entire R&D system. The outcome of this program will help in finalizing the critical choice of the system for ITER RFPS procurement. During this reporting period, the major emphasis was to manufacture/procure the components/systems up to pre-driver stage amplifier for the R&D unit. Procurement of necessary components and sub-systems for testing up to pre-driver stage is completed & acceptance test for Low Power RF components is under progress. Cavity for the pre-driver stage amplifier is manufactured & factory acceptance test is conducted successfully. Assembly & integration of the same along with vacuum tube, input circuit & various other components has been initiated for powering the amplifier. Manufacturing of auxiliary power supplies (SGPS, CGPS & FPS) for pre-driver stage is completed and final acceptance test at factory is underway. Local Control Unit (LCU) is under development along with industrial partner. Project Design Document, Software Design Document and Quality Procedure Manual for LCU were developed and approved. As the Software Design Document is live document, it will be updated during the project execution phase as & when required. PLC panel is delivered to ITER-India lab and initial testing has been initiated. Indigenous developed analog, digital and RF signal processing board is under up-gradation for standardization process. GUI screens for application program is finalized & under development at vendor site. Interlock logic & Control loop logic discussed with vendor and development process is initiated. Tender document for development of driver & final stage amplifiers reviewed at various levels, incorporated comments, received approval from IO on technical part and published globally. Pre-bid meeting with potential vendors organized on 27th Jan 2011, in presence of national & international experts. Offer received from the vendors and the technical offers are under review process. Design activity for the rest of the system is initiated. An overall specification has been derived for auxiliary power supplies related to driver & final stage amplifiers and kept ready for initiation of tender process. Transmission line components have been procured for R&D unit. Test bed design is finalized and vendor development process has been initiated. RF design of high power 50 Ohm dummy load is completed using high frequency software MWS. Mechanical design for the same is underway. Feasibility study for manufacturing different components for the dummy load within India is on-going. Infrastructure development for testing R&D unit is under progress. Crane installation (1Ton) & electrical grounding in RF ext lab is completed. Campaign on the up-gradation work of RF generator at IPP, Germany as per collaborative contract between ITER-India and Max Planck Institute IPP went smoothly and within schedule. RF output power of 600kW/150ms, 500kW/5s, 1.1MW/1s & 1.2 MW/20 ms achieved. Modifications are identified in the system & IPP is procuring sub-systems/components for increasing RF power level more than 1.5 MW and duration around 10s. First report on Risk Management Plan as agreed in section 8 of Annex A of PA 5.1.P3.IN.01.0 is approved by IO. Procurement description of PA 5.1.P3.IN.01.0 between ITER-India and IO for RFPS package is approved.

WBS 5.2 ECH Start-Up

During the FY 2010-11, the project has progressed further with the various design and prototype studies along with necessary supporting academic activities. From the procurement package point of view, the package is approaching towards the first formal design milestone (Conceptual Design Review) to be held in Jun-2011 by ITER and the Procurement Arrangement is likely to be issued during Mar, 2012. Some of the main highlights of the activities carried during this period are summarized below:

- ***Activity related to Gyrotron Source System & Test Facility:*** A draft on detailed layout & equipment arrangement for Gyrotron Test stand with 3D CATIA models has been prepared.
- A report on Vacuum analysis of Transmission Line for Gyrotron Test Stand at ITER-India has been prepared. A report on the Transmission Line configurations with required components and their requirements is prepared for the Gyrotron Test Stand.
- A conceptual report on Gyrotron Frequency Diagnostics is prepared, based on which equipment procurement has been initiated and purchase orders for the same have been placed.
- A Conceptual Design of Mirror Mounting & Movement Mechanism for a Gyrotron Matching Optic Unit is under progress
- Gyrotron Cathode Cooling phenomenon has been studied to develop a model for its active compensation.
- Conceptual Design of Gyrotron Tank & HV circuitry has been initiated.
- Based on the successful prototype results, procurement of an Industrial Crowbar unit for Gyrotron Protection is in progress.
- The CDR of the Local Control Unit is progress with about 80% progress being made and associated documents like preliminary list of signals and sensors have been prepared.
- The design concept & prototype development of a generic Signal Conditioning module is on-going.
- A concept and development of a prototype for the critical Gyrotron Hardware Interlock module has been initiated
- A conceptual scheme on Gyrotron Power Measurement is prepared, based on which low power mm-wave components procurement has been initiated
- Activities in relation to the procurement package with ITER
- Follow up actions and responses for the ITER proposals & issues concerning the procurement package such as the removal of two Gyrotron units, building space constraints etc.
- A proposal to effectively utilize spare Gyrotrons by using a waveguide switch scheme has been prepared and submitted to ITER for review.
- Preparations for upcoming Conceptual Design Review (CDR) & Procurement Arrangement (PA) milestones are on-going. CDR is planned during Jun-2011 & PA is likely to be signed during Mar-2012
- Progress presented at the Gyrotron Progress meeting held by ITER
- Scope, Specifications & interfaces of Gyrotron package were discussed with ITER to finalize the Annex-B document
- An additional Test Gyrotron to support ITER deliverables is being pursued
- Discussions & exploration with Gyrotron suppliers is being initiated.

WBS 5.3 Diagnostic Neutral Beam (DNB)

Activities under the Diagnostics Neutral Beam (DNB) in the past 1 year can be classified under the following: (i) follow-up of Procurement Arrangement, (ii) support to ITER in interface engineering, (iii) finalizing configuration and procurement processing for Indian Test Facility (IN-TF) components. While the engineering design has been completed for most of the components of the DNB system, the need to ensure compatibility with Remote Handling (RH) continued to have a major emphasis on the activities involving modifications in the configurations. The report on the component level descriptions highlights the same.

(i) In the follow-up of the procurement arrangements (DNB beam line and SPIDER Beam Dump (SBD)), activities have laid primary emphasis on ensuring the process of market survey and arriving at a set of eligibility criteria for identifying the bidders for the DNB and IN-TF Beam Line Components (BLC's) and also for the SBD. Interaction with the industry has also been initiated for the development of the HV bushing (involving the manufacturing of a large ceramic ring and brazed transition pieces made out of Kovar).Primary emphasis on the activities on IN-TF have been the consolidation of layout and incorporating the civil requirements for supporting the vacuum vessel in the DNB lab, configuring the layout of components within the vessel and interface integration of the same and configuring major interface integrations in form high voltage feed through for the beam source.
Summary of major activities are presented below, with a particular emphasis on the activities on interface engineering.

(ii) Engineering Activities

HV bushing : DNB HV bushing is designed for the ITER considering all Safety, vacuum, radiation and high voltage requirement. Routing of the feed lines is being modified according to RH requirement. Major changes are being incorporated in the form of providing a maintainable lip-seal for the Kovar – SS transition for the ceramic ring and the SS-SS transition for the FRP ring. Various options for FRP to metal casting are also being explored. Further, localized changes are being incorporated for the maintainability of the design. Lip seal is provided at ceramic metal transition. Structural analysis has been carried out analytically as well as using ANSYS. Deformations and stresses are within limits. Vendor interaction for different sub-component of prototype has been initiated for the feasibility assessment of manufacturing.

DNB vessel : Analysis has been carried out for a vessel model based on the pressure loading, as per the prescribed loading conditions. The result showed high levels of displacement which was not in acceptable limit. Modifications were carried out to reduce the weight and displacements by changing rib size and rib to rib gap. Results obtained after these modifications, are within the allowable limit. The design code has been changed from the previously defined ASME to the present, RCCM-R and work is on going for the completion of the preliminary design of the DNB vacuum vessel based on the load specifications provided by IO.

Beam line components : Expression of Interest (EOI) of the BLC is finalized and procurement description document is approved by IO and process of advertisement and the first level interaction with vendors in the form of a Scope Appraisal Meeting (SAM) has been completed. Further, a prototype development program is initiated for BLC and MoU has been signed with NFTDC.

Activity listing on other components follows:

Calorimeter: Earlier design of the Calorimeter Movement Mechanism (CMM) which was mounted on the front side of the DNB vessel (based on the principle of converting the linear motion of the Actuator feed through into rotary motion through the combination of the rotating & sliding link) found difficult to be remote maintained, due to its mechanical connection with calorimeter base structure, linearly very sensitive & its mounting position. As a next step in the direction of fulfilling all the interface requirements, RH requirements, vacuum compatibility, Safety & reliability in terms of its mechanical operation a stored Energy based Rack & Pinion based single sided actuation CMM bought to configurationally design level after several iteration& incorporation of inputs & feedbacks from IO & IN DA. The calorimeter consists of two movable panels, forming a V-shaped configuration. Each panel is formed from a set of horizontally directed Heat Transfer Elements (HTEs). Beam power measurement will be done when the calorimeter panels are in closed position & after measurement the panel should be in open position, this closing & opening motion will be done by Calorimeter Motion Mechanism (CMM). CMM is based on the rack & pinion system which primary function is to convert rotary motion of the pinion to linear motion of the rack & vice versa. This rack & pinion based mechanism contains one close coiled helical spring which will act as energy reservoir, it is placed between stationary part of the calorimeter base & linearly moving end of the rack. Spring will absorb the mechanical energy during closing motion of the panel, which will be achieved by external actuator feed through. This stored energy of the spring will be utilized in bringing the panel in open position. The base line concept behind the CMM is to push the panel door through actuator & self opening of the panel will be achieved by stored energy of the spring. In the present design, the calorimeter actuator feed through are mounted in the RHS of the DNB vessel at a distance 1m from the top of the vessel surface, where this actuator feed through is contained in a oval cross section cylindrical shell with independent actuation to calorimeter panels, Actuator feed through design is equipped with mechanical interlock & inter space monitoring for the co-axial bellows, this feed through is not directly connected to the CMM whereas it is just butting against the long pivot arm of the CMM through the rollers at one end as shown in Figure B.2.9. Work on the RH integration of the same is ongoing.

Exit Scraper : The Exit Scraper (ES) defines the edge of the beam line as it leaves the DNB Vessel during Normal operation and off –normal events. Limit the power to downstream components from direct beam interception, re-ionised power deposition and reflected particles during normal operation and defined off normal events. The initial dimension is decided based on the power loading available from the BTR code simulations and optimized based on the max power delivery of the Neutral beam to plasma. The exit scraper has been positioned in the front wall of the DNB Vessel, just after the Calorimeter in the downstream of the Beam line. Considering the 10 mrad horizontal and vertical beam divergence, the maximum power deposited obtained in 85 KW on the Top and Bottom plates of ES. The Peak Power Density is 1.17 MW/m2. The exit scraper is made of four OFHC Copper plates and is actively cooled by water. Each plate is mounted to the SS flange using bolted joints. The flange is also cooled

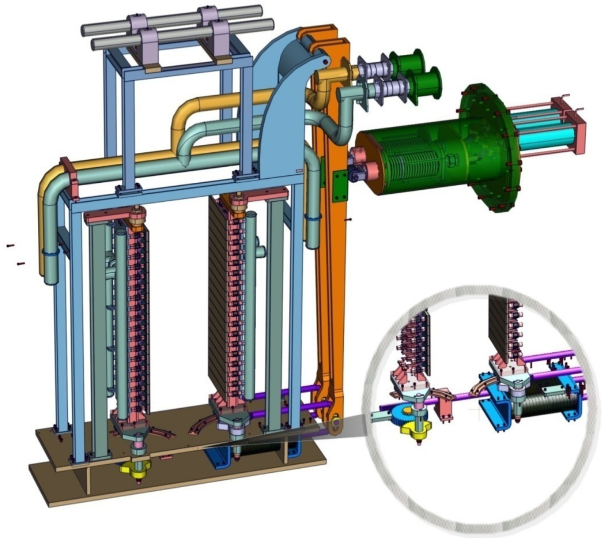


Figure B.2.9: Calorimeter with CMM & Actuator feed through assembly

to protect from the heating by deflected particles. Thermo structural (for the above heat loads)and gravity analysis have been carried out using FEA software for the bottom plate of the ES, as this plate is subjected to maximum gravity loads. The thermal loads on the top and bottom plates are identical. It is also to be noted that the side plates does not have any direct heat load. Major part of engineering of the ES is now completed and RH integration is in progress, with appropriate inputs from IO on this interface.

DNB Drift Duct :

Drift Duct Bellow : The drift duct Bellow (DDB) is classified under the front end components of DNB forms the part of primary vacuum confinement, which isolates the DNB injector from the thermal movements of Tokomak Vacuum Vessel. The DDB has been designed based on the Load spec Document generated by the DNB group. The bellow design was carried out in collaboration with Witzenmann India. The dimension of Neutral beam connecting duct which connects the DDB and equatorial port of the tokomak Vacuum vessel has been changed. Due to these changes the interface of DDB with the NB duct flange is being modified. A draft Load specification document for the Drift Duct is also being written by IO. Under this situation the current Drift Duct bellow design will be changed slightly to meet the requirements.

Drift Duct Liner (DDL) : The DDL is placed concentric to the DDL to protect the DDB from the heat from re ionized particles. The design has been adopted from HNB. The interface

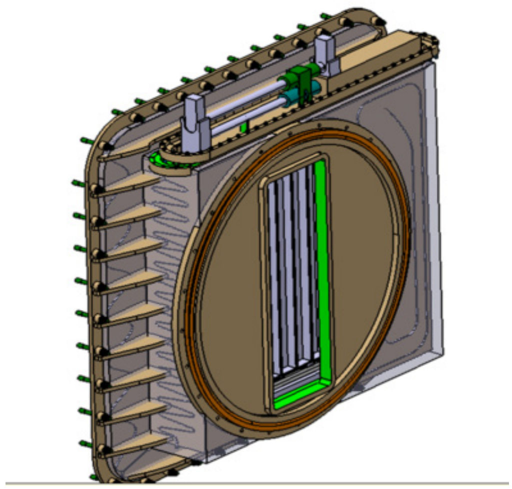


Figure B.2.10: DNB fast shutter

design & RH interation is being addressed. The thermo mechanical design will be carried out once the approved Load Spec document is available from IO.

Fast Shutter

The Fast Shutter (FS) is shown in Figure B.2.10 is placed at the exit of the DNB vessel. The fast shutter closes in a very fast manner (less than 1 sec) when the Beam is OFF. This prevents the tritium entry into the DNB vessel. The fast shutter casing forms the part of primary vacuum confinement. The conceptual design made available by IO has been studied. Modifications on the actuator connecting rod seal door frames are being carried out. Different options of actuation mechanism of the shutter are under study. Details of the design is being carried out however, a formal activity would begin, once the approved Load specification document for the FS is provided by IO.

Remote Handling of ITER Deliverables

Presently, the RH compatibility of three systems (HV Bushing – Beam Source (BS), BLC coolant piping, Remote-handling of ES) is being addressed with a priority. The details of the same are presented below:

a) HV bushing feed lines to Beam source : The beam source is classified as an RH class 1 (frequent removal from the vessel is foreseen) component. In order to facilitate the removal, all feed lines from the HV bushing to the source need to be detached. This detaching process has to be realized by Remote handling Tools. These tools are basically capable for cutting & welding the water pipes remotely and disconnecting & connecting the electrical and diagnostic cables. The RH process demanded modifications in the layout of the feed lines from HV Bushing and design of physical features on the cooling water pipes. DNB Group has performed these activities and integrated the RH tool in the modified models. These RH compatibility designs are continuously undergoing iterations and reviews.

b) Coolant header pipes of Beam Line Components (BLCs)
All Beam line components in DNB are actively cooled by water. The inlet & outlet headers are penetrated through the DNB Vessel. In cases of failure of any of the BLCs, the particular component needs to be removed from the vessel and transferred to the hot cell. These activity needs to be carried out by RH tools. The components upon failure will be detached from its bottom table. Then the connection between the header pipe and the component will have to be disconnected. This is realized by cutting the pipes. These pipes will be welded later on once the component is replaced after maintenance. Therefore the pipe headers are to be designed in such a way that, they are compatible to the RH Cutting & welding tools.

c) Remote Handling of Exit Scraper
Remote handling concept is shown in Figure B.2.11. The flange of the exit scraper is mounted on the front wall of the vessel. The monorail crane cannot access its flange. Therefore

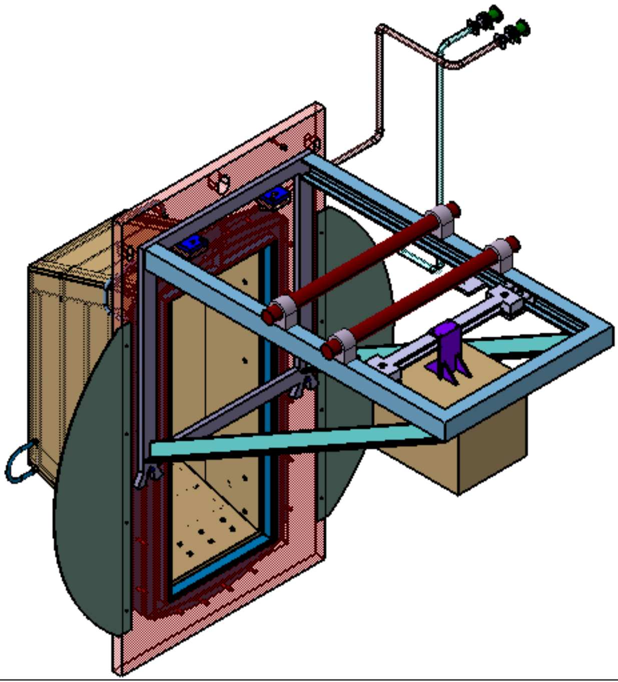


Figure B.2.11. Remote handling tool for exit scrapper

a lifting attachment which interfaces with ES and monorail crane has been designed. In order to avoid excessive moment on the crane, a movable counter weight also designed for the lifting attachment. This attachment will be connected to ES at the time of RH only. Like the other BLCs, physical interface also attached to ES coolant header pipes for RH cutting & Welding. The process of finalizing the RH for the BLCs and the Front End Components (FECs) for DNB is on-going and can be considered as finalized once the RH interfaces have been integrated in the design.

Activities related to SPIDER facility
On 15th December 2010, the Procurement Arrangement (PA) for the 100 kV Power Supply of the SPIDER test facility and calorimeter was signed between Indian Domestic Agency and ITER Organization.
SPIDER is the source for Production of Ion of Deuterium Extracted Radio Frequency plasma. SPIDER– together with MITICA (Megavolt ITER injector & Concept Advance) - comprise PRIMA (Padua Research on ITER Megavolt Accelerator) that is also known as the Neutral Beam Test Facility (NBTF). The NBTF will be located in Padua, Italy.

SPIDER Beam Dump: The design activities are undertaken for fulfilling the design requirements stated in Annex B of PA. SPIDER Beam Dump is designed for absorbing the beam power, up to 6.1 MW total power for a time duration up to 3600 s. It consists of two actively cooled panels composed of axial arrays of hypervapotron bases Heat Transfer Elements(HTEs);The coolant manifolds and flexible connects; two panel support frames to support the HTEs allowing free thermal expansion of HTEs; a beam dump support structure to the front lid of SPIDER Vacuum Vessel. The activities related to the procurement of SPIDER Beam Dump have been initiated along with that of those of DNB Beam Line Components. A Request for Expression of Interest (EOI) has been advertised for the fabrication, testing and supply of the components. A Scope Appraisal Meeting has been conducted with the engineering companies who have registered themselves against Request for EOI. The next phase of the procurement activities of short listing of the eligible engineering companies is on-going.

SPIDER Power Supply : The SPIDER Power Supply (PS) System shall provide the electric power to the SPIDER accelerator grids and shall supply the SPIDER ion source and the auxiliary components. A section of the SPIDER PS system, called -100 kV PS, shall be capable of voltage regulation and of switch off in case of grid breakdown.

WBS 53.P4, 52.4, 51.4 ITER-India, Power Supply Group

The Group is responsible for the power supplies of the Diagnostic Neutral Beam (DNB), the Ion-Cyclotron (IC) Systems and the Start-up Electron Cyclotron (EC) Systems. These systems will be used in the Indian Test facility (IN-TF), before delivery to ITER, to test corresponding systems to full operational parameters. Preliminary design for DNB power supply approaches final stage. Technical working-session on proposed design and interface requirements carried out at IO during a visit of INDA PS team in March'2011. Related design documents submitted to IO to initiate Design review procedures. Preliminary design review scheduled on 26-27 May'2011. Procurement Arrangement (PA) for RFX-SPIDER 100kV Power Supply has been signed. Various technical and interface issues were discussed during Interface management meeting (IMM) at IO with participation of RFX, INDA during 24-25 March'2011. Work Contract awarded to ECIL for prototype full scale IC HVPS. This shall bring ECIL in participation for ITER deliverables. Under separate task ECIL completed documentation for the prototype HVPS that includes tender documents for Transformers and SPS modules. Procurement Arrangement (PA) for IC HVPS has been signed. Initiated voluntary task {TA No. C52TD41FI} for ECPS "Estimation of the physical characteristics, layout and interface requirements", draft report submitted to IO. 22kV feeders at IN-TF, preliminary estimates of the loads indicate extension of existing 132kV substation. A committee to assess the upstream transformer (132/22kV) recommended go-ahead.

WBS 5.5 ITER-India Diagnostics

ITER-India is responsible for delivering four major items for the ITER Diagnostics (a) Electron Cyclotron Emission (ECE) Diagnostics - Ex-cryostat transmission and receiver equipment and a set of Radiometers and a Michelson Interferometer (b) Beam emission Spectroscopy (BES) - a set of ex-port-plug optical assemblies, spectrometers and 2-D array detectors (c) X-Ray Spectroscopy (XCS) - A Survey Spectrometer to be mounted an Equatorial Port and one High Resolution Spectrometer, viewing the edge plasma, mounted at an Upper Port-plug along with 2D-array detectors and (d) Upper port-plug (UPP 09) – a structure that would house the XCS (edge) spectrometer and other ITER specified diagnostic equipment. The activities during the year aimed at progressing towards the goal of finalizing the Procurement Arrangement (PA) which would define the scope and delivery of deliverables. This is expected to be completed in 2012 in phases, the first phase covering the XCS system. The Conceptual Design Review (CDR) of the XRCS (edge) system was completed on Nov 2010. ITER-India Diagnostic team members collaborated with IO in the development of the design. Calculations of X-ray signal strength, noise level, the extent of nuclear radiation on the dispersing crystals and detectors were performed to arrive at a safe design, which has

Scenario	Peak Halo Current (toroidal) magnitude (MA)		Peak Halo Current (poloidal) magnitude (MA)	
	TSC	DINA	TSC**	DINA
MD with fast Ip quench (6eV)	2.18	1.58	0.6	0.876
VDE-UP with fast Ip quench (6eV)	2.58	1.26	1.1	1.11
VDE-DN with fast Ip quench (6eV)	2.97	3.3	1.45	3.0
MD with slow Ip quench (55eV)	3.11	--	7.25	--
VDE-DN with slow Ip quench (55eV)	2.32	5.76	6.1	6.41

Table B.2.2: Comparison of predicted peak halo current magnitudes during Disruptions and VDEs in ITER by TSC and DINA codes been included in the Design Description Document. Similar work for the XRCS (survey) is continuing from last year, with a view of concluding the CDR in Apr 2011. Annexure-B , which is expected to specify the technical aspects of the Procurement Arrangement, as based on the XCS conceptual design, is also being drafted.

The Design Work Orders (DWO) accepted from ITER Organization for Seismic and Thermal Hydraulic and Neutronics analyses for a design of generic Upper Port Plug were completed. The results were submitted to IO for arriving at a preliminary design, reviewed in June 2010. The important features of the ITER design were elucidated and distributed to Indian Industries, which would be interested in competing for the manufacture of ITER Portplugs. Efforts are underway to prepare documentation on Portplugs needed for seeking a Cost Evaluation and Expression-of-Interest from industries. Work related to Port Integration issues arising from the above mentioned conceptual designs of XCS systems, which would be housed in India's Portplug and that of Russia, has been initiated. This detail would be needed for the finalization of Procurement Arrangement.

The CDR for the ECE diagnostics is expected in Nov 2011. A possible lay out for the ECE transmission lines for the Tokamak to the diagnostics area has been worked out. The transmission of 70 to 1000 GHz radiation through corrugated waveguide was addressed. A report was presented at 16th Workshop on ECE and ECRH at China, April-2010. A survey on ECE spectra measurements on various Tokamaks has been done to identify the problems associated with waveguides for ITER's need for very wide band transmission, calibration procedures and sources, rapid switching between a number of waveguide channels, extent of polarization scrambling and similar issues specific to ITER. Many of these were recognized as requiring resolution for conceptual design. The findings were reported at the US ITER Diagnostics Conceptual Design Workshop held at PPPL, USA Sept. 20-26, 2010. A proposal for collaborative work with US ECE team is being worked out to perform experiments to resolve the above and seek alternatives, prior to a CDR.

The CDR for the Beam Emission Spectroscopy is expected in 2012. A survey of different designs of spectrometers is undertaken to optimize the BES measurements on ITER. This is in view of the possible limits on light collection efficiency due to constraints imposed by neutron irradiation, deposition and heat load on the first mirror. The calculations on effects of wall reflections were completed and submitted for publication. Efforts are underway for collaborations for joint experiments on active spectroscopy diagnostics and development of software for ensuing analysis of CXRS/BES spectral data.

The ITER-India Diagnostics Laboratory is expected to be operational in August 2011. In preparation thereof, many general lab and test equipment have been procured or have been ordered. Experiments related to ECE have been already initiated using existing facilities at IPR. Simulation of ECE emission from Tokamak plasma using NOTEC software has also been initiated.

Activities of the Fusion Physics, Information Technology and IO-DA coordination group

Physics Modeling : The ongoing activity of ITER VDE and Disruption modeling using the Tokamak Simulation Code (TSC) under the ITER task agreement C19TD27FI was continued this year and final report submitted to ITER-IO in Nov 2010. The report was accepted after minor corrections and consequently the payment (60kEuro) for the same was received by ITER-India for the completed task. The detailed disruption and VDE simulations validated the earlier calculations carried out using the DINA code and the results will be very useful to estimate the electromagnetic impulse forces to be experienced in ITER during these events due to both induced and Halo currents. Table B.2.2 shows a comparison of the predicted maximum halo current magnitudes by the simulations using the TSC and DINA. The differences have been identified to the different way the halo region is treated in the two models and further work will be carried out (on a voluntary basis) to narrow down these difference by making the two models as close as possible. Figure B.2.15 shows the snapshot plasma equilibria during a typical downward VDE in ITER. This work was also presented in the IAEA-Fusion Energy Conference in Korea in 2010.

Information Technology : In 2010-11, Information technology group maintained a high quality of network, both for the Internet as also the leased line link to ITER via the TIFR-CERN connection. The leased line connection was extensively used for the numerous Video Conferences as also for sharing of CAD database with ITER. A new very high performance IBM Blade server (shown in Figure B.2.16) was procured and installed at ITER. The Blade Server has the following specifications: Model: IBM BladeCenter E with 8/14 blades populated, Each blade having HS 22 (8677) Xeon 4C E5504 80W 2.00 GHz processor with800 MHz/4MB L2 Cache, 8GB ECC DDR3 RAM and 2x146GB SAS HDD. The server is also connected to a SAN storage of 5TB storage ca-

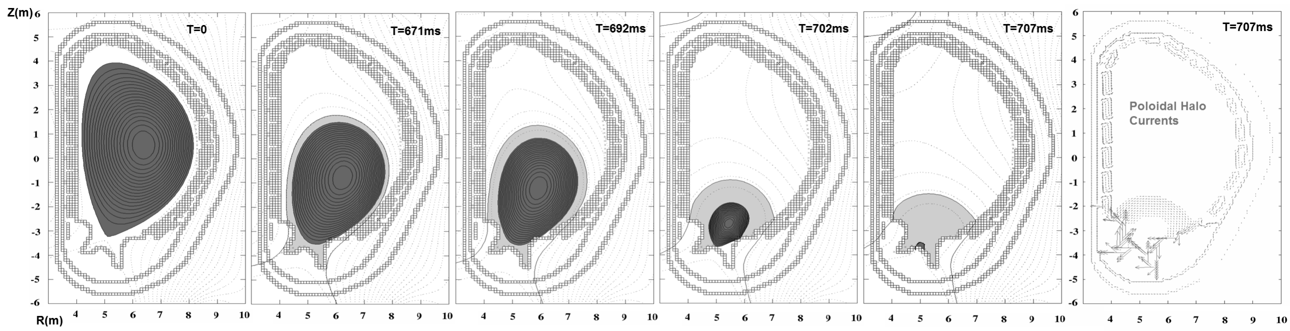


Figure B.2.12 shows the snapshot plasma equilibria during a typical downward VDE in ITER

pacity and an autoloader tape drive for backup. The operating system in the blades is a combination of VMware, Windows Professional and Linux operating system. The server will be used primarily for SAP ERP application presently being implemented at ITER-India. Two of the blades are presently also being used as MATLAB server for scientific computation. The Information Technology division also spent significant effort in discussion with vendors and ITER-India/IPR personnel for implementation of a comprehensive ERP solution at ITER-India, which will be finally extended to the whole of IPR. An initial committee internal to ITER-India was formed to evaluate various ERP solutions and evaluate the most suitable solution. This committee after a series of discussions with various vendors, recommended to procure SAP through DGS&D rate contract. Accordingly the DGS&D vendor M/s Resseaux Tech Pvt Ltd gave a proposal for implementation, which was evaluated by a high level evaluation committee comprising experts from ITER-India, IPR as also external experts from NPCIL and TIFR. This committee, after further negotiations with the Ressaeaux Tech, recommended a more optimized solution of SAP at a somewhat reduced cost. The contract for the SAP implementation was awarded on 23 March 2011 and implementation activity immediately started thereafter. The total implementation time will be about 7 months with go-live planned in December 2011.

IO-DA Coordination : The new ITER DG, after he assumed office, decided to split the IO-DA coordination efforts in two sets of meetings, one high level ITER Heads Coordination Meeting (IHCM) and the other IO-DA coordination meeting. The IHCM meeting has two members from each DA, plus IO higher management members. From India, Project Director, Shishir Deshpande and IO-DA coordinator Indranil Bandyopadhyay are the members to IHCM. IHCM is the highest decision making body within the IO and the DAs and the IO-DA coordination group reports to the IHCM after more detailed discussions on various techno-managerial issues. The IHCM meeting takes place roughly every fortnightly, mostly through Videoconference and a few in-person meeting in conjunction of other in-person meetings like the STAC/MAC or IC meetings. The IHCM meetings started in October 2010 with the first meeting being held parallel to the IAEA-FEC Conference; between Oct'10-Mar'11 a total of 12 IHCM Video Conference meetings were held. In addition a total of 10 IO-DA coordination meetings were held between Apr'10-Mar'11.

Activities of the Project Office

(i) Schedule related activities on various packages are beingregularly updatedas per project progress using Primavera. Project Schedule Task Force (PSTF) activities going on in collaboration with ITER-IO for making a strategic management plan (SMP) for effective monitoring& control of the project.Primavera advanced training conducted for ITER-India schedule concerned persons for enhancing awareness with respect to the software functionality and applications.
(ii) Risk register and Risk Management Plans (RMPs) made for DNB, ICRF, IWS, CWHR &CDCL packages, and have been approved by ITER-IO. Updates are sent to IO periodically.
(iii)Participation in the Configuration Management and Change control process for reviewing the Project Change Requests (PCRs) due to the design improvements, new procedures & documentation, impacts on scope, schedule and cost.
(iv) Activities on Earned Value Management (EVM) have been initiated to relate physical progress and cash flow.
(v) Regular assessments of project progress, schedule variances, recovery plans, budgeting are done which is further reported to Empowered Board (EB).
(vi) Preparation and review of documents towards finalization of Procurement Arrangements (PAs). The PAs signed in

2010-11 are of Early Delivery Cryolines, SPIDER Test Facility and IC HV Power Supplies.
(vii) To discuss the issues & developments in ITER Project Planning, Scheduling & Monitoring,an in-person meeting of Project Management Working Group was organized at ITER-India from 20-22 July 2010.This meeting was attended by representatives of the seven Domestic Agencies and IO
Activities of ITER-India Design Office

ITER-Data base replication: Successful installation of ENOVIA for production and IO data replication at ITER-India. Using this replication Design work ongoing for 3 signed PA in synchronous mode. 29 DETs were exchanges between IO and DA and associated Technical support provided.

3 Design collaboration implementation forms (DCIFs) have been signed with IO prior to signing of respective PA.
Preliminary design development of radiation shield and Diagnostic Port Plug drawings preparation at preliminary design level.

Preparation of CMM of the ITER-India laboratory

Non-linear transient thermal analysis of Hyper vapotron for ECRH group

Meetings:
All Technical co-ordination meeting (TCM), CCB2 (Change control board) Meetings were attended on the behalf of ITER-India, and information affecting the packages were co-ordinated between IO and DA.CAD Users Meetings were organized to assess Design office resource.CAD WG08 Meeting 20-22th Jul-10 and CAD WG09 Meeting 30-02rd Dec-10 have been attended.
<u>Training:</u>
ENOVIA Certification Training:
6 Key CAD users ENOVIA traininghave been completed, and two Designers are certified as Trainer from IO Cadarache France.
8 Designers including 5 from Suppliers have been certified as Designer-B by our Certified Trainer.
Staff skill enhancement Training:
3DVIA-composer training - 2 days
HYPERMESH–training (twice in a year each of 2 days)

<u>CATIA Training</u>
CATIA Training in three different phases with skill level from beginner to experts, each phasecomprising of 4 days training to increase the skill of relevant ITER-India staff.

ANSYS and CATIA Training for TTP2010 at ITER-India duration one week

<u>ANSYS Training</u>
Two days ANSYS Training and 2 days ANSYS workshop arranged at ITER-India for ITER-India and IPR staff.
Dedicated “ANSYS Core Group” created at ITER-India with five members taken from Different groups including one from the Design Office to work on analysis activities.

Quality Assurance Activities during 2010-2011

One day ASME-NQA -1:2008 awareness program conducted on 17/08/2010. Participated by Project manager, Group leader and QMS core group member. Total 17 persons participated
One day IAEA GS-R-3 awareness program conducted on 18/08/2010. Participated by Project manager, Group leader and QMS core group member. Total 23 persons participated
Organized one week program (4-7 January 2011) for IO safety requirements which consist of various topics like French nuclear licensing process, on safety classification, Quality Order 1984, safety requirements for PA, Preliminary Safety Report (RPRs) . Participated by Project manager, Group leader and QMS core group member.
One day ISO 9001:2008 awareness program conducted. Participated by Project manager, Group leader and QMS core group member.
Employee feedback system “Issue card” has been successfully launched
ITER-India Quality procedure (25 nos.), has been prepared
Quality Plans for various PA like VV IWS, CWS, CDCL etc. have been prepared and submitted to ITER-IO
ITER-India Projects Apex Safety & Quality Manual has been prepared.
Departmental process mapping procedure has been prepared for various department like Purchase, PMO(Project Office), IT, QA(Quality Assurance) etc.
Training given to various contractors (ICH&CD, VVIWS, Power Supply etc.)for “How to prepare Quality Plan”

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B.3. Centre of Plasma Physics, Guwahati

3D MHD and Heat Transfer analysis for rectangular ducts of LLCB TBM : Liquid metals (LM) are considered as prospective coolant in many designs of fusion reactor blankets. The motion of LMs in a strong magnetic field generally induces electric currents, which while interacting with the magnetic field produce electromagnetic forces that change the velocity distribution of the flow. This in turn change the heat transfer characteristics, pressure drop and the required pumping power for the cooling system from those of the case where no magnetic field is present. Hence the knowledge of LM MHD/HT flow characteristics under fusion relevant conditions is one of the key issues in making a design for fusion reactor LM cooling system. The initial theoretical formulation leading to MHD simulation of the problem has been completed. And a 2-D lid driven cavity benchmark of the 2D CFD code is underway. The code solves the 2D CFD equations over a uniform rectangular grid. The initial benchmark calculations have been done with the code over a 100 x 100 uniform grid.

Neutronics Modeling and Simulation

A. Shielding Calculation for Indian DEMO : For most fusion reactor designs, it is most desirable that the blanket/shield system requires a minimum of space. Blanket is defined as the portion of the design which is needed to breed tritium. Since every blanket also acts as a radiation shield, it is necessary to consider the combination of a tritium breeding blanket with any additional primary shielding as a blanket/shield system. A complete blanket/shield optimization under all conceivable constraints is a formidable task because for each allowable material combination a large variety of material arrangements (blanket designs) has to be analyzed.

In terms of fusion reactor, the role of radiation shielding is to protect the reactor components, the reactor operators and the public from intolerable levels of radiation exposure. The most sensitive components are super conducting magnets, some elements of plasma heating and exhaust systems, and instrumentation and control. Shielding must reduce the radiation damage and the nuclear heating of these components as well as biological dose below the design criteria or regulatory level. In an attempt to develop methodology to assess performance of a shielding blanket, we conducted neutronic analysis of a few shield variants for the Indian DEMO. Shielding calculations have been carried out for the inboard mid-plane of the reactor where the shielding is most crucial due to the limited space available for the blanket and shielding system, while at the same time the neutron wall loading shows a peaking value due to the concentration of the plasma source around the mid-plane (the neutron wall load at inboard and outboard mid-plane locations for Indian DEMO is calculated to be 3.19 and 2.48 MW/m^2 respectively). We estimated neutronic parameters like the fast neutron fluence to the superconductor, the peak nuclear heating in the winding pack, the radiation damage to the copper stabilizer and the radiation dose absorbed by the Epoxy insulator and compared them with ITER design limits for radiation loads to the TF-coil. We considered the following five shield variants: (a) Shield1: 16 cm of SS-316 (65%) and Water (35%)), (b) Shield2: 11 cm of SS-316 and 5 cm of WC (cooled by He)), (c) Shield3: 11 cm of SS-316 and 5 cm of WC (cooled by Water)), (d) Shield4: 21 cm of SS-316 (65%) and Water (35%)), and (e) Shield5: 11 cm of WC (cooled by Water)). It is found that shield variant 5 is the most effective shield, meeting all the ITER design limits; while variant 3 meets three out of the four design limits. These results are very preliminary in view of the simplified geometry model used for the simulation, and the calculated quantities may be highly under-estimated. Detail model of the reactor would consist of breeder in modular structure, heating and diagnostics ports, pipe forest and many other complexities; where streaming of high energy neutrons would occur. Works are under progress to prepare a more realistic model and re-run the simulation.

B. Usage Validation Calculations with Attila : Attila is a 3D deterministic radiation transport code designed to solve the linearized Boltzmann transport equation for a wide variety of radiation transport application. Attila can perform neutron transport calculation, charged particle transport calculations and infrared steady state calculations for radiative heat transfer purposes. Attila solves the standard first order form of the steady state, linearized Boltzmann transport equation.

As Attila is a deterministic code, it solves the problem by directly discretizing the problem with respect to each element of the phase space to obtain a system of equations that are then solved using some numerical algorithm. Attila uses multi-group energy discretization, discrete-ordinate (Sn) angular discretization and linear discontinuous finite element spatial differencing (LDFEM). The problem geometry is prepared by solid works, a 3 D modeling software and is imported to Attila as ".xt" file. Together with the geometry, sources and boundary conditions the equations are solved to produce a particle distribution function in space angle and energy. From this particle distribution function user edits can be produced as required. Several usage validation calculations have been performed using the Attila and results are compared with results obtained using Monte Carlo method. Attila is relatively new radiation transport tool and its validation in fusion studies are being conducted in many laboratories around the world. Most of the literature reported so far show a deviation of about 10-15% of the results obtained using MCNP. It may also be noted that these results are obtained using a coarse discretization. Due to electricity problem, we have not yet been able to use the full parallel computing facility of the cluster and thus these calculations are limited in terms of energy and angular discretization.

Studies on plasma dynamics across magnetic filter field for negative ion source.

A.Effect of magnetic filter on diffused plasma and sheath structure : A transverse magnetic filter field (TMF)), with magnetic poles kept 15 cm apart, is placed between the source and target regions of the double plasma device. A grid structure (G) is placed coplanar to the TMF. Both the TMF and grid are insulated from the magnetic cage. To study the sheath structure in the target region a metallic plate (P), 3.5 cm diameter, is placed at the center of the target region 10 cm away from the mesh grid. This plate is biased at –20 V with respect to the chamber (ground) potential. Plasma is created in the source region by filament discharge technique. Discharge voltage and discharge current are fixed at 80 V and 1 A respectively. Plasma diffusing from the source region to the target region is subjected to the TMF and an electric field applied on the grid (Grid bias VG = -15 V to -45 V). Plasma thus obtained in the target region forms a sheath on the biased plate. The influence of TMF together with the electric field, applied between the grid and the chamber wall, on the sheath structure formed on the biased plate is studied. It is found that the TMF significantly influences the sheath structure. This is due to the dependence of the sheath on the plasma parameters that are considerably affected due to the TMF. Electron density in the source, with TMF and increasing negative grid bias, varies from just 1.15 x 10^{17} m^{-3} to 1.19 x 10^{17} m^{-3} and hence remains almost constant. Without TMF and grid bias it varies from 7.5 x 10^{16} m^{-3} to 10^{17} m^{-3}. In the target region, with TMF and increasing negative grid bias, electron density falls from 5.5 x 10^{15} m^{-3} to 1.5 x 10^{15} m^{-3} Without TMF and grid bias it varies from just 1.6 x 10^{16} m^{-3} to ~1.2 x 10^{16} m^{-3} . Thus, it is seen that presence and absence of TMF together with grid bias affects electron density differently in the source and target regions. se of a grid together with the presence and absence of a TMF can have considerably different affect on the plasma parameters and sheath dimension. Presence of a grid and TMF can increase the sheath thickness by six times. The plasma potential also shows an increase in magnitude with the increase in negative grid bias when the TMF is used.

B. Effect of anode area on plasma parameters near a magnetic filter field : Double plasma device has two regions: Source region and Target region. The experiment is carried out only in the source section, where plasma is produced by hot filament discharge method. Discharge voltage and discharge current are kept fixed at 80 V and 0.5 A respectively. A transverse magnetic filter field (TMF), N-S, is applied between the source and target sections. The strength of the filter is varied from 80 Gauss to 230 Gauss by reducing the separation between the transverse magnetic field channels and the rest of the portion is blocked by stainless steel plate. Plasma parameters are measured along the axis of the chamber by a cylindrical Langmuir probe. It is found that the electron temperature (Te), as one moves axially towards the magnetic filter, changes its profile when the TMF field strength along with the anode surface area is increased. The axial scans of the electron density, plasma potential and floating potential also are found to change their shape when the TMF field strength is increases. It appears that these changes are related to the dependent on the anode area, which is related to the loss of particles on the plate together with the effect of the strength of the confining magnetic field. The increase in the strength of the transverse magnetic field together with an increase in the plasma particle loss area can change the axial profile of the electron density, electron temperature, plasma potential and floating potential in the source region.

Effect of energetic electrons on dust charging in hot cathode filament discharge : The effect of energetic electrons on dust charging for different types of dust is studied in hydrogen plasma. The hydrogen plasma is produced by hot cathode filament discharge method in a dusty plasma device. A full line cusped magnetic field cage is used to confine the plasma elements. To study the plasma parameters for various discharge conditions, a cylindrical Langmuir probe having 0.15 mm diameter and 10.0 mm length is used. An electronically controlled dust dropper is used to drop the dust particles into the plasma. For different discharge conditions, the dust current is measured using a Faraday cup connected to an electrometer. The effect of secondary emission as well as discharge voltage on charging of dust grains in hydrogen plasma is studied with different dust. Plasma parameters, namely plasma density, electron temperature are calculated at the center of the plasma chamber for different discharge conditions. The discharge voltage is varied from 60 to 80 V and the discharge current is varied within the range of 100–500 mA. For a particular discharge voltage, the discharge current is changed by changing the filament current, which in turn increases the number of primary electrons. It is seen that there is a decrease in the magnitude of the dust current as the discharge current increases for different discharge voltages. The reduction of charge in terms of current from the alumina dust with increase in discharge current can be attributed to emissions from the dust grains due to increase in primary electron energy (higher discharge voltage) and number of primary electrons (higher discharge current by increasing filament current). It shows that in case tungsten dust, the dust current increases with discharge current for each discharge voltage. The secondary emission effect is not observed in tungsten dust because the SEE yield of tungsten is very low compared to Al2O3 dust. This work shows that secondary electron emission plays a significant role in dust charging mechanism. The charging of dust having low SEE yield value is more compared to that of having higher SEE yield. For application, like dust accelerator where higher dust charging state is required, dust with low SEE yield is preferable.

Study on plasma parameters and dust charging in an electrostatically plugged multicusp plasma device : The effect of the electrostatic confinement potential on the charging of dust grains and its relationship with the plasma parameters has been studied in an electrostatically plugged multicusp dusty plasma device. Electrostatic plugging is implemented by biasing the electrically isolated magnetic multicusp channel walls.Plasma parameters, namely plasma density, electron temperature, and plasma potential are measured at the center of the plasma chamber with the help of the single cylindrical Langmuir probe. The magnetic cage biasing voltage is changed from –30 to +30 V in 10 V steps, while the discharge voltage is maintained at 60 and 80 V and the discharge current is maintained at 100 mA. it is clear that when the magnetic cage biasing voltages change from positive to negative (+30 to -30 V), the plasma density increases and the electron temperature decreases. The magnetic cage biasing voltage changes the effective discharg voltage. When the magnetic cage is negatively biased, the electrons experienced an additional repulsive force, which reduces the loss of electrons at the cusp region of the magnetic cage This helps to increase the plasma density. On the contrary, when the magnetic cage is positively biased, the electrons experienced an additional attractive force to move toward the cusp's wall, which increases the loss of electrons at the cusp region of the magnetic cage. Therefore, a decrease in plasma density is observed, when the magnetic cage is positively biased. Due to the similar magnetic cage biasing, a small variation in electron temperature is observed. When the magnetic cage is positively biased, the effective discharge voltage experienced by the plasma electron increases. Due to that reason, a small increase in electron temperature is observed, while the magnetic cage is positively biased. It is observed that positive magnetic cage biasing enables higher dust charging and negative cage biasing increases plasma density by improving the plasma confinement. To control the dust charging, magnetic cage biasing potential can be used as an external controlling parameter.

Experiments on cesium (Cs) coated dust and its effects on hydrogen plasma : The main objective of this work is to study the effect of Cs coated dust on the parameters of hydrogen plasma and to find whether Cs coated dusty plasma can be used as a surface assisted volume negative hydrogen ion source. The work involves in this experiment is to test the performance of Cs oven and the dust coating unit for production of in situ Cs coated dust which in turn contributes to efficient production of negative hydrogen ions in the plasma volume. The experimental setup is shown in Figure B.2.1 The first experimental campaign of this experiment which included Langmuir probe measurements, Dust current measurements by Faraday Cup, H-Balmer lines intensity measurement by the spectrometer, Cs atom density in the coating chamber was reported earlier. Based on the earlier observations, cesium evaporation was improved, detection of the spectral line was improved for better intensity (For OES Studies), dust density was increased with a new dust dropper. The second experimental campaign with improvisation is going on. It is seen from the Langmuir probe IV characteristics that there has been a decrease in electron saturation current in presence of cesium coated tungsten dust.

Studies on Thermal Plasma Assisted Synthesis of Nanostructured Materials : One of the key issues in the emerging field of nanotechnology is to develop bulk synthesis methods for nanostructured materials. Particularly over the last decade, the thermal plasma assisted techniques have emerged as a promising candidate in this regard. A very good crystallization of the synthesized material because of the presence of very high temperature may be termed as another acute advantage of plasma mediated methods. Unlike the wet chemical methods, this helps in avoiding further heat treatment of the materials, which is notorious for changing particle size distribution and phase composition. This laboratory is involved in developing thermal plasma assisted processes for synthesis of some novel nanostructured materials, and study the physics and chemistry issues involved for their ultimate optimization. Over the last few years, a particular experimental reactor configuration was developed, where a plasma beam

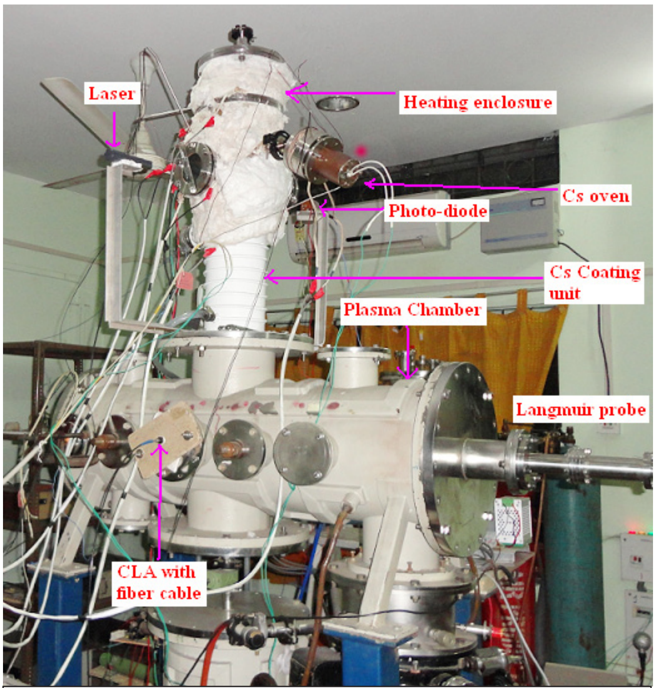

Figure B.2.1 Dusty Plasma Device at CPP

seeded with the reactants expands supersonically into a low pressure sample collection chamber, out of which fine particles nucleate by homogenous condensation. This can maintain a very sharp (106 -107 K/s) and almost one dimensional temperature gradient, which helps in achieving very small particle sizes with a narrow distribution. Particles after nucleation may get charged up unipolarly by collecting a non-equilibrium electron distribution, which may also reduce inter particle agglomeration. Some recent experimental results pertaining to the period mentioned above are reported here.

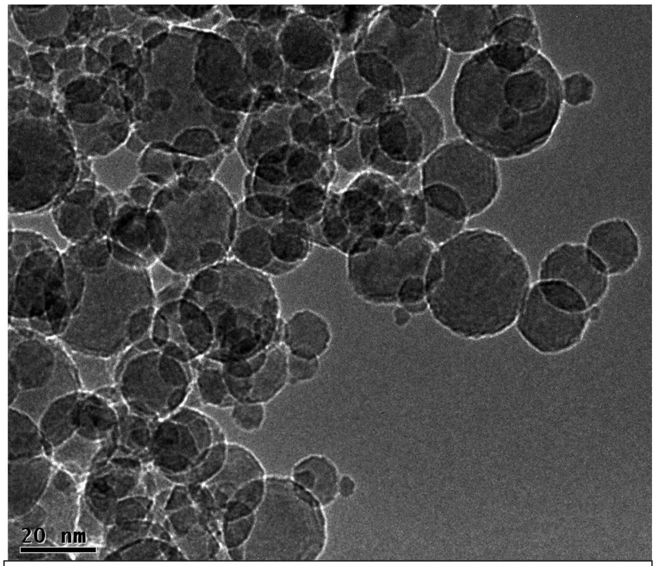

Figure B.2.2 HRTEM photograph of nano aluminum

Studies on the Effect of Pressure on the Product Materials : The supersonic nozzle allows reducing the pressure in the sample collection to few mbar levels without disrupting the plasma discharge. Average size for titanium nitride and aluminum oxide nanoparticles for this pressure range were measured to be less than 10 nanometers, which is one of the lowest reported values for these materials by a plasma assisted method. Particles had fine crystallinity and an impressive very narrow size distribution. HRTEM photograph of nano aluminum is shown in figure B.2.2.

Nanostructured Carbon and Encapsulated Iron Nanoparticles : Different carbon nanostructures were synthesized by plasma decomposition of gaseous hydrocarbons (acetylene and methane). A unique combination of both conductivity and high surface area (340-360 m^2/g) is likely to make them most suitable to be used as an alternative low cost catalyst for hydrogen fuel cell applications. TEM/HRTEM reveals graphene sheets stacked together in crumpled paper like structure inside individual particles along with carbon-onion like structures. Another significant observation was, average number of graphene sheets in a single layer decreases with decreasing pressure in the chamber. This explains superior specific surface area of nanomaterials synthesized under low pressure. Another field of interest is carbon encapsulated magnetic (iron, cobalt, nickel) nanoparticles. We have demonstrated rapid synthesis of this material with uniform sizes of 2-3 nanometers, which are now being extensively characterized for correlating to their material properties. The setup now is being modified to study the synthesis of carbon nanotubes. The regular experiments were little hampered as the new torch components were not working properly. Order was placed for another set of segmented torch components just before the end of this financial year.

Development of a Segmented Plasma Torch Assisted System as a 1-10 MW/m² Level Tailored Heat Source : This system was developed with a long-term aim of establishing a complete Tokamak Divertor simulator, not only in terms of heat flux (1-10 MW/m^2), but also for reproduction of the typical electron temperature (1-5 eV), hydrogen ion density (10^{20}-10^{21} m^{-3}) and ion flux (10^{24} $m^{-2}s^{-1}$). It can also work as a test bed for performance evaluation of fusion grade materials/Tokamak components under simulated high heat load conditions. Electron beam sources are more suitable for producing this level of heat flux, but use of a segmented type plasma torch operating typically at high pressure offered with the additional advantage of producing Tokamak type/grade very high density hydrogen plasma with intense ion flux. In the first phase of this experiment, we have concentrating on maximizing the heat flux produced with the torch operated with argon alone. For the optimum experimental conditions, a maximum heat flux of about 3.9 MW/m^2 was recorded, which can be improved only upon enhancing the input power (a 30 kW DC Thyristorised power supply). Order was placed for another 80 kW thyristorised power supply recently.

Plasma Focus (PF)

A.Proton Emission Analyses : We have used CR39 track detector for rough estimation of proton energy by using Al filters (2 to 10 µm Al- filters) in front of track detectors. Individual and well-separated tracks are mostly seen in the micrograph along with a few overlapped tracks. Protons of above 220keV can pass through the 2 µm Al filter and, therefore, the tracks formed. We have also attempted to get a rough estimation of maximum proton energy by putting higher thickness Al filter in front of the detector. The track density as a function of track diameters at various etching hours, have been studied. When we increase the etching hours in case of different thickness of the Al filters the most probable track diameter has shifted from 2.5 to 4.5 µm, 3.5 to 6.5µm and 1.5 to 5µm in case of 2, 4 and 6 µm Al filters, respectively. The track diameters roughly increase linearly with respect to etching time. Distinct differences on the surface morphology are marked after bombardment of neon ions. Microcracks induced due to bombardment of neon ions are marked at lower magnification micrographs. The bubbles/ blisters are also appeared in exposed samples probably because of the trapping of neon ions. Moreover, pit holes and craters have been found due to bombardment of neon ions. Tungsten specimen exposed to 10 shots of neon ions was subjected to the compositional analyses using EDX. As expected, the spectrum mainly shows many W peaks along with small peaks of Fe and Cr which are appeared due to the presence of the traces of electrode material (SS in our case). However, the spectrum does not show any evidence of neon ions. The absence of neon peak may be viewed in different angles. The said EDX machine might not be sensitive to low Z atomic elements. Other reason of absence of neon peaks may be because of little inclusion neon ions inside the tungsten lattice. Structural changes occurred on tungsten a specimen due to exposure of neon ion was carried out by employing powder XRD. XRD spectra do not indicate any major changes and thereby probably confirming the absence of ion induced structural changes.

B. Vacuum Photo Diode (VPD) : We have extended the study of the detection efficiency of different photodiode on the basis of cathode anode separation, cathode diameter. The observed results can be explained in the following ways. The emissions of photoelectrons are in two directions for the photo-cathode of the VPDs. The polished front surface of the photo-cathode emits surface photoelectron and it is collected by filtered pinhole sheet of aluminum. In addition to this some volume photoelectrons are emitted in the cathode- anode lateral gap. In the operating condition of plasma focus, the photoelectrons emitted in the lateral direction of photo-cathode plays a crucial role to increase the efficiency of the detector. Decreasing the cathode anode lateral gap and reducing the diameter of the photocathode can increase the collection of these photoelectrons and consequently improve the performance of the VPD. Therefore the efficiency of VSVPD whose cathode-anode lateral gap (1.5 mm) and diameter of the photo cathode (10 mm) is highest in our case. In an attempt to check the performance of VPD as a diagnostic tool, we have used the VPD to measure electron temperature of the pinched plasma column of PF device using intensity ratio technique. Initially detectors were normalized and the normalization procedure is done to rectify the geometrical or mechanical errors of the detector. The normalization factor found to be 1 and 1.203 for the two VPDs. Thus putting Be filter of having thickness 5 µm and 10 µm in the two identical VSVPD, we find out the electron temperature around 0.6426 keV. The temperature was estimated putting the data in the standard plot between intensity ratio and electron temperature. The pinched plasma focus device is a source of neutron when it is operated in a deuterium medium. The neutron emission ranges from 106/shot to 1011/shot depending pn the energy of the device. The energy of the neutron emission has been determined by time of flight technique using scintillator-combined photomultiplier (PMT). To acquire time resolved neutron signal we have used two high gains PMT coupled with plastic scintillator (NE102A type), which is placed at a distance of 2m and 3.5m away from PF device in axial and radial direction. Initially the detection of neutron pulse emission was confirmed by putting a 3mm thick lead sheet in front of PMT. The cathode of the PMT was biased to –2000V by high voltage biasing power supply. Out put pulses of PMT replicates the time resolved pulse of corresponding X-rays and neutrons and it could be observed in an oscilloscope. Thus by putting the PMT in axial and radial direction with respect to the axis of the coaxial electrode assembly, we could record the corresponding hard X-ray and neutron pulses. The energy of the neutron is determined taking the peak of the hard X-ray pulse as reference zero in the time scale. The initial results of neutron emission from PF device showed that the energy of the neutron emission in axial and radial direction is 3.24 MeV and 2.08 MeV respectively. From the initial results we are observing anisotropy of neutron energy between the radial and axial direction of the device. The typical neutron pulses along with hard X-ray observed in the oscilloscope. There seems to be multiple neutron pulses emitting from the device. The optimized condition for neutron emission from CPP-IPR PF device is yet to be found out. At present we are trying to find the optimized operating pressure for neutron emission from our PF device.

Plasma Nitriding on Duplex Coated AISI M2 Steel : The present study examines the mechanical and structural properties of plasma nitrided, plasma nitride +Titanium Nitride (TiN) coated, plasma-nitrided + TiN coated + plasma nitrided AISI M2 steel. The plasma nitriding process was carried out under various conditions of temperature (500^{o}C), time (24hrs), and gas mixture (80% N_2 + 20% H_2) and (80%H_2 + 20%N_2) at 5-mbar working pressure. The titanium nitride coatings were deposited using a planar magnetron sputtering system. Titanium nitride coating was deposited with different contents of nitrogen to form TiN coating on the surface. After TiN coating plasma nitriding was carried out at 500 oC for 4 hours. Plasma nitrided, plasma nitrided +TiN coated and Plasma Nitrided + TiN + plasma nitrided sample surface were characterized using microhardness tests, X-ray diffraction (XRD), and scanning electron microscopy (SEM). The highest microhardness of 800HV was obtained on plasma nitrided AISI M2 steel when treated with 80%H_2 + 20% N_2 gas mixture compared to 600 HV obtained using 20%N_2 + 80% H_2. The effect of plasma nitriding on different TiNx coated samples are investigated in the present work.

B.4. Board of Research in Fusion Science and Technology (BRFST)

During the year 2010-11, in the review held in February 2011 and that to be held in August 2011, The total committed budget for R&D projects is expected to be approximately Rs. 547 Lakhs. Till March 2011, BRFST has awarded 61 R&D projects with a total commitment of ~ Rs. 1,866 Lakhs of which 13 were awarded to industries with a total commitment of Rs. 121 Lakhs. Thirty conferences in various areas of fusion science & technology were supported by BRFST in this period with a total commitment of ~ Rs. 44 Lakhs. From April 2011, BRFST board has sanctioned travel support to students working in fusion related Indo-EU collaborative projects to visit and work in the EU laboratories. Since currently there are about 60 ongoing and completed projects supported by BRFST, the board decided that it would be good to hold a biennial conference of all the BRFST funded projects. The first of this series of conferences is planned to be organized next year. The board also plans to conduct focused topical meetings on areas in which BRFST has been funding multiple projects. The purpose of the meeting was to bring together the various groups working in this area in order to bring synergy as well as a direction to the R&D in this area. The first such meeting is to be held at NIT Rourkela on "Development Of Lithium Based Ceramics For Tritium Breeding". More such meetings are planned in the future.

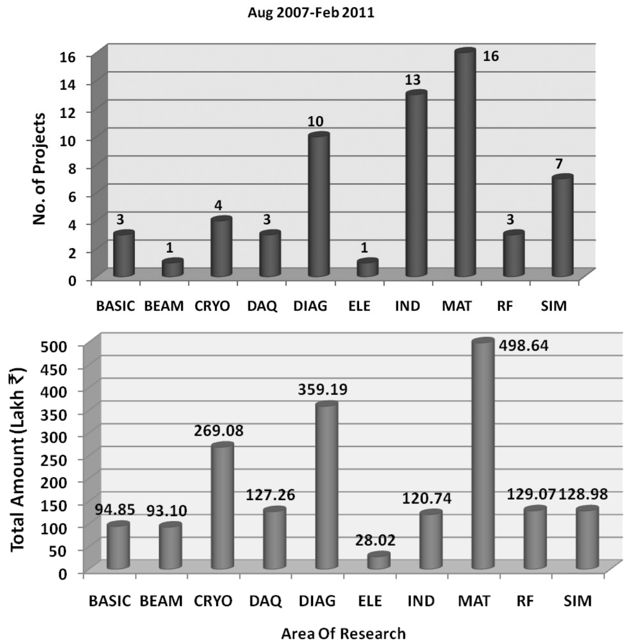

Figure B.4.1 Areas of R&D supported by BRFST and Distribution of funding in various R&D areas

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C. ACADEMIC PROGRAMMES

C.1 DOCTORATE PROGRAMME

In the Ph.D. programme conducted by the institute twenty (20) research scholars have been enrolled at present. Out of them, eleven (11) are working in theoretical and simulation projects while eight (8) are engaged in experimental projects. One (1) new student has joined this programme during the year and is going through the course work. After successful completion of this course work, they will be enrolled for their Ph.D. works.

Ph.D. THESIS SUBMITTED (during April 2010 - March 2011)

Simulation studies on co-deposited hydrocarbon films and hydrogen retention
P.N. Maya
Devi Ahilya Vishwavidyalaya, Indore, 2010

Molecular Dynamics Simulations of Nanometer Sized Devices based on Carbon Nanotubes
Sunita Negi
Homi Bhabha National Institute, 2010

Plasma Assisted Physical Vapor Deposition of Nano-structured Coatings
K. Kishor Kumar
Devi Ahilya Vishwavidyalaya, Indore, 2011

Electron Magnetohydrodynamic (EMHD) Studies on Electron Transport in an Inhomogeneous Plasma Medium
Sharad Kumar Yadav
Homi Bhabha National Institute, 2010

C.2 SUMMER SCHOOL PROGRAMME

Twenty-five (25) students participated in this programme, which aimed at providing an opportunity to M.Sc. students 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 routinely offered in Computer, Electronics and Electrical Engineering for regular students as a part of their academic requirements.

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D. TECHNICAL SERVICES

D.1. Engineering Services

D.1.1. Air conditioning (AC) and Water cooling (WC)

WC system for Negative Ion Neutral Beam Injection System for ITER India Diagnostic Neutral Beam System : Cooling Water System has been designed, installed & commissioned for Negative Ion Neutral Beam Injection System for the ITER India Diagnostic Neutral Beam System to transfer the heat dissipated by each of the Negative Ion Neutral Beam Injection subsystem to the atmosphere. The cooling water system provides the water to various components at required temperature, flow, pressure and quality. The Negative Ion NBI subsystems, which require cooling water, consist of Grid Box, Extraction Grid, Ground Grid, RF Coil, Calorimeter, RF Generator, RF Oscillator RF Power supply, Dummy Load, Plasma box, Back Plate & Faraday Shield. The cooling water system is designed with a duty factor of ~20% to remove heat load of ~ 700 KW by Chilled Water system. Depending upon the experimental requirement, the supply water temperature at 20^{o}C, Pumping head 10 bar, flow rate 500 liters/min., conductivity $\leq$ 0.1 µS/cm and dissolved oxygen content $\leq$ 0.5 ppm is to be supplied to the experimental system. Since the cooling water requirement is very stringent for healthy operation of Negative Ion NBI experiment, the DAC system has been designed for online monitoring and control of water parameters like flow, temperature, pressure, conductivity and dissolved oxygen content through SCADA system.

Commissioning of Kitchen Basement Air Conditioning System : Design, Installation, Testing and commissioning of 3 Nos. X 125 TR Screw type water cooled chillers, 2 Nos. X 350 TR cooling towers, chilled water pumps, condenser pumps, pipings , State of the art Building Management System for online monitoring of parameters , Diverting valves for AHUs, FCUs of 1.5 TR and all related accessories for kitchen basement Air Conditioning plant at IPR.

Commissioning of DX type Air Conditioning System for FCIPT Building : Design, Installation, Testing and commissioning of DX type air conditioning system of 17 TR (for staff area), 11 TR (for Admin/library area), 8.5 TR (for Basic experimental lab) and 8.5 TR (for Spix and XPS lab) with

Figure D.1.1 WC system for Negative Ion Neutral Beam Injection System

all ducting, electrical work etc. at FCIPT, Gandhinagar. This system consists of direct expansion type Air Handling Units and Condensing Units.

Commissioning of Packaged Air Conditioning System for FCIPT Seminar Hall and Negative NBI Lab at IPR : Design, Installation, Testing and commissioning of Package type air conditioning system of 2 Nos. X 15 TR (for N-NBI, IPR) and 2 Nos. X 10 TR (for Seminar hall, FCIPT) with all ducting, electrical works etc was also done.

D.1.2. Drafting services

Detailed engineering drawings were made for following systems and sub-systems of SST-1: Poloidal Field (PF) coil current lead chamber, lead layout from CLC, hydraulic layout for Toroidal field (TF) coils, TF manifold, IC and IP joints, RCC and saddle coil, PF3 top new bridge type joints, PF3 bottom lead layout and hydraulic, PF 4 and 5 top, bottom hydraulic new joint box, 80 K shields, 890 K supply and return hearders, plasma facing components - 3d model, valve box for LN_2 supply and return hearder etc.

New software, CATIA V5R20 was procurred and a basic training was arranged on the same. A new plotter cum scanner, HP T2300, was also procurred.

D.1.3. Computer Services

Work done by Computer division can be categorized as

a) Infrastructure maintenance and augmentation :

- Internet bandwidth increased to 8 Mbps
- Connection to National Knowledge Network
- Upgradation of network backbone equipment and rearrangement of connections for optimal network performance
- Networking of new FCIPT building
- Fiber connectivity to Magnet lab
- Troubleshooting and overseeing hardware maintenance of system and networking hardware

b) Software development & installations

- New comprehensive paybill generation program
- Web interface for paybill and tax related forms viewing
- Enhancement of Eoffice software to incorporate online workshop job and drawing submission
- Software installations and related troubleshooting of Hypermesh, Ansys, Catia and associated license servers
- IPV6 compliant software installation/upgradation

c) Hardware & software procurements

- PCs, scanners, printers, laptops and networking products as required by individual groups as well as for central facility upgradation
- Windows and Unix and Linux software

D.2. Library Services

Library plays an important role as a center of information in supporting all the research activities. IPR Library has also played very vital role in development of the institutional research activities. It is always proactive in procuring best appropriate resources, extending quality services, and creating vibrant ambiance for Learning, Developing Lightning

Reflexes and to address the diverse users' needs of various projects and levels in research activities. Library is the Virtual Research Laboratory before Real Research starts. Users strongly advocate that IPR Library is the best Library in the field of Plasma Physics and allied subjects.

At present IPR Library consisting of four major divisional libraries – Main library, FCIPT Library, ITER-India Library at Gandhinagar campus and CPP Library, Guwahati. Main library procures and processes all types of documents and online resources for all divisional libraries.

In recent years, the IPR Library placed a highest priority on providing with access to more and more e-access to research resources through the network. Library subscribes major databases, such as SCOPUS, SCIENCE DIRECT, IOP Archives, APS journals, & PROLA. It also provides access to more than 3800 e-journals. Online Archives of Journal of Plasma Physics is also added. All these e-resources are also accessible to all users at all divisional libraries. About 850 books, 100 new research reports, 82 software, and 225 reprints were added into the library collection and subscribed to 105 periodicals.

Digitization of valuable research reports of library is in progress. During reporting period total 1600 reports were digitized and added to online resources. Provided current awareness services to all local scientists as well as 25 plasma physicists at national level by providing table of contents of all important journals through online and print copy. Full text e-bibliography compiled for senior scientist. IPR Library website is a very useful starting point to find and get information for study and research. Constant improvement and updation of website is being done regularly. In addition to regular issue of documents 92% of user demand was satisfied through ILL services. Total 120000 photocopies were provided to users.

New CDM server with 4 Terabytes capacity installed and about 10100 documents mirrored and made available to all users through Intranet. To make the space in library procured Godrej Optimizers to store backvolumes. Library also added upgraded computers and printers.

Budget of 1.52 Crores utilized.

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E. PUBLICATION AND PRESENTATION

E.1 RESEARCH REPORTS (Published in Scientific Journals and Proceedings)

Deposition of Thick and Adherent Teflon-like Coating on Industrial Scale Stainless Steel Shell using Pulsed DC and RF PECVD
A. SATYAPRASAD, S.K. NEMA, N.K. SINHA, and BALDEV RAJ
Applied Surface Science, 256, 4334, 2010

Experimental Investigation of Different Structures of a Radio Frequency Produced Plasma Column
RAJNEESH KUMAR and DHIRAJ BORA
Physics of Plasmas, 17, 043503, 2010

Fast Integrator based Data Acquisition System for the SST-1 Thomson Scattering System
KIRAN PATEL and AJAI KUMAR
Review of Scientific Instruments, 81, 043501, 2010

Free Energy Source for Flow Shear Driven Instabilities in Electron-magnetohydrodynamics
SITA SUNDAR and AMITA DAS
Physics of Plasmas, 17, 042106, 2010

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L. M. AWASTHI, S. K. MATTOO, R. JHA, R. SINGH, and P. K. KAW
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Physics Letters A, 374, 2555, 2010

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Spectrochimica Acta Part B: Atomic Spectroscopy, 65, 415, 2010

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Journal of Applied Physics, 107, 123307, 2010

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E 2. TECHNICAL REPORTS

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T. PRABAHARAN, A. SHYAM, R. SHUKLA, P. BANERJEE, S. SHARMA. P. DEB, R. VERMA, R. KUMAR, R. DAS, B. DAS and B. ADHIKARY
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SAMEER KUMAR, RATNESHWAR JHA, PRAVEEN LAL, CHANDRESH HANSALIYA, M.V. GOPALKRISHNA AND THE ADITYA TEAM, SANJAY KULKARNI, KISHORE MISHRA, AND THE ICRH GROUP

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RISHI VERMA, A. SHYAM, R. KUMAR, B. ADHIKARY, R. SHUKLA, P. BANERJEE, S. K. SHARMA, P. DEB, T. PRABAHARAN AND R. DAS
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K. SATHYANARAYANA, NIDHI SHAH and S.V. KULKARNI
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N.C. PATEL, CHHAYA CHAVDA, RAKESH TANNA, PRABAL CHATTOPADHYAY
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AMIT K. SRIVASTAVA, MONIKA SHARMA, IMRAN MANSURI, ATISH SHARMA, TUSHAR RAVAL and SUBRATA PRADHAN
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E 3. CONFERENCE PRESENTATION

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Transmission Line and its Components for ITER ECE Diagnostic
H. K. B. Pandya, Suman Danani and Kaushal Patel

Testing of ECE SIM Code in MATLAB for ECE Emission Estimates from ITER Plasma in the Presence of Polarization Scrambling in Wall Reflections
Suman Danani, H.K.B. Pandya, M. E. Austin and P. Vasu

Progress in Integration of ITER Microwave Diagnostics
V. S. Udintsev, G. Vayakis, B. Cantone, A. Encheva, C. Walker, M. Benchikhoune, A. E. Costley, A. Dammann, M. A. Henderson, I. Kuehn, C. H. Lee, B. Levesy, A. Martin, K. M. Patel, C. S. Pitcher, A. Tesini, Y. Utin, M. J. Walsh, S. Danani, H. Pandya, P. Vasu, M. Austin, W. Rowan, R. Feder, D. Johnson, D. Shelukhin, V. Vershkov, G. Counsell, Ch. Ingesson and S. Arshad

9th Workshop on Frontiers in Low Temperature Plasma Diagnostics, Greifswald /Zinnowitz, Germany, 09-12 May 2011

Diagnostics Performed to Measure Charge on Dust in Hot Cathode Discharge
B.K. Saikia, S.S. Kausik and B. Kakati

6th International Conference on the Physics of Dusty Plasmas, Garmisch-Partenkirchen, Germany, 16-20 May 2011

Simulations of Compressible Dust Ball
V. Saxena

Influence of Polarization Force on Jeans Instability of Dusty Plasma
R. P. Prajapati

Kelvin Helmholtz Instability in Dusty plasmas
S. K. Tiwari

Secondary Electron Emission from Dust and its Effect on Charging
B.K. Saikia, B. Kakati, S.S. Kausik and M. Bandyopadhyay

Effect of Electrostatic Confinement on Charging Of Dust Grains
S.S. Kausik, B. Kakati and B.K. Saikia

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Active Spectroscopic Measurements using the ITER Diagnostic System
D. M. Thomas, G. Counsell, D. Johnson, P. Vasu, and A. Zvonkov

Librarians' Meet for Local Librarians, IPR, Gandhinagar, 19th June 2010

Digital Technology
S. Shravan Kumar and P.J. Pathak

37th EPS Conference on Plasma Physics, DCU, Dublin, Ireland, 21st – 25th June 2010

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P.K. Sharma, M. Goniche, A. Ekedahl, V. Basiuk, J.Decker, D. Mazon, Y. Peysson, J.F.Artaud, C. Balorin, G.Berger-By, S. Bremond, E. Corbel, X. Courtois, E. Delmas, L. Delpech, D. Douai, C. Goletto, D. Gulhem, J. P. Gunn, P. Hertout, J.Hillairet, G.T.Hoang, F.Imbeaux, X. Litaudon, R. Magne, P. Mollard, P. Moreau, T. Oosako, S. Poli, M. Preynas, M. Prou, F. Saint-Laurent, F. Samaille, B. Saoutic, J. Belo, C. Castaldo, S. Ceccuzzi, R. Cesario, F. Mirizzi, Y. Baranov, K. K. Kirov, J. Mailloux, V. Petrzika, Y. S. Bae, J. Kim, S. Lee, X. Bai and X. Ding.

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A. Ekedahl, J. Achard, C. Balorin, G. Berger-By, S. Br´emond, E. Corbel, X. Courtois, E. Delmas, L. Delpech, D. Douai, C. Goletto, M. Goniche, D. Guilhem, J.P. Gunn, P. Hertout, J. Hillairet, G.T. Hoang, F. Imbeaux, X. Litaudon, R. Magne, D. Mazon, P. Mollard, P. Moreau, T. Oosako, S. Poli, M. Preynas, M. Prou, F. Saint-Laurent, F. Samaille, B. Saoutic, P.K. Sharma, J. Belo, C. Castaldo, S. Ceccuzzi, R. Cesario, F. Mirizzi, Y. Baranov, K.K. Kirov, J. Mailloux, V. Petrzilka, Y.S. Bae, J. Kim, S. Lee, X. Bai and X. Ding

Lower Hybrid Current Drive for the Steady-State Scenario
M Goniche, Y Baranov, V Basiuk, P. Bonoli, G Calabro, A Cardinali, C Castaldo, R Cesario, J. Decker, A. Ekedahl, J Garcia, G Giruzzi, E Joffrin, A Hubbard, K Kirov, X Litaudon, J Mailloux, R Parker, V Pericoli, Y Peysson, P. K. Sharma, C Sozzi, G Wallace and JET EFDA Contributors

Results of ITER Test Blanket Module Mock-Up Experiments on DIII-D
J.A. Snipes, M.J. Schaffer, P. Gohil, P. de Vries, M.E. Fenstermacher, T.E. Evans, X. Gao, A.M. Garofalo, D.A. Gates, C.M. Greenfield, W.W. Heidbrink, G.J. Kramer, S. Liu, A. Loarte, M.F.F. Nave, N. Oyama, J-K. Park, N. Ramasubramanian, H. Reimerdes, G. Saibene, A. Salmi, K. Shinohara, D.A. Spong, W.M. Solomon, T. Tala, J.A. Boedo, R. Budny, V. Chuyanov, E.J. Doyle, M. Jakubowski, H. Jhang, R.M. Nazikian, V.D. Pustovitov, O. Schmitz, T.H. Osborne, R. Srinivasan, T.S. Taylor, M.R. Wade, K-I. You, L. Zeng, and the DIII-D Team

National Workshop on Infrared Thermography and its Application-2010, Institute for Plasma Research, Gandhinagar, June 28-30

Applications of Thermography in Fusion Research
Santosh P. Pandya

12th Annual Genetic and Evolutionary Computation Conference, (GECCO-2010), Portland, 7 -11 July 2010
Improved Forecasting of Time Series Data of Real System using Genetic Programming
D.P. Ahalpara

6th International Conference on Combustion, Incineration/ Pyrolysis and Emission Control: Waste to Wealth (6th i-CIPEC - W2W 2010), Malaysian Nuclear Agency, Putra World Trade Center, Kuala Lumpur, Malaysia, 26-29 July 2010

Plasma Pyrolysis of Medical Waste and Energy Recovery from Plastic Waste
S. K. Nema

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Plasma Processing for High End Technical Textile
P.B. Jhala,

35th International Conference on Infrared, Millimeter and THz Waves (IRMMW-THz 2010), Rome, Italy, 5-10 September 2010

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C. Darbos, F.Albajar, S.Alberti, T.Bonicelli, A.Bruschi, R.Chavan, M.deBaar, D.Farina, T.P.Goodman, J.P.Hogge, W.Kasparek, S. Kern, A.Moro, G.Ramponi, D.Ronden, G.Saibene, T.Scherer, D.Strauss, O.Sauter, H Zohm, U.Baruah, S.L.Rao, K.Kajiwara, N.Kobayashi, Y.Oda, K.Sakamoto, K.Takahashi, G.Denisov, T.Bigelow, J.Caughman, D.Rasmussen, M.Shapiro, R.Temkin, B Becket, D.Cox, F.Gandini, T.Gassman, M.Henderson, O.Jean, C.Nazare, T.Omori and D.Purohit

24th International Conference on Surface Modification Technologies (SMT 24), International Congress Center, Dresden, Germany, 7-9 September 2010

Glow discharge Plasma Nitriding – Role of Hydrogen
S. Mukherjee, Suraj Sinha

12th International Conference on Plasma Surface Engineering, Garmisch-Partenkirchen, Germany, 13-17 September 2010

Study of Structure Development of Titanium Nitride Coatings on Inclined Substrates
S. Mukherjee, K. Kishor Kumar, P.M. Raole, Pratipal Rayjada, N.L. Chauhan

DAE-BRNS International Conference on Physics of Emerging Functional Materials (PEFM-2010), BARC, Mumbai, India, 22-24 September 2010

Comparative Study of Optical, Structural and Electrical Properties of Tin Oxide Films Deposited by Thermal Evaporation and Plasma Assisted Thermal Evaporation
C. Jariwala, Tarun Garg, A. Chainani, R. Rane, N. Chauhan, P. A. Rayjada, C. J. Panchal and P.I. John

IEA International Workshop on Liquid Metal Breeder Blankets, Madrid, Spain, 23-24 September 2010

Overview of the Lead-Lithium Ceramic Breeder (LLCB) Test Blanket Module (TBM) activities in India
A. K. Suri, T. Jayakumar and E. Rajendra kumar

3D Thermo-fluid MHD Simulation of Single Straight Channel Flow in LLCB TBM
Rajendra Bhattacharyay

Development of Buoyancy Driven Lead-lithium Loops for Corrosion Studies
R.Fotedar, P.Chakraborty, A. Sarada Sree, E. Rajendra Kumar and A.K. Suri

26th Symposium on Fusion Technology (SOFT), Porto, Portugal, September 27- October 1, 2010

Design Optimization of the 100 kV HV Bushing for ITER-DNB
Sejal Shah, S. Rajesh, B. Srusti, M. Bandyopadhyay, C. Rotti, M. J. Singh, G. Roopesh, A. K. Chakraborty, B. Schunke, R. Hemsworth, J. Chareyre

ITER DNB Ion Source Movement Mechanism
M. Bandyopadhyay, Irfan Ahmed, G. Roopesh, M. J. Singh, C. Rotti, Sejal Shah, A. Phukan, R. K. Yadav and A. K. Chakraborty

An Indian Test facility to Characterize Diagnostic Neutral Beam for ITER
M.J.Singh, M.Bandyopadhyay, C. Rotti, N.P.Singh, Sejal Shah, G. Bansal, A. Gahlaut, J. Soni, H. Lakdawala, I. Ahmed, Roopesh G., U.K. Baruah, A.K. Chakraborty

Proposed High Voltage Power Supply for the ITER Relevant Lower Hybrid Current Drive System
P.K. Sharma, F.Kazarian, P.Garibaldi, T.Gassman, J.F.Artaud, Y.S.Bae, J.Belo, G.Berger-By, J.M. Bernard, Ph.Cara, A.Cardinali, C.Castaldo, S.Ceccuzzi, R.Cesario, J.Decker, L.Delpech, A. Ekedahl, J.Garcia, M.Goniche, D.Guilhem, C.Hamlyn-Harris, J.Hillairet, G.T.Hoang, H.Jia, Q.Y. Huang, F.Imbeaux, S.H.Kim, Y.Lausenaz, R.Maggiora, R.Magne, L.Marfisi, S.Meschino, D. Milanesio, F.Mirizzi,W.Namkung, L.Pajewski, L.Panaccione, Y.Peysson, A.Saille, G. Schettini, M.Schneider, O.Tudisco, G.Vecchi, S.R.Villari, K.Vulliez, Y.Wu and Q.Zeng

Contribution to the Design of the Main Transmission Line for the ITER Relevant LHCD System
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High Voltage Power Supplies for ITER RF Heating and Current Drive Systems
T.Gassmann, B. Arambhadiya, B.Beaumont, U.K. Baruah, T.Bonicelli, C.Darbos, D.Purohit, H.Decamps, F.Albajar, F.Gandini, M.Henderson, F.Kazarian, P.U.Lamalle, T.Omori, D.Rathi, N.P.Singh, Amit Patel , Darshan Parmar

Benchmark of Coupling Codes (ALOHA, TOPLHA and GRILL3D) with ITER-Relevant Lower Hybrid Antenna
D. Milanesio, J.Hillairet, L.Panaccione, R.Maggiora, J.F.Artaud, Y.S.Bae, A.M.A.Barbera, J. Belo, G.Berger-By, J.M.Bernard, Ph.Cara, A.Cardinali, C.Castaldo, S.Ceccuzzi, R.Cesario, J. Decker, L.Delpech, A.Ekedahl, J.Garcia, P.Garibaldi, M.Goniche, D.Guilhem, C. Hamlyn-Harris, G.T.Hoang, H.Jia, Q.Y.Huang, F.Imbeaux, S.H.Kim, Y.Lausenaz, R. Magne, L.Marfisi, S.Meschino, F.Mirizzi, W.Namkung, L.Pajewski, Y.Peysson, A.Saille, G. Schettini, M.Schneider, P.K.Sharma, A.A.Tuccillo, O.Tudisco, R.Villari, K.Vulliez, Y.Wu and Q. Zeng

Mode Filters for Oversized Transmission Lines
S. Ceccuzzi, S.Meschino, F.Mirizzi, J.F.Artaud, Y.S.Bae, J.Belo, G.Berger-By, J.M.Bernard, Ph. Cara, A.Cardinali, C.Castaldo, R.Cesario, J.Decker, L.Delpech, A.Ekedahl, J.Garcia, P. Garibaldi, M.Goniche, D.Guilhem, J.Hillairet, G.T.Hoang, Q.Y.Huang, F.Imbeaux, H.Jia, S.H. Kim, Y.Lausenaz, R.Maggiora, R.Magne, L.Marfisi, D.Milanesio, W.Namkung, L. Pajewski, L.Panaccione, Y.Peysson, A.Saill, G.Schettini, M.Schneider, P.K.Sharma, A.A. Tuccillo, O.Tudisco, G.Vecchi, R.Villari, K.Vulliez, Y.Wu and Q.Zeng

RF Modeling of the ITER-Relevant Lower Hybrid Antenna
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Bends in Oversized Rectangular Waveguide
S. Meschino, S.Ceccuzzi, F.Mirizzi, L.Pajewski, G.Schettini, J.F.Artaud, Y.S.Bae, J.H.Belo, G. Berger-By, J.M.Bernard, A.Cardinali, C.Castaldo, R.Cesario, J.Decker, L.Delpech, A. Ekedahl, J.Garcia, P.Garibaldi, M.Goniche, D.Guilhem, H.Jia, Q.Y.Huang, J.Hillairet, G.T. Hoang, F.Imbeaux,

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Steady State Long Pulse Tokamak Operation using Lower Hybrid Current Drive
A. Bécoulet, G.T. Hoang, J.F. Artaud, Y.S. Bae, J. Belo, G. Berger-By, J.M. Bernard, Ph. Cara, A. Cardinali, C. Castaldo, S. Ceccuzzi, R. Cesario, M. H. Cho, J. Decker, L. Delpech, H. J. Do, A. Ekedahl, J.Garcia, P. Garibaldi, M. Goniche, D. Guilhem, C. Hamlyn-Harris, J. Hillairet, J. Hua, Q.Y. Huang, F. Imbeaux, F. Kazarian, S.H. Kim, Y. Lausenaz, R. Maggiora, R. Magne, L. Marfisi, S. Meschino, D. Milanesio, F. Mirizzi, P. Mollard, W. Namkung, L. Pajewski, L. Panaccione, S. Park, H. Park, Y. Peysson, A. Saille, F. Samaille, G. Schettini, M. Schneider, P.K. Sharma, O. Tudisco, G. Vecchi, S. R. Villari, K. Vulliez, Y. Wu, H.L. Yang and Q. Zeng

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L. Marfis, M.Goniche, C.Hamlyn-Harris, J.Hillairet, J.F.Artaud, Y.S.Bae, J.Belo, G. Berger-By, J.M.Bernard, Ph.Cara, A.Cardinali, C.Castaldo, S.Ceccuzzi, R.Cesario, J. Decker, L.Delpech, A.Ekedahl, J.Garcia, P.Garibaldi, D.Guilhem, G.T.Hoang, H.Jia, Q.Y. Huang, F.Imbeaux, F.Kazarian, S.H.Kim, Y.Lausenaz, R.Maggiora, R.Magne, S. Meschino, D.Milanesio, F.Mirizzi, W.Namkung, L.Pajewski, L.Panaccione, Y.Peysson, A. Saille, G.Schettini, M.Schneider, P.K.Sharma, A.A.Tuccillo, O.Tudisco, G.Vecchi, R. Villari, K.Vulliez, Y.Wu and Q.Zeng

Pre-qualification of Plasma Facing Components of Divertor Target Elements for ITER like Tokamak Application
K.P. Singh, Santosh P. Pandya, S.S. Khirwadkar, Alpesh Patel, Y. Patil, J.J.U.Buch, M.S Khan, Sudhir Tripathi, Shwetang N. Pandya, J. Govindrajan, P.M. Jaman, Devendra Rathore, L. Rangaraj, C. Divakar

Operational Experience on SST-1 NB Test Stand
P. Vatti Palle, L. K. Bansal,U.K. Baruah, P.Bharathi, A.K. Chakraborty, C. Chakrapani, B. Choksi, N. Contractor , L .N. Gupta, M.R. Jana, K. Ojha, B.Pandya, S. L. Parmar, P. J. Patel, V.B. Patel, K. Qureishi, C.B. Sumod, D. Thakkar, V.Tripathi, and V.Vadher

Power Supply Upgrades for Improved Plasma Discharges in Aditya Tokamak
C. N. Gupta and Aditya team

TEXTOR, IPP-Juelich, Germany, 5th October 2010

The SST1-NBI Development and Current Status
Prahlad Vatti Palle

23rd IAEA Fusion Energy Conference, Daejeon, Republic of Korea, 11 - 16 October 2010

First Experimental Results with the ITER-Relevant Lower Hybrid Current Drive Launcher in Tore Supra
A. Ekedahl, J. Achard, C. Balorin, G. Berger-By, E. Corbel, X. Courtois, E. Delmas, L. Delpech, C. Goletto, M. Goniche, D. Guilhem, J. P. Gunn, J. Hillairet, G.T. Hoang, X. Litaudon, R. Magne, P. Mollard, S. Poli, M. Preynas, M. Prou, F. Samaille, B. Saoutic, P. K. Sharma, G. Belo, C. Castaldo, S. Ceccuzzi, R. Cesario, F. Mirizzi, Y. Baranov, K. K. Kirov, J. Mailloux, V. Petrzilka, Y.S. Bae, J. Kim, S. Lee, X. Bai, and X. Ding.

Role of Flow Shear Layer and Edge Plasma Turbulence in Density Limit Physics
R. Singh, P. K. Kaw, M. Tokar, and P. H. Diamond.

Intrinsic Toroidal and Poloidal Flow Generation in the Background of ITG Turbulence
Rameswar Singh, R. Ganesh, P. Kaw, A. Sen, and R. Singh.

Progress in Understanding the Multiscale Analysis of Magnetic Island Inter-acting with Turbulence in Tokamak
O. Agullo, M. Muraglia, T. Voslion, S. Benkadda, Z.O. Guimaraes-Filho, X. Garbet, M. Yagi, A. Sen, F.L. Waelbroeck, I.L. Caldas, I.C. Nascimento, and Y.K. Kuznetsov.

Heat Flux Reduction by Helical Divertor Coils in the Heliotron Fusion Energy Reactor
N. Yanagi, A. Sagara, T. Goto, S. Masuzaki, T. Mito, G. Bansal, Y. Suzuki, Y. Nagayama, K. Nishimura, S. Imagawa, and O. Mitarai.

ITER Test Blanket Module Error Field Simulation Experiments at DIII-D
M.J. Schaffer, J.A. Snipes, P. Gohil, P. De Vries, M.E. Fenstermacher, T.E. Evans, X. Gao, A.M. Garofalo, D.A. Gates, C.M. Greeneld, W.W. Heidbrink, G.J. Kramer, S. Liu, A. Loarte, M.F.F. Nave, N. Oyama, J.K. Park, N. Ramasubramanian, H. Reimerdes, G. Saibene, A. Salmi, K. Shinohara, D.A.Spong, W.M. Solomon, T. Tala, J.A. Boedo, V. Chuyanov, E.J. Doyle, M. Jakubowski, H. Jhang, R.M. Nazikian, V.D. Pustovitov, O. Schmitz, T.H. Osborne, R. Srinivasan, T.S. Taylor, M.R. Wade, K.I. You, L. Zeng, and DIII-D Team.

Overview of High Priority ITER Diagnostic Systems Status
M. Walsh, P. Andrew, R. Barnsley, L. Bertalot, R. Boivin, D. Bora, R. Bouhamou, S. Ciattaglia, A.E. Costley, G. Counsell, M.F. Direz, J.M. Drevon, A. Encheva, T. Fang, G. Janeschitz, D. Johnson, J. Kim, Y. Kusama, H.G. Lee, F. Le Guern, B. Levesy, A. Martin, R. Reichle, K. Patel, C.S. Pitcher, A. Prakash, S. Simrock, N. Taylor, D. Thomas, V.S. Udintsev, Y. Utin, P. Vasu, G. Vayakis, E. Veshchev, C. Walker, and A. Zvonkov.

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M.A. Henderson, F. Albajar, S. Alberti, U. Baruah, T. Bigelow, B. Becket, R. Bertizzolo, T. Bonicelli, A. Bruschi, J. Caughman, R. Chavan, S. Cirant, A. Collazos, C. Cox, C. Darbos, M. de Baar, G. Denisov, D. Farina, F. Gandini, T. Gassman, T.P. Goodman, R. Heidinger, J.P. Hogge, S. Illy, O. Jean, J. Jin, K. Kajiwara, W. Kasparek, A. Kasugai, S. Kern, N. Kobayashi, H. Kumric, J.D. Landis, A. Moro, C. Nazare, Y. Oda, T. Omori, I. Paganakis, B. Piosczyk, P. Platania, B. Plaum, E. Poli, L. Porte, D. Purohit, G. Ramponi, T. Rzesnicki, S. Rao, D. Rasmussen, D. Ronden, G. Saibene, K. Sakamoto, F. Sanchez, T. Scherer, M. Shapiro, C. Sozzi, P. Spaeh, D. Strauss, O. Sauter, K. Takahashi, A.Tanga, R. Temkin, M. Thumm, M.Q. Tran, V.S. Udintsev, H. Zohm, and C. Zucca.

TSC Modelling of Major Disruption and VDE Events in NSTX and ASDEX-
Upgrade and Predictions for ITER
I. Bandyopadhyay, S. Gerhardt, S.C. Jardin, R.O. Sayer, Y. Nakamura, S. Miyamoto, G. Pautasso, M. Sugihara, and ASDEX Upgrade and NSTX Teams.

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Conceptual Design of Large Cryoline for Fusion Reactor
S. Badgujar, H. Naik and B. Sarkar

Design Approach of Seismic Interface for Cryoline with Tokamak Building for ITER
S. Badgujar, B. Sarkar, H. Vaghela, N. Shah and H. Naik

Detailed Design of Control System for Prototype Cryoline Test
R. Bhattacharya, S. Muralidhara, N. Shah, S. Badgujar and B. Sarkar

Experiences during Fabrication, Assembly and Preliminary Cooldown of Prototype Thermal Shield for ITER Cryoline
H. Vaghela, R. Bhattacharya, N. Shah, , K. Choukekar, S. Badgujar, P. Patel, S. Muralidhara, and B. Sarkar

Reliability and Functional Testing Scheme for Cold Circulating Pumps Required to Cool Large Size Fusion Grade Superconducting Magnets and Cryopumps
H. Vaghela, R. Bhattacharya, B. Sarkar, S. Badgujar and N. Shah

Thermo-hydraulic Analysis of a LTS Current Feeders System for SST-1
N. Bairagi, N.C. Gupta and V.L. Tanna

Development of SCADA System for Testing of 10KA Vapour Cooled Current Leads for SST-1
R.Patel, G. Mahesuria, R.Panchal, D.Sonara, P. Panchal, N.C.Gupta, A.N.Sharma, V.L.Tanna and S. Pradhan

Steady State Operation of 10 kA Vapor Cooled Conventional Current Leads during TF Coil Test
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52nd Annual Meeting of the APS Division of Plasma Physics, Chicago, USA, 8–12 November 2010

ITER ECE in Situ Prototype Calibration Source and its Integration into the ITER ECE Diagnostic
P.E. Phillips, M.E. Austin, W.L. Rowan, J. Beno, A. Ouroua, R.F. Ellis and H.K.B. Pandya

Electron Cyclotron Emission Diagnostics on ITER
Richard Ellis, Max Austin, Perry Phillips, William Rowan, Joseph Beno, Abelhamid Au-
Roua, Russell Feder, Ashish Patel, Amanda Hubbard and Hitesh Pandya

LVPD Plasma for Studies on ETG Turbulence
L.M. Awasthi, S. K. Singh, P. K. Srivastava, U. Dhobi, R. Singh, S. K. Mattoo and P. K. Kaw

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Use of Plasma in Textiles
S. K. Nema

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Design and Overview of 100 kV Bushing for the DNB Injector of ITER
Sejal Shah, S. Rajesh, S. Nishad, B. Srusti, M. Bandyopadhyay, C. Rotti, M. J. Singh, G. Roopesh, A. K. Chakraborty, B. Schunke, R. Hemsworth, J. Chareyre, L. Svensson

RF - Plasma Source Commissioning in Indian Negative Ion Facility
M.J. Singh, M. Bandyopadhyay, G. Bansal, A. Gehlaut, J. Soni, Sunil Kumar, K. Pandya, K.G. Parmar, J. Sonara, Ratnakar Yadava, A.K. Chakraborty

Cesium Delivery System for Negative Ion Source at IPR
G. Bansal, K. Pandya, M. Bandyopadhyay, A. Chakraborty, M.J.Singh, J. Soni,
A. Gahlaut, K.G. Parmar

Conceptual Design, Implementation and Commissioning of Data Acquisition and Control System for Negative Ion Source at IPR
Jignesh Soni, Ratnakar Yadav, A. Gahlaut, G. Bansal, M. Bandyopadhyay, M.J.Singh, K G Parmar, K. Pandya, A. Chakraborty

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Engineering Design of DNB Beamline Components
C. Rotti

DNB - Status Update
Arun Chakraborty

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The Resonance Hairpin Probe- Concept, Theory and Application in Magnetized Plasma
G. S. Gogna and S. K. Karkari (**Buti Award**)

Development of a Segmented Plasma Torch Assisted Tailored Heat Source for Performance Evaluation of Plasma Facing Components in Fusion Devices
M. Kakati, B. Bora, N. Aomoa, P. M. Raole and S. Khirwadkar (**Sholapurwala Award**)

Programming Testing and Integration of New ADC Module (IP-330) for SST-1 Coil Power Supply Control System
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Plasma Response to Transient High Voltage Pulse
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Plasma Physics Experiments for M.Sc. Physics – UGC syllabus
J. Alphonsa, R. Rane, G. Ravi, N. Chandwani, S. Mukherjee, A. Satyaprasad, C. Jariwala, A. Vaid, P. M. Raole, S. Gupta, C. Balasubramanian

Electron Injection Studies in Toroidal Non- Neutral Plasma Device
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Binary Coulomb Collision in Plasma using Monte Carlo Method
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Characterization of DC Glow Discharge Plasma for Boroniztion Experiment
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Self Consistent Relationship between Observed Fluctuations and Density Profile in Simple Magnetized Torus
R. Kaur and S. K. Mattoo

Nonlinear Lower Hybrid Oscillations in Cold Plasma
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Design and Manufacturing of Prototype Hot Tungsten Plate Based Ionizer for Cesium Plasma in a Multi-Cusp Field Experiment
Gandhi J. C., Prajapathi Chirag, Bedakihale Vijay, Ramasubramanian N. and Saxena Y. C.

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

Breaking of Nonlinear Oscillations and Waves in Cold Plasma
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Excitation of Nonlinear Wakefields by an Intense Ultra Relativistic Positron Beam
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Dynamics of Current Spots Observed in a Planar Glow Discharge Plasma
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Nanomotor Based on a Double Walled Carbon Nanotube: A Molecular Dynamics Study
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Vacuum Acceleration of Charged Particle in an Relativistically Intense Ultra Short Laser Pulse
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Status of Resources for ITER Ion Cyclotron Heating & Current Drive System
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Design of Direct Coupled 125kW RF Amplifier for ITER ICRF Source
Raghuraj Singh, Ajesh P, R. G. Trivedi, Kumar Rajnish, Harsha Machchhar, Gajendra Suthar, Dipal, Patadia Manoj Patel and Aparajita Mukherjee

Phase Detection Module for ICH & CD System
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Development of Local Control Unit for ITER R & D Source
Kumar Rajnish, R. G. Trivedi, Manoj A. Patel, Raghuraj Singh, Harsha Machchhar, Gajendra Suthar, P. Ajesh and Aparajta Mukherjee

Integrated Test of Low Power System for R & D ICRF Source
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Development of Frequency Measurement Module for R & D ICRF Source
Manoj Patel, Harsha Machchhar, R. G. Trivedi, Raghuraj Singh, Kumar Ranjish, Ajesh P., Gajendra Suthar, Dipal Patadia and Aparajta Mukherjee

Auxiliary Power Supplies for ITER R & D Sources
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Parameter optimization of the Washer Gun Plasma of SYMPLE
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Design and Development of a PEN for the Washer-Gun in SYMPLE
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Possible Excitation of Solitary Electron Holes (EHs) in a Laboratory Plasma
S. Kar, S. Mukherjee, G. Ravi and Y. C. Saxena

Development of Penning Discharge Source for Establishment of a Calibration Technique for VUV Spectrometer- Detector System
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Mechanism for Scavenging Energetic Electrons and Exerting Control on Electron Temperature Gradient of LVPD Plasma
S. K. Singh, P. K. Srivastava, L. M. Awasthi, R. Singh, S. K. Mattoo and P. K. Kaw

Theoretical Investigation of Coupled Whistler- Electron Temperature Gradient Turbulence in High Beta Plasma
S. K. Singh, L. M. Awasthi, R. Singh, S. K. Mattoo and P. K. Kaw

Plasma for Studying Electron Temperature Gradient Driven Turbulence in LVPD
L. M. Awasthi, S. K. Singh, P. K. Srivastava, U. Dhobi, R. Singh, S. K. Mattoo and P. K. Kaw

Impact of Anode Glow on the Properties of a Constricted Hollow Anode Plasma Source
S. K. Karkari, M.A. Mujawar and M. Turner

Numerical Solution of KdV Partial Different Equation using Genetic Algorithm
Dilip P. Ahalpara and Abhijit Sen

Theory of Current Free Double Layers in Electronegative Plasma
N. K.Deka, P.J. Bhuyan and K. S. Goswami

Behavior of Flow Velocities of Ions in Magnetized Two Ion-Species Plasma
Bomali Sharma and Devendra Sharma

Numerical Modeling of Edge Plasma in the Presence of Secondary Electrons
K. Saharia, K. S. Goswami, D. Sharma and P. K. Kaw

Effect of Anode Area on Electron Temperature near a Magnetic Filter Field
B. K. Das, M. Chakraborty and M. Bandyopadhyay

Effect of Magnetic Filter on Diffused Plasma and Sheath Structure
B. K. Das, M. Chakraborty and M. Bandyopadhyay

Measurement of Absolute Neutron Yield of D –T Neutron Generator Using Foil Activation
Shrichand Jakhar, Mitul Abhangi, C. V. S. Rao and T. K. Basu

Studies of Plasma Flows in Scrape-Off Layer (SOL) of Aditya Tokamak
Deepak Sangwan, M. V. Gopalkrishna and Ratneshwar Jha

Effect of Ion Beam Irradiation on PL Deposited Tungsten Films
A. T. T. Mostako, Mitul Abhangi, Rajnikant Parmar, Sudhirsinh Vala, Shrichand Jhakhar, C. V. S. Rao, T. K. Vasu and Alika Khare

Fiber Bragg Grating (FBG) Sensors for Fusion Technology Applications
B. Ramesh Kumar, Karthika Chandran

Synthesis and Characterization of Li2TiO3 Powders by Sol-Gel Method
Sanjeev Kumar, S. K. Sinha and P. M. Raole

High Voltage Conditioning of Neutral Beam Injector Power Supply System
L. N. Gupta, N. P. Singh, Vibhu Tripathi, Dippal Thakkar, Kapil Oza, Vishnu Patel and U. K. Baruah

Aditya Grounding Scheme and Troubleshooting During Fault
M. B. Kalal, D. S. Varia, Deepak Sangwan, Pravesh Dhyani, P. K. Chattopadhyay, R. Jha, K. Satyanarayana, S. B. Bhatt, Nirav Mecwan, Kumarpal Jadeja, Amita Prajapati, Bharat Kumar and Aditya Team

Design of USB-CAN Converter Electronics
Hitesh Mandaliya, Pramila and Rachna Rajpal

Development of Signal Conditioning System for the Thermal Diagnostics in Neutral Beam Injector for SST-1
Karishma Kureshi, L. K. Bansal, P. Bharathi, U. K. Baruah, V. Patel, P. Vatti Palle and NBI Team

Core-Ion Temperature Estimation of Aditya Tokamak Using Charge Exchange Neutral Particle Analyzer (NPA)
Kumar Ajay, Santosh P. Pandya, Priyanka Mishra and J. Govidarajan

Neutron Irradiation Study of Lithium Titanate Pebbles for Blanket Application of Fusion Reactor
S. K. Sinha, Sanjeev Kumar, Srichand Jhakhar, C. V. S. Rao and P. M. Raole

Characterization of Fusion Debris on Tokamak Window and the Development of an Automated Set up for cleaning the Window
S. Sasanka Kumar, M. K. Jayaraj, Ajai Kumar and Ravi A. V. Kumar

Swept Frequency Reflectometer to Measure the Redial Profile of Plasma Density in Aditya Tokamak
Varsha Siju, P. K. Atrey, Praveen Shukla and Surya K. Pathak

Construction of High Voltage Pulse Generator for Aditya Tokamak Coil Insulation Test
D. S. Varia, M. B. Kalal, Deepak Sangwan, Pravesh Dhyani, P, K, Chattopadhyay, R. Jha, K. Satyanarayana, S. B. Bhatt, Nirav Mecwan, Kumarpal Jadeja, Amit Prajapati, Bharat Kumar and Aditya Team

Frequency Measurement Concept for 170 GHz Gyrotron at ITER-India Test Facility
Vipal Rathod, Ronak Shah, S. L. Rao, Mahesh Kushwah, Anjali Sharma, Deepak Mandge and Gaurav Joshi

RAMI Analysis of ITER EC H & CD System
Mahesh Kushwah, Vipal Rathod, R. G. Trivedi, D. Van Houtte, F. Sagot and Okayama K.

PLC Based Sequence Control System for Gyrotron Source of ITER-India Test Facility
Vipal Rathod, Deepak Mandge, S. L. Rao, Mahesh Kushwah, Ronak Shah, Anjali Sharma and Gaurav Joshi

Design and Thermal Analysis of Bending Magnet Coils
Sudhirsinh Vala, Mitul Abhangi, Manu Bajpai, Mukti Ranjan Jana and C. V. S. Rao

Anchor Bolt Design of ITER-Cryostat Support System
Vipul More, Girish Gupta, Jagrut Bhavsar and Anil Bhardwaj

Fabrication and Welding of PF#4,5 Super Conducting Magnet Joint Boxes in SST-1
S. J. Jadeja U. Prasad, A. N. Sharma and S. Pradhan

Study of Residual Stresses deformation and Heat Affected Zone of ITER Cryostat Circumferential Field Joint
Mukesh Jindal, Rajanikant Prajapati and Anil Bhardwaj

Conceptual Design of Auxiliary Power Supplies for 170 GHz Gyrotron
Mahesh Kushwah, S. L. Rao, Vipal Rathod, Gaurav Joshi, Ronak Shah, Anjali Sharma and Deepak Mandge

Absolute Measurement of 14 MeV D-T Neutron Generator Yield using Water Activation Analysis
Saheb Hussain Md, Srichand Jakhar, Mitul Abhangi, Rajnikant Makwana, Sudhirsinh Vala, C. V. S. Rao, A. Gopala Krishna and T. K. Basu

Manufacturing and Assembly Study of ITER- Cryostat
Girish Gupta, Vipul More, Rajnikant Prajapati, Jagrut Bhavsar, Mukesh Jindal and Anil Bhardwaj

Thermal and Structural Analysis of ITER-Cryostat
Anil Bhardwaj, G. Gupta, Vipul More and Jagrut Vyas

Advance Cutting and Welding Technologies for Fusion Reactor Vacuum Vessel Fabrication
B. Ramesh Kumar and R. Gangradey

Study of Steaming and Leakage Neutron Effects on Vacuum Vessel in ITER like Conditions
S. Jakhar, Mitul Abhangi, B. Ramesh Kumar, C. V. S. Rao, T. K. Basu and R. Gangradey

Present Status of the COMPASS Tokamak
R. Panek, J. Brotankova, M. Hron, J. Stockel, V. Weinzettl, J. Ghosh and the COMPASS Team

Initial Studies of Neutron and X-Ray Emission from Low Energy Plasma Focus Device
N. Talukar, T. K. Borthakur and N. K. Neog

High Power CW Test of 82.6 GHz Gyrotron
B. K. Shukla, Mahesh Kushwah, Rajan Babu, Jatin Patel, K. Sathyanarayana, S. Laxmikant Rao, Pragnesh Dhorajiya, Harshida Patel, Sunil Belsare, Vipal Rathod, Satish D. Patel, Vishal Bhavsar, Priyanka A. Solanki, Anjali Sharma and Ronak Shah

Testing and Commissioning of Solid State Anode Modulator Power Supply for 82.6 GHz Gyrotron System
N. Rajan Babu, B. K. Shukla, K. Sathynarayana, Sunil Belsare, Pragnesh B. Dhorajiya, Jatin Patel and Harshida R. Patel

Development of Crowbar Firing Card for Ignitron-Crowbar System
Harshida Patel D. Purohit, B. K. Shukla, Jatin Patel, K. Sathyanarayana, Pragnesh Dhorajiya, Rajan Babu, Sunil Belsare, Satish Patel and Vishal Bhavsar

Operation and Maintenance Experience on Utility Power Distribution for Aditya and SST-1 Tokamaks
A. R. Chavda, V. Balakrishnan, H. D. Parekh

110 W @ 3.8 K Cryo Plant Operation for 1.7 MW NBI Cryopumps
V. B. Patel, Chakrapani, B. Sridhar, B. Choksi, Nilesh, D. Thakkar, L. N. Gupta, A. Chakraboty, V. Prahlad, U. K. Baruah and NBI Team

Application of Sweep Frequency Response Analysis (SFRA) to Evaluate Mechanical Integrity of Transformer
Chandra Kishor Gupta & SST-1 Power System Division

Design and Development of 10 kA High TC Super conducting Current Leads
A. Amardas

Influence of Pulsed DC Glow Discharge Plasma Nitriding Process on the AISI 1045 and AISI 4140 Steels
Abhishek Sharma, P. Rayjada, K. Sachdev, Alphonsa J., P. M. Raole and K. C. Swami

Study of Corrosion Properties of Pulsed DC Glow Discharge Plasma Nitrided AISI D3 Steel
Abhishek Sharma, Shubhra Mathur, P. Rayjada, K. Sachdev, Alphonsa J. P. M. Raole, S. K. Sharma and K. C. Swami

Molybdenum Oxides Thin Films via PLD
A. T. T. Mostako, Partha Dey, Himanshu S. Jha, Mukesh Singh, Pratima Agarwal and Aloka Khare

Development of Al-Carbon Bi-Layer PVD Coating and its Characterization
P. A. Rayjada, P. A. Nayak, N. L. Chauhan, N. P. Vaghela, P. M. Raole, S. P. Pandya, S. N. Pandya and J. Govindrajan

Deposition and Qualification of Plasma Assisted IN-SITU Tungsten Coating for Fusion Reactors
A. K. Sanyasi, H. G. Esser and V. Philips

Study of Effects of Cathode Geometry and Process Pressure for Achievement of High Deposition Rate of Hydrogenated Silicon (Si:H) Thin Film by VHF-PECVD
C. Jariwala, P. Vasu, A. Chainani, V. Dalal and P. I. John

Surface Modification of Polypropylene Woven Fabric by Dielectric Barrier Discharge
Nisha Chandwani, N. Chauhan, Purvi Kikani and S. K. Nema

High Power Microwave Generation from an Axially Extracted Virtual Cathode Oscillator Powered by AMBICA-600
Rishi Verma, Tushar Patel, A Shyam and Y. C. Saxena

Deposition and Characterization of Silicon Oxynitride Coating by Plasma Enhanced Chemical Vapour Deposition as a Protective Layer for Nickel Surface
P. Kikani, C. Jariwala, N. Chauhan, A. Chainani, S. K. Nema and P. I. John

Studies on Proton Emission from a Plasma Focus Device and its Application on Material Modification
M. Bhuyan, N. K. Neog, S. R. Mohanty, C. V. S. Rao and P. M. Raole

Synthesis of Nanostructured Carbon with improved Crystallinity by a Supersonic Thermal Plasma Expansion Technique
N. Aomoa and M. Kakati

Characteristics of an ICP RF Plasma Torch Operating in Atmospheric Pressures
P. J. Bhujan and K. S. Goswami

SST-1 Vacuum Modules and its Temperature Measurement Employing Thermocouples
M. Zeeshan, G. R. Babu, A. B. Darshan and I. A. Ansari

Spacecraft Plasma Interaction Experiments (SPIX-II)
Suryakant Gupta, Keena Kalaria, Naresh Vaghela, Hiren Bhat, S. Mukherjee, E. P. Suresh, M. Sudhakar, R. Ekkundi and G. Venketshwarulu

Pulsed Laser deposited ruby Thin Film as Temperature Sensor
Satchi Kumari and Alika Khare

Ion Acceleration by Relativistic Laser Pulses
Ujjawal Sinha, Sudip Sengupta and P. K. Kaw

Experimental Studies on DC Discharge Dusty (Complex) Plasmas
Manjit Kaur, A. Sharma, J. Ghosh, P. K. Chattopadhyay

Effect of Confining Wall Potential on Charging of Dust grains
B. Kakati, S. S. Kausik, B. K. Saikia and M. Bandyopadhyay

Theoretical Study of Sheath Structure in Electro Negative Dusty Plasma
N. K. Deka, P. J. Bhuyan and K. S. Goswami

Development of Glow Detector System for ADITYA Tokamak
B. N. Darji, K. A. Jadeja, Amit Prajapati, Prakash Bawankar and S. B. Bhatt

Automation of Anode Operation for Glow Discharge Cleaning in ADITYA Tokamak
Prakash S. Bawankar, K. A. Jadeja, Bharat Darji, Amit Prajapatia and S. B. Bhatt

Visible Emission Spectroscopy Diagnostics of Metal Halide HID lamp
B. Ramesh Kumar and M. B. Chowdhuri

Determination of Spatial Variation of the Foil Parameters used as Radiation Absorbing Element in Infrared Imaging Video Bolometer
Santosh P. Pandya, Nabarun Dev, Shwetang N. Pandya and J. Govindarajan

Magnetic Field Measurement using B Probes
Sayak Bose, Manjit Kaur, Kashitish Barada, Payal Mehta, Pravesh Dhyani, Ketan M. Patel, H. Nimawat, N. Chanchpara, J. Ghosh, P. K. Chattopadhyay and Ravindranath Pal

Design and Development of High Temperature Black Body Source for ECE Radiometry in Tokamak Plasmas
S. K. Pathak, V. Subramaniam, Varsha Siju and P. K. Atrey

VUV Spectra from Adutya Tokamak Plasma and its Application to Estimation of Electron Temperature
R. Manchanda, M. B. Chowdhuri, J. Ghosh, S. Banerjee, K. M. Patel, Vinay Kumar, P. Vasu and Aditya Team

5KA Pulsed Power Supply for Inductive Load and Plasma Discharge in LVPD
P. K. Srivastava, S. K. Singh, L. M. Awasthi and S. K. Mattoo

Revisiting Plasma Hysteresis with an Electronically Compensated Langmuir Probe
P. K. Srivasatva, S. K. Singh, L. M. Awasthi and S. K. Mattoo

Opacity Effect on Photon Emissivity Coefficients (PECs) of Neutral Helium Line Emissions and its Impact on Line Ratios
Jalaj Jain, Gheesa Lal Vyas, Ravindra Kumar, R. Manchanda and Ram Prakash

On Doppler Shift Spectroscopy Diagnostics in SST-1 NBI Test Stand
B. Choksi, P. Bharathi, V. Prahlad, N. S. Contractor Ch. Chakrapani, Vishnu Patel, L. N. Gupta, S. L Parmar, Dipal Thakkar, Paresh J. Patel, Vibhu Tripathi, M. R. Jana and Ujjwal K. Baruah

Measurement of Plasma Parameters by Langmuir Probe and Spectroscopic Diagnostics in a Novel Plasma System
Ashish Patel, Santanu Banerjee, Joydeep Ghosh, Probal Chattopadhaya, Nilam Ramaiya, Supin Gopi, Payal Mehta and Arun Sharma

Development of GUI Based Data Plotting Utilities for SST-1 Data Acquisition Integrated Testing
Imran Mansuri, Amit Kumar Srivastava and Subrata Pradhan

Development of Measurement and Data Acquisition Technique for High Temperature Sensors to be used in SST-1 Tokamak
Gattu Ramesh Babu, Ziauddin Khan, Firozkhan Pathan, Yuvakiran Paravastu, Siju George, Arvind Chawda, Himabindu M., Pratibha Senwal, Kalpesh Dhanani, D. C. Raval, Prashant Thankey and Subrata Pradhan

Understanding the Temperature and Current Profile of Laser Heated Emissive Probe Materials
Arun Sharma, Payal Mehta, Joydeep Ghosh, Shwetang Pandya, Santosh Pandya, Paritosh Choudhuri and J. Govindarajan

Influence of Secondary Gas on Control Characteristics of ICP-RF Plasma
P J Bhuyan, R Moulick and K S Goswami

Effect of Magnetic Cage Biasing Potential on Dust Charging
B. Kakati, S.S. Kausik, B.K. Saikia and M. Bandyopadhyay

National Welding Seminar-2010 (NWS-2010), Indian Institute of Welding(IIW), Vishakhapatnam Steel Plant, Vishakhapatnam, 21-23 December-2010

Testing of SS 304 TIG Weld Samples for Fusion Reactor Fabrication Technologies
B. Ramesh Kumar

Acoustic Emission Characterization Techniques for Welding Materials: An Overview
S.V. Ranganayakulu, B.Ramesh Kumar

Estimation of Residual Stresses in Welded Parts: A Design Requirement
Suresh Akella, M.V.Ramana, Ramesh Kumar Buddu, Y.Krishnaiah

55th DAE Solid State Physics Symposium 2010, Manipal, India, 26–30 December 2010

Impact of Bending Strain on Critical Current of Second Generation 344 YBCO High Tc Coated Conductor
Ananya Kundu, Piyush Raj, and Subrata Pradhan

Lowering the Sintering Temperature of MgB2/Fe Wires with High Transport Current by Nano Cu Doping
Neson Varghese, K. Vinod, S. Rahul, K. M. Devadas, Syju Thomas, P. M. Aswathy, S. Pradhan, and U. Syamaprasad

Takniki Evam Vygyanik Jagrukta Hetu Hindi Ke Upyog Par Rashtriya Sammelan, Plasma Anusandhan Sansthan (IPR), Gandhinagar, January 27-28, 2011

Antarashtriya Taapnabhikiya Prayogik Reactor (ITER) Sanyukt Prayas Me Bharat Ki Hissedari
Ratneshwar Jha

Jaiv Chikitsa Labh Ke Liye Plasma Takniki Ka Anuprayog
S K Nema, V. Jain

SST-1 Punarnirman / Punarsanyojan Ki Sthiti
Subrat Pradhan, Evam SST-1 Mission Team

Bharat Me Nabhikiya Urja- Itihas Ke Darpan Me
Tejenkumar Basu

Cryogenic (Atishitalan) Surksha
Nareshchandra Gupta

10 KA Uccha Tapman Suchalak Dhara Dandika Ka Design Aur Vikas
A. Amardas

Cryogenic Se Judi Chunautiya
Nitin Bairagi

SST-1 NBI Ke Liye Tapyugm Dwara Punj Shakti Ka Mapan
L K Bansal, K Qureshi, P J Patel, L M Gupta, Kapil, B K Patel, D Thakkar, C B Sumod, P Bharati, U K Barua

ITER-Cryostate Ka Tapiya Aur Sanrachantmak Vishleshan
Anil Bhardwaj, Girish Gupta, Vipul More, Rajanikant Prajapati, Mukesh Jindal, Aavik Bhattacharya Aur Jagrut Bhavsar

Chumbakiya Plasma Me Asthayitva Ki Vivechana
R K Chhajlani Evam R P Prajapati

SST-1 Anaveshit Punj Kshepan Pranali Ke Liye Gas Poorti Pranali
B Choksi, S K Sharma, Brijesh Prajapati, V B Patel, L K Bansal, V Prahlad, P Bharati, N S Contractor, Swapnil Parmar, S N Parmar, C Chakrapani, S Shridhar, U K Baruah

Anaaveshit Punj Shepan Pranali Ke Prakash Sangrahak Ke Liye Nirvat Abhediya Pravesh Dwar Evam Avamlab Sanrachna Ka Nirman
Nilesh Contractor, B Choksi, C Chakrapani, P Bharati, V Prahlad, U K Baruah

ITER Ushma Utsarjan Pranalee Ki Abhinavrachna
Jinendra Dangi, Hiren Patel, Dinesh Gupta, Nirav Patel, Ajith Kumar, Gumansingh Gohil, Mahesh Jadhav, Lalit Sharma (Won First Prize Award)

Transformer Ki Yantriki Akhandta Ka Mulyankan Karne Ke Liye Sweep Aavruti Vyvahar Vishleshan Ka Upayog
Chandrakishore Gupta Evam SST-1 Vidyut Pranali Vibhag

ITER Cryostat Ke Nirman Aur Sanyojan Ka Adhyayan
Girish Gupta, Mukesh Jindal, Rajnikant Prajapati, Jagrut Bhavsar, Vipul More, Aavik Bhattacharya Aur Anil Bhardwaj

SST-1 Anaaveshit Punj Shepan Pranali
(SST-1 NBI SYSTEM)- Ek Parichay
Lakshminarayan Gupta

Prashitanee / Tusharjanik (Cryogenic)- Ek Sankshipt Parichay
Manojkumar Gupta

Helium Vashp Sheelit Dhara Dandika: Prayog Evam Anubhav
Nareshchandra Gupta

Vayumandal Me Adbhut Prakashiya Ghatnayen
Pratibha Gupta

SST-1 Chumbak Ke Liye Gunvatta Aashvasan Aur Gunavatta Niyantran
Pratibha Gupta Evam SST-1 Chumbak Vibhag

Dielectric Barrier Discharge Prakriya Dwara Petrochemicals Udyog Me Nikalane Wali Jahrili Gason Ka Vayumandaliy Surakshit Gason Me Vighatan
V Jain, V Chauhan, S K Nema, P.I. John

ITER Cryostat Mukhy Paridhiya Jod
Mukesh Jindal, Rajnikant Prajapati, Girish Gupta, Vipul More, Aavik Bhattacharya Aur Anil Bhardwaj

Plasma Nitriding- Ek Paryavaran Ke Anukool Prakriya
Alphonsa Josheph, Ghanshyam Jhala, Vidya Nair, Suryakant Gupta, Keena Kalaria, Naresh Vaghela, S Mukherjee

Automatic Matching Network Karya Pranali
Ramesh Joshi

Uccha Taap Pravaah Vyavastha Ka Vikas Plasma Fencing Upkarno Ki Jaanch Hetu
Mohmmad Shoiab Khan, K Raj Mannar Swami, Sameer S Khirwadkar, Sunil Belsare

Vaigyanik Soochna Sanchar Me Pahchankartao (Identifiers) Ki Bhoomika
Shilpa Khandker

Nyun-Urja Udaan-Kaal Vishleshan (TOFLEA) Takniki Dwara Aditya Plasma Ke Aayan-Taap Ka Nirdharan
Kumar Ajay, Priyanka Mishra, Santosh P Pandya, Evam J.Govindarajan

Electron Plasma Prayog Ke Liye Uccha Vidyut Pravah Aur Vidyut Dabaav Pranali
Hitesh Mandaliya, Minsha Shah, Rachna Rajpal, D Chenna Reddy, Karan, Sambaran Pahari Aur Jignesh Patel

Aditya Tokamak Me Aavesh-Vinimay Nidan Tantra: Ek Parichay
Priyanka Mishra, Santosh Pandya, Kumar Ajay Evam J Govindarajan

Plasma Anusandhan Sansthan Me Plasma Tvarak Prayog
Mohandas K K, Ravi A V Kumar

ITER Cryostat Ke Langar Bolt Ki Rachana
Vipul More, Girish Gupta, Rajnikant Prajapati, Jagrut Bhavsar, Mukesh Jindal, Aavik Bhattacharya Aur Anil Bhardwaj

Plasma Stah Abhiyantriki
S Mukherjee

Taral Helium Shitalan SST-1 Ke Liye Helium Punahprapti Sanyantra Ki Navinatam Niyantran Pranaali
R Panchal, Manoj Singh Evam V.L. Tanna

Aditya Seemak Ka Tapiya Alekhan
Santosh P Pandya, Shwetang N Pandya, J Govindarajan, Kumar Jadeja Aur S B Bhatt

Parmanu Urja Ke Shantipurna Upyog
Anita Patel

"Viniyamit Ucch Vijdab Aapoorak" (RHVPS)
Paresh Patel, C B Subod, Dipal Thakkar, L N Gupta, V B Patel, V Vadher, L K Bansal, K Qureshi, Kush Mehta, Kalpvikalp Patel, Niranjanpuri Goswami, Chirag Patel, Ankit Jhala, Mukesh Devare, Kapil Ojha, N P Singh, Suryakant Gupta, Ujjwal Baruah

SST1 NBI Data Adhigrahan Aur Niyantran Pranaali
V B Patel, Paresh Patel, V Vadher, K Qureshi, D Thakkar, L N Gupta, N P Sinha, V Prahlad Aur U K Baruah

Microwave Nidan Ke Liye SST-1 Ka Electronics System
Pramila, Rachna Rajpal, S K Pathak, P K Atrey

Satat Sthiti Atichalak Tokamak Ke Chouthi Evam Panchvi Poloidal Kshetra Vidyut Chumbak Ke Jod Bakse Ki Nirman Evam Welding Takniki
Upendra Prasad, S J Jadeja, S Pradhan, M Prajapati, P Jaisawal Evam P Gupta

SST-1 Vidyut Chumbakiya Nidan Electronics Me CAN Network Ke Sath Door Se Parameter Ke Niyantran Ke Liye Pahle Pravardhak Ka Naya Abhikalpan Aur Vikas
Praveenlal E V, C J Hansalia, Rachna Rajpal, Electronics Group, Sameer Kumar, S Raju Aur R Jha

NBI Sahayak Yojana Ke Signal Mapan Evam Niyantran Karne Ke Liye Optical Isolation Card Ka Vikas
Karishma Qureshi, P J Patel, L K Bansal, V B Patel, C B Sumod, V Vadher, L N Gupta, D Thakkar, Brijesh Prajapati, Sanjay Parmar Evam U K Baruah

Plasma Ayano Ke Dwara Gasb Ki Satah Pa Bane Nano Bindu Sangrah Par Chandi Ke Nano Kano Ka Svatah Sangrahit Hona
Mukesh Ranjan, Stiphen Fasko

Neutron Sanbandhi Adhyayan Ke Liye Plasma Anusandhan Sansthan Me Uplabdh Suvidhaye
C V S Rao, Tejen Kumar Basu , Shrichand Jakhad, Sudheer Singh Vala, Mitul Abhangee Tatha Rajnikant Makwana

Ksh- Kiran Vivartan- Ek Dravya Lakshnikta Nirdharan Taknik
P A Rayjada

SST-1 Me Spectroscopy Nidaniki Ke Liye Electronics Ka Abhikalpan Evam Vikas
Minsha Shah, C J Hansaliya, Rachna Rajpal, Hitesh Mandliya Evam Samast Electronics Vibhag

ITER Bharat Ghatak Sheetlakjal Pranaali (Gh..Shee..Ja.. Pra..), Sheetal Jal Pranaali (Sheet.Ja.Pra.), Ushma Utsarjan Pranaalee (U. Uts. Pra.)
Lalitkumar Sharma, Ajitkumar, Dinesh Gupta, Nirav Patel, Guman Gohil, Jinendra Dangi, Hiren Patel, Mahesh A Jadhav

Jaiv Prerit Parnikaon Dwara Pranodan
Prabhat Kumar Sharma (Prob Diagnostic Vibhag)

Manav Rahit Viman: Vigat Karya Ev Navin Vichar
Prabhat Kumar Sharma

Atisuchalak Sanlayan Chumbak Ke Insulator Sanyantra Par Vikiran Prabhav
Rajiv Sharma

Nabhakiya Sanlayan- Ek Nai Disha Bhavishya Urja Srot Ki Or, Atisuchalak Chumbak Tokamak Sanlayan Machine
Rajiv Sharma

SST-1 – Jal Sheetalan Pranaali
Prashant Singh, S K Sharma, Y Trivedi, Manish Vasani, Evam D. Chenna Reddy

SST –1 Machine Ki T F R Power Supply Ke Liye Niyantran Evam Data Adhigrahan Pranaali
Akhileshkumar Singh, Dinesh Kumar Sharma, Murtaza M Vora, Kirti Mahajan, Harish Masand, Aavegkumar, Manisha Bhandarkar, Hitesh Chudasama Aur SST-1 Viddhut Pranaali Prabhag

1.3 KW, 4.5 K Helium Refrigerator/ Liquid Sanyantra Ke Liye, Uccha Kshamta, 315KW Low Voltage, Preran Motor Ka Punahnirman
Manoj Singh, J C Patel, D Christian, R Panchal, R Patel, Ketan Patel Evam V L Tanna

Antarashtriya Naabhikiya Taapan Ki Prayogatmak Bhatti Hetu Ion Cyclotron Radio Aavruti Sroto Ka Sankshipt Parichay
Raghuraj Singh, G Trivedi, Harsha Macchar, Dipal Patadiya, Ajesh P. Gajendra Suthar, Manoj Patel Evam Aparajita Mukherjee

Switched Power Module (SPM): "Viniyamit Uccha Vijdab Aapoorak" (RHVPS) Ka Abhinn Ghatak
C B Sumod, Paresh Patel, Dipal Thakkar, L N Gupta, Vishnu Patel, L K Bansal, Karishma Qureshi, Vijay Vadher, Kush Mehta, Kalvikalp Patel, Niranjanpuri Goswami, Chirag Patel, Ankit Jhala, Mukesh Devare, Kapil Ojha, N P Singh, Ujjwal Baruah

Cryogenic Sanyantra Ka Sanlayan Pranaali Ke Liye Takniki-Aarthik Pahlu
Vipul L Tanna

Anaveshit Punj Kshepan Pranaali Ke Liye Filament Tatha Discharge Vidyut Aapoorak
Dipal Thakkar, Paresh Patel, C B Sumod, V B Patel, L N Gupta, V Vadher, L K Bansal, K Qureshi, U K Baruah

Jaivic Plasma
Akshay Vaid

SST-1 Coil Power Supply Niyantran Pranaali Ke Liye Naye A.D.C. Module (I.P.330) Ka Programming Parikshan Evam Ekikaran
Murtaza M Vora, Dineshkumar Sharma Aur SST-1 Vidyut Pranaali Prabhag

Sthir-Sthiti Ati-Sheetvahak Tokamak-1 (SST-1) Ke Nirvat Vyvastha Ki Aankada Sankalan Evam Sanchalan Vyavastha
Yogesh Govind Yeole Evam Sthir-Sthiti Ati-Sheetvahak Tokamak-1 (SST-1) Ke Nirvat Vyvastha Ke Sabhi Sadasya

Ubharti Plasma Takniki Ka Vastron Ki Processing Me Mahatv
P B Jhala

6th National Conference on Nonlinear Systems and Dynamics (NCNSD-2011), School of Physics, Bharathidarshan University, Tiruchirapalli, 27-30 January 2011

The Non-Linear Behavior of the Constricted Anode Glow and its Influence on the Discharge Properties
S. K. Karkari, M. A. Mujawar and M. Turner

International Symposium on Semiconductor Material and Devices (ISSMD 2011), M. S. University, Vadodara, India, 28-30 January 2011

Optimization of Process Pressure for Achievement of High Growth Rate of Mixed Phase Hydrogenated Silicon Thin Film using Multi-Hole Cathode VHF PECVD
C. Jariwala, P. Vasu, A. Chainani, V. Dalal, and P.I. John
(Won the Best Poster Award)

Comparison of Thermal Evaporation and Plasma Assisted Thermal Evaporation Processes for Deposition of Tin Oxide Thin Films
C. Jariwala, T. Garg, A. Chainani, R. Rane, N. Chauhan, P. A. Rayjada, C. J. Panchal and P. I. John

Asian Winter School in the Graduate University for Advanced Studies (Sokendai), N.I.F.S., Toki, Japan, February 15-17, 2011

Infrared Thermography Research Activities at IPR
Shwetang N. Pandya

DAE-BRNS Indian Particle Accelerator Conference, 2011 (InPAC2011), Inter-University Accelerator Centre (IUAC), New Delhi, 15 - 18 February 2011

Fault protection system in a "Regulated high voltage power supply (80kV, 130A)" for Neutral beam injector
Paresh Patel, C. B. Sumod, Dipal Thakkar, L.N Gupta, V. B. Patel, L. K. Bansal, K. Qureshi, V. Vadher, Niranjanpuri Goswami, Kalpvikalp Patel, Kush Mehta, Kapil Oza, Chirag Patel, U.K. Baruah

Gas Feed System in Negative Ion Source Experimental Facility at IPR
G. Bansal, K.B. Pandya, J. Soni, M. Bandyopadhyay, M.J. Singh, R.K. Yadav,
A. Gahlaut, K.G. Parmar, A. Chakraborty

International Symposium on Advanced Ceramics, Composites and Nanostructured Materials (ISACCNM-2011), Department of Materials Science, Sardar Patel University, Vallabh Vidyanagar, 17-18 February 2011

Experiments for Developing Erbia Coating for In-LLCB TBM Design
P. A. Rayjada, P. A. Nayak, N. L. Chauhan, N. P. Vaghela, P. M. Raole,
E. Rajendrakumar

12th IEEE International Vacuum Electronics Conference (IVEC - 2011), JN Tata Auditorium, National Science Seminar Complex, IISc Campus, CV Raman Avenue, Bangalore, India, February 21 - 24, 2011

Quasi-optical Mode Converter for High Power Gyrotron
B.K. SHUKLA, D. BORA

A Conceptual Scheme for Focusing of High Power Microwaves in SYMPLE
R. Bahl, K. Sathyanarayna, V.P. Anitha, P.J. Rathod, Y.C., Saxena

A Plasma Source for System for Microwave Plasma Experiments (SYMPLE)
V.P. Anitha, R. Bahl, P.J. Rathod, J., Raval, Y.C. Saxena

Interaction of High Power Microwave with Plasma
V.P. Anitha, A. Das, Y.C. Saxena, A. Shyam, P.K. Kaw

Design and Testing of a PFN for the Washer-gun in SYMPLE
P.J. Rathod, V.P. Anitha, Z.H. Sholapurwala, J. Raval, R. Bahl, Y.C. Saxena

A Compact Generator Based on Tesla Transformer and Water Pulsed Forming Line for POS Application
R. Kumar, J. Patel, V.P. Anitha, A. Shyam

Short Pulse High Power Microwave Generation from an Axially Extracted Virtual Cathode Oscillator
R. Verma, A. Shyam, T. Patel, Y.C. Saxena

National Conference on Electric Propulsion Systems, LPSC, ISRO, Bangalore, India, February 23-24, 2011

Operational Experience of Positive Ion Neutral Injector on SST-1 Neutral Beam Test Stand
V. Prahlad, A. K. Sahu, M. R. Jana, C. Chakrapani, S. Rambabu, S. K. Sharma, P. Bharthi, B. Pandya, B.V.V.S. Sridhar, B. Choksi, S. Parmar, N. Contractor, P. J. Patel, L. K. Bansal, V. B. Patel, C. B. Sumod, K. Qureishi, V. Vadher, L .N. Gupta, D. Thakkar, and U. K. Baruah

Development of Probe Based Thruster Plume Diagnostics for LPSC
R. Rane, M. Ranjan, N. Vaghela, K. Kalaria, P. M. Raole, G. Ravi, S. Mukherjee

Non Intrusive Diagnostics for Thruster Plasma Characterization and Thrust Optimization
N.Ramasubramanian and J.Govindarajan

Frontiers of Science Conference & Exhibition, Kolkata, India, 2-3 March 2011

Indian Contributions to ITER
Dilshad A. Sulaiman

National Conference Physics for Tomorrow, St. Xavier's College, Ahmedabad, 3-4 March 2011

Deposition and Characterization of SiOxCyHz Films by PECVD Method to Investigate Dielectric Properties
P. Kikani, K. Pandey, P. Yadav, S. Prajapati, P. Arun, B. Desai, U. Joshi, V. Rana, S. Mukherjee and S. K. Nema

Nuclear Fusion: A Future Source of Green Energy
Shishir Purohit (**Awarded Best Abstract Prize**)

PATENT APPLIED

Multilayer Sensing Module for Infrared Imaging Bolometer
Santosh P. Pandya, Shwetang N. Pandya and J. Govindarajan
Indian Patent, Application No.: 2834/MUM/2010

Process of Creating Worn-out Effect in a Fabric
S. K. Nema, N. Chandwani, A. Sanghariyat, R. Rane, C. Balasubramanian, P. B. Jhala, and S. Mukherjee
Indian Patent, Application No.: 84/MUM/2011

AWARDS

Dr. S. K. Nema, a senior scientist at FICPT, IPR, has been conferred with the coveted NASI-Reliance Industries Platinum Jubilee Award for Application Oriented Innovations in Physical Sciences for the year 2010.The award was presented on December 2, 2010 at Jaipur National University, Jaipur. The award carries Rupees two lakh cash prize and a plaque.

E 4. INVITED TALK DELIVERED BY IPR STAFF

RATNESHWAR JHA

Gave an invited talk on "Measurements in the Harsh Environment of Fusion Plasma", at the Symposium on Advanced Measurement Techniques and Instrumentation (SAMTI-2011), held at Bhabha Atomic Research Centre, Mumbai, February 2-4, 2011

S.V. KULKARNI

Gave an invited talk on "High Power RF and Microwave Sources: Requirements of Fusion Reactors" at National Workshop on Vacuum Electron Devices and Applications (VEDA 2010), Moradabad, November 18-19, 2010

S. B. BHATT

Gave an invited talk on "UHV Activities at Institute for Plasma Research" at "The Indian Road-Map for Gravitational Wave Astronomy", INDIGO- ACIGA Meeting, arranged by DST-INDIGO, Jamia Millia Islamia University (JMIU), Delhi, February 8-9, 2011

PRAHLAD VATTI PALLE

Gave an invited talk on "The SST1-NBI Development and Current Status" at TEXTOR, IPP-Juelich, Germany, 5th October 2010

L.M. AWASTHI

Gave an invited talk on "A Study on High Beta Turbulence in Large Volume Plasma Device" at West Virginia University, WV, USA, 16th November 2010

N. RAMASUBRAMANIAN

Gave an invited talk on "Tokamak - Challenge for the 21st Century" during the one day seminar 'Innovation in Collegiate Science education and Research' at V. P. & R. P. T. P. Science College, Vallabh Vidyanagar, Anand, Gujarat, 8th January 2011

Gave an invited talk on "Teaching Physics through Web-Media" in the Orientation Programme for Science Teachers in Higher Education in Science City, Ahmedabad during 3-5 March 2011 and during 8-10 March 2011. This programme was jointly organized by the Knowledge Consortium of Gujarat (KCG) and Gujarat Council of Science City

MAINAK BANDYOPADHYAY

Gave an invited talk on "Fusion Technology" in INSPIRE-DST sponsored program, Nagpur, 8-11 January 2011

B. SARKAR

Gave an invited talk on "Cryolines and Cryo-distribution system for ITER: Technical Challenges of INDIA" at IPP, Greifswald, Germany, 26th July 2010

Delivered a keynote address entitled "Cryogenics for Mankind: The milestones of enabling technological achievements in Indian Perspectives, at 23rd National Symposium on Cryogenics (TTNSC), at NIT, Rourkela, India, 28-30 October, 2010

S. MUKHERJEE

Gave an invited talk on "Plasma Surface Engineering" at National Fusion Research Institute, Daejeon, South Korea, under Indo-Korean Collaboration Program, 21 March 2011

S. K. NEMA

Gave an invited talk on "Safe Disposal of Organic Waste and Energy Recovery using Plasma Pyrolysis Technology" at National Symposium on Municipal Solid Waste Management, Organized by CII and APTDC, at Hotel Taj Krishna, Hyderabad; 11-12 June 2010

Gave an invited talk on "Plasma Pyrolysis Technology" and "Plasma Polymer Interaction and its Applications" at School of Chemistry & Physics of Plasmas, SCAPP-2010, Ravenshaw University, Cuttack, Orissa, 27-30 October 2010

Gave an invited talk on "Plasma Technology developed at FCIPT, IPR, for Organic Waste Pyrolysis/Gasification" at Indo German Workshop on Biomass and Plasma Technology, BalticNet-PlasmaTec e.V, Lavasa, Pune, 31st October-2nd November 2010

Gave an invited talk at the award receiving ceremony on "Innovations in Plasma Based Applications at Institute for Plasma Research" at NASI-Reliance Industries Platinum Jubilee Awards, 2010; 80th Annual Session, NASI, National University, Jaipur; 2-4 December 2010

Gave an invited talk on "Surface Modification of Metals and Polymers using Low Temperature Plasmas" at NUiCONE-2010, "Current Trends in Technology", Dept. of Chemical Engineering, NIRMA University, Ahmedabad; 9-11 December 2010

Gave an invited talk on "Plasma Based Technologies Developed at FCIPT, IPR" at Takniki Evam Vygyanik Jagrukta Hetu Hindi Ke Upyog Par Rashtriya Sammelan, Plasma Anusandhan Sansthan (IPR), Gandhinagar, January 27-28, 2011

Gave an invited talk on "Plasma Pyrolysis of Various Types of Waste – Development at FCIPT, Institute for Plasma Research" at One day Workshop on E-Waste Management, IISc, Bangaluru, 29th January 2011

Gave an invited talk on "Thermal Plasma Technology for Safe Disposal of Infectious Biomedical Waste & Energy Recovery from Other Organic Waste" at National Fusion Research Institute, Daejeon, South Korea, under Indo-Korean Collaboration Program, 21 March 2011

P. M. RAOLE

Gave an invited talk on "Plasma Processing - Present Scenario and Future Directions" at 25th National Symposium on Plasma Science and technology (Plasma 2010), IRSST, Guwahati, 8-11 December 2010

Gave an invited talk on "Sanlayan Shakti Nirman Me Padarth Vigyan Tatha Takniki Ka Mahatv" at Takniki Evam Vygyanik Jagrukta Hetu Hindi Ke Upyog Par Rashtriya Sammelan, Plasma Anusandhan Sansthan (IPR), Gandhinagar, January 27-28, 2011

Gave an invited talk on "Low-Temperature Plasma Processing and Characterization of Materials" at International Symposium on Advanced Ceramics, Composites and Nanostructured Materials (ISACCNM-2011), S. P. University, India, 17-18 February 2011

P. B. JHALA

Gave an invited talk on "Plasma Technology for Performance Enhancement of Technical Textiles" at National Symposium on Technical Textiles: Emerging Growth and Opportunities, SGCCI, MANTRA, ITTA, Surat, 23rd December 2010

Gave an invited talk on "Innovation in Green Textile Technology and Apparel Design" at InFashion Conference, IAM, FAITMA, IMAGES, Mumbai, 15-17 March 2011

Gave an invited talk on "High Altitude Clothing: Design and Material Concerns" at National Level One Week Program on Protective Textile, Anchor Institute (Textile Sector), Department of Textile Technology, MSU, Vadodara, 21-25 March 2011

Gave an invited talk on "High Altitude Clothing: Design, Material and Manufacture" at National Conference on Technical Textiles: Technology for Growth, MANTRA, ITTA, ROTC, Ahmedabad, 30th March 2011

SURYAKANT GUPTA

Gave an invited talk on "Plasma Technology & its Contribution in Sustainable Management of Natural Resources" at International Seminar & workshop on Sustainable Management of Water and Land Resources, Central Kalimantan, Palangka Raya, Indonesia, 27-29 September 2010

Gave an invited talk on "Bioelectrics: A bridge between physical plasma and the biological plasma", Plasma Technology Research Centre, University of Malaya, Kuala Lumpur, Malaysia, October 2010

Gave an invited talk on "Surface engineering activities at FCIPT" at Indo German workshop on Biomass and Plasma Technology, BalticNet-PlasmaTec e.V, Lavasa, Pune, 31st October-2nd November 2010

C. BALASUBRAMANIAN

Gave an invited talk on "Nanoscience and Nanotechnology - Research Areas in Plasma Assisted Processes" at Autumn School on Physics and Chemistry of Plasmas, School of Physical Sciences, Ravenshaw University, Cuttack, 27-30 October 2010

Gave an invited talk on "Application of Plasma Technology in Traditional Crafts" at National Level Brainstorming Meeting on Science and Technology Interventions in Traditional Crafts, Sri Paramakalyani College, Alwarkurichi, Tamil Nadu, 6-7 December 2010

CHETAN JARIWALA

Gave an invited talk, as a part of Guest Lecture Series Program, on "Thin Film Processing by Plasma Techniques for Photovoltaic Applications" at Department of Chemical Engineering, Nirma University, Ahmedabad, 22nd March 2011

MUKESH RANJAN

Gave an invited talk on "Application of ion induced pattern substrate in plasmonics" at International conference on Ion-beam Induced Nanopatterning of Materials (IINM-2011), Institute of Physics, Bhubaneswar, 6-10 February 2011

P. VADIVEL MURUGAN

Gave an invited talk on "Safe Disposal of Biomedical and Plastic Waste using Plasma Pyrolysis Technology" at UGC sponsored "National Level Seminar on Urban Waste Disposal and its impact on Environment and Public health: Quests for Solutions", at Sibsagar College, Joysagar, Assam; 23-25 September 2010

Gave an invited talk on "Plasma Pyrolysis Technology" at "Awareness - cum Training Workshop on Bio-medical Waste Management", organized by Central Pollution Control Board, Lucknow, 20-21 January 2011

M. KAKATI

Gave an invited talk on "A Supersonic Thermal Plasma Jet Assisted Reactor for Synthesis of High Temperature Ceramic Nanoparticles", at International Conference on Nanomaterials, ICN2010, Centre for Nanoscience & Nanotechnology, Mahatma Gandhi University, Kottayam, Kerala, India, 27-29 April 2010

P. J. PATHAK

Gave an invited talk on "Role of Libraries in Learning, Teaching and Research" at Gandhi Mahila College, Bhavnagar, Gujarat, 5th April 2010

Gave an invited talk on "Incultivating Reading Habits" at IGNOU Educational Channel, 105.6FM Radio, on 16th November 2010

Plenary & Invited talks given at 25th National Symposium on Plasma Science & Technology (PLASMA-2010), Institute of Advanced Study in Science & Technology (IASST), Paschim Boragaon, Garchuk, Guwahati, India, 8-11 December 2010

DHIRAJ BORA gave Plenary & Invited talk on "Fusion – A Limitless Energy Source in the Horizon"

K. S. GOSWAMI gave Plenary & Invited talk on "Current Free Double Layers and its Existence and Applications"
PRABAL CHATTOPADHYAY gave Plenary & Invited talk on "Basic Plasma Experiment: Discovery and Exploration of New Plasma Regimes"

SUBRATA PRADHAN gave Plenary & Invited talk on "Thermo – Nuclear Fusion: an Overview"

BEDAKIHALE VIJAY gave Plenary & Invited talk on "Material R & D for Fusion Program – Issues and Challenges"

V. L. TANNA gave Plenary & Invited talk on "Cryogenic Forced Cooling System for Fusion Devices"

P. M. RAOLE gave Plenary & Invited talk on "Plasma Processing – Present Scenario and Future Directions"

B. K. SAIKIA, S. S. KAUSIK, M. CHAKRABORTY and M. KAKATI gave Plenary & Invited talk on "Studies on Dust Charging in Hot Cathode Discharge Plasma"

RATNESHWAR JHA gave Plenary & Invited talk on "Advances in Plasma Diagnostics"

M. BANDYOPADHYAY gave Plenary & Invited talk on "An Overview of Negative Ion Diagnostics"

R. SRINIVASAN gave Plenary & Invited talk on "Numerical Modeling of Plasma"

B. K. SAIKIA and C. DANANI gave Plenary & Invited talk on "Preliminary Study of Shielding Performance of IN DEMO LLCB Blanket".

E 5. TALKS DELIVERED BY DISTINGUISHED VISITORS AT IPR

Prof. C. S. Shukre, Director, J. N. Planetarium, Shri T. Chowdaiah Road, High Grounds - BANGALORE 560 001 India gave a lecture on "Understanding Pulsars".

Dr. Hemen Kakati, Institute of Advanced Study in Science and Technology, Paschim Boragaon, Guwahati, India gave a lecture on "Discharge and Deposition Characteristics of RF Magnetron Plasma".

Shri N. Vijayan, LPSC, ISRO - Trivandrum, India gave a lecture on “Hall Effect Thruster based Electric Propulsion System for ISRO Satellites”.
Dr. R.P. Prajapati, Dept. of Physics, Vikram University, Ujjain, India gave a lecture on “Study of Hydromagnetic Instabilities of Gaseous, Dusty and Quantum Plasma”.

Dr. Bhimsen K. Shivamoggi, University of Central Florida, Orlando, FL 32816-1364 gave a lecture on “Hall Magnetohydrodynamic Reconnection”.

Mr. Ganapati Sahoo, Centre for Condensed Matter Theory, Department of Physics, Indian Institute of Science, Bangalore 560 012 gave a lecture on “Systematics of the Magnetic-Prandtl-number Dependence in Magnetohydrodynamic Turbulence”.

Prof. Osamu Motozima, Director General, ITER Organization gave a lecture on “Fusion Research as of Today”.

Prof. Dhiraj Bora, Deputy Director General, Department for CODAC and IT- Heating and CD - Diagnostics, ITER Organization gave a lecture on “Contribution of Indian staff at IO”.

Dr. Vipin K Yadav, Space Science Division, Indian Space Research Organization (ISRO) Head-quarters, Bangalore gave a lecture on “X-ray Imaging Experiments using Shadow Masks for Space Applications”.

Dr K Bodi, Technopole de Chateau-Gombert, Marseille, France gave a lecture on “Generation of Blobs in Tokamak Edge Plasma”.

Dr. L. Palodhi, Department of Physics, University of Pisa, Italy gave a lecture on “Electromagnetic Instabilities due to Temperature Anisotropy in the Heart of Collisionless Plasma”.

Prof. Ramachandran, Karunya University, Coimbatore, India gave a lecture on “Numerical simulation of thermal plasma generation and its interaction with substrate and particles”.

Prof. Andre Thess, Mechanical Engineering Department, Ilmenau University of Technology, Germany gave a lecture on “Overview of MHD Research at Ilmenau University of Technology”.

Prof. T. J. Dolan, NPRE Department, Univ. of Illinois, 104 South Wright Street, Urbana, IL 61801, USA gave a lecture on “Low Energy Nuclear Reactions”.

Prof. T. J. Dolan, NPRE Department, Univ. of Illinois, 104 South Wright Street, Urbana, IL 61801, USA gave a lecture on “Fusion-Fission Hybrid Reactors”.

Dr.Richard Nygren, Sandia National Laboratories, Albuquerque, USA gave a lecture on
“Activities Related to Development of Plasma Facing Components of Tokamaks at Sandia National Laboratories (USA)”.

Prof. T. J. Dolan, NPRE Department, Univ. of Illinois, 104 South Wright Street, Urbana, IL 61801, USA gave a lecture on “Plasma Diagnostics”.

Prof. T. J. Dolan, NPRE Department, Univ. of Illinois, 104 South Wright Street, Urbana, IL 61801, USA gave a lecture on “Compact Toroids”.

Mr. Monojoy Goswami, Center for Nanophase Material Sciences, Oak Ridge National Laboratory, Oak Ridge, TN, 37831, USA gave a lecture on “Nanoscale Polymeric Materials: Can Computer Simulation Help?”.

Dr. Kamlesh Jain, Shimadzu Research Laboratory (Europe), Manchester, UK gave a lecture on “Ion Mass Matters”.

Dr. S.M. Mahajan, Institute For Fusion Studies, The University of Texas, Austin, USA gave a lecture on “Twisting Space - Time: “Ideaz” Origin of Vorticity / Magnetic Fields”.

Mr. Nishant Sirse, NCPST, Dublin City University, Ireland gave a lecture on “Investigation of Electronegative Plasma by Microwave Resonator Probe”.

Mr. Jaydeep Belapure, Astrophysical and Laboratory Plasma Studies (ALPS) group, IPP, Garching gave a lecture on “Soft and Hard X-Ray Diagnostics using SDD detectors”.

Mr. Sarvagya Dwivedi, COMSOL Multiphysics Pvt. Ltd. Banglore gave a lecture on “Introduction to COMSOL Multiphysics Simulation Software”

Prof. Steven Cowley, Director, Culham Centre for Fusion Energy, CEO,United Kingdom Atomic Energy Authority, Culham Science Centre, Abingdon OX14 3DB, UK gave a lecture on “Compact Fusion”.

Mr. Dhagash Mehta, Syracuse University gave a lecture on “Computational and Numerical Algebraic Geometry and their Applications in Theoretical Physics”.

Prof. Arata Nishimura, National Institute for Fusion Science, Japan gave a lecture on "Recent Activities on Superconducting Magnet for Fusion Reactor".

Dr. A. Pochelon, EPFL, CRPP, Association Euratom-Confederation Suisse, CH-1015 Lausanne, Switzerland gave a lecture on "Turbulence and Transport Reduction with Innovative Plasma Shapes in TCV Correlation ECE Measurements and Gyrokinetic Simulations".

Dr. Awadhesh Prasad, Department of Physics and Astrophysics, University of Delhi, India gave a lecture on "Targeting Fixed Point Solutions in Nonlinear Oscillators".
Dr. Stefan Facsko, Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, D-01314 Dresden, Germany gave a lecture on "Modifying surfaces at the nanoscale with low energy ions".

Dr. Victor Malka, Laboratoire d'Optique Appliquée, Ecole Nationale Supérieure des Techniques Avancées, ParisTech – CNRS, UMR7639 -Ecole Polytechnique, Chemin de la Hunière, Palaiseau F-91761, France gave a lecture on "Laser Plasma Accelerators Delivering High Quality and High Current Electron Beam".

Dr. Debjyoti Basu, Saha Institute of Nuclear Physics, Kolkata gave a lecture on "Electrode Biasing Experiments in SINP-Tokamak".

Dr. Shreekrishna Tripathi, Physics and Astronomy, UCLA gave a lecture on "Laboratory Simulation of Magnetic Flux Rope Eruptions on the Sun".

E 6. COLLOQUIA PRESENTED AT IPR

Dr Bhimsen K. Shivamoggi, University of Central Florida, Orlando, FL 32816-1364
given a talk on "Motion of a Vortex Filament in Superfluid --> 4He" (Colloquium #208)

Dr Christian Hopf, Max-Planck-Institut fr Plasmaphysik, EURATOM Association,
Boltzmannstrasse 2, 85748 Garching, Germany given a talk on "Chemical sputtering of carbon an overview of dual beam experiments at IPP" (Colloquium # 209)

RNDr. Jana Brotankova, Institute for Plasma Research, Bhat, Gandhinagar - 382 428, India
given a talk on "Edge plasma turbulence measurements on the CASTOR tokamak"
(Colloquium # 210)

Mr. Raj Singh, Institute for Plasma Research, Bhat, Gandhinagar - 382 428
given a talk on "Grounding for Safety and Signals" (Colloquium # 211)

Dr. A. Pochelon, EPFL, CRPP, Association Euratom-Confederation Suisse, CH-1015 Lausanne, Switzerland given a talk on "Present Status and Future Plan for TCV Tokamak"
(Colloquium # 212)

RNDr. Jana Brotankova, Institute for Plasma Research, Bhat, Gandhinagar - 382 428, India
given a talk on "Probe diagnostic systems on the CASTOR tokamak and other devices"
(Colloquium # 213)

E 7. SCIENTIFIC MEETINGS HOSTED BY IPR

Scientific Workshop Hosted by IPR on Infrared Thermography, 28-30 June 2010

National Workshop on Infrared Thermography and its application (NWIT-2010) was conducted in IPR during June 28–30, 2010. This is the first workshop of this kind. The aim of the workshop is to gather all the people who are working in Infrared Thermography field and to provide common platform. Various experts in IR thermography field were called for invited talk and total 16 talks were arranged with domo experiments. More than 70 participates working in this field participated in the workshop. Workshop received great success from entire community of Infrared Thermography.

Basic Course on Plasma Physics applied to Electric Propulsion System arranged for the participants from LPSC Trivandrum and Bangalore at Institute for Plasma Research, Gandhinagar, 19-24 July 2010

Basic Plasma Physics
R. Ganesh

Concept of Magnetic Mirror, Plasma Lens and Magnetic Bottle
R. Ganesh

Fluid Theory
R. Ganesh

Numerical Modeling of Plasma - PIC
M. Kundu

Numerical Modeling of Fluid Plasma - Fluid
M. Kundu
Waves, Transport and Instabilities
R. Singh

Methods of Plasma Production
S. Mukherjee

Plasma Sheath
S. Mukherjee

Principles of Thrusters like Hall, PPT, MPD, Helicon
P. Chattopadhyay

EMI Effects of Plasma Plumes and Charged Particle Interaction
P. Chattopadhyay

Principles of Operation of Hollow Cathode
G. Ravi

Magnetic Probes
G. Ravi

Basic Design of Thrusters
R. Srinivasan

Collisional Processes in Thruster Plasma
R. Srinivasan

Plasma Diagnostics Introduction and Infrared Thermography
J. Govindrajan

Optical Emission Spectroscopy (OES)
N. Ramasubramanian

Advanced diagnostics (LIF)
N. Ramasubramanian

Erosion of Ceramics
P.M. Raole

Langmuir Probes
R. Rane

National Workshop on Eco-friendly Plasma Applications in Textile, Institute for Plasma Research, Gandhinagar, 11-12 November 2010

Takniki Evam Vygyanik Jagrukta Hetu Hindi Ke Upyog Par Rashtriya Sammelan, Plasma Anusandhan Sansthan (IPR), Gandhinagar, January 27-28, 2011

Fusion Reactor & Design Course, as a part of the course for M. Tech. in Nuclear Science and Technology offered by Delhi University, has been conducted at the Institute for Plasma Research, Gandhinagar, 10th to 25th March 2011

More than 16 faculty members gave around 40 lectures on various topics of the syllabus including - Tokamak Structures and Modelling, RF Heating, Electric Probes & Magnetic Probes, Diverter Design and Structures, Microwave Diagnostics and Other Plasma Diagnostic Techniques like Spectroscopy, Nuclear Materials, Test Blanket Module Structures, Design and Modeling, Cryogenics, Neutronics, Neutral Beam Injection etc. In addition to that, Tutorials were included in this course work and laboratory visits were organized for the M.Tech students.

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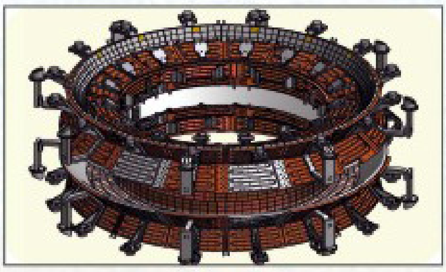
IPR Director lighting lamp during inauguration of National seminar on use of Hindi for technical and scientific awareness

तकनीकी एवं वैज्ञानिक जागरूकता हेतु हिन्दी के उपयोग पर आयोजित राष्ट्रीय सम्मेलन के उद्घाटन पर दीप प्रज्वलित करते हुए आई पी आर के निदेशक

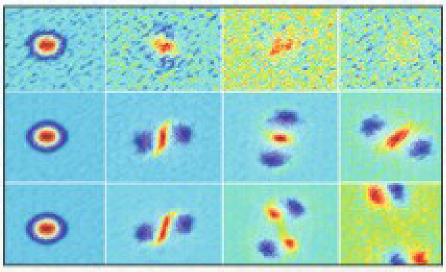


Plasma facing components of SST-1

एसएसटी-1 के प्लाज़्मा मुखित घटक

Please refer A.3.1., Cross-sectional view of vacuum vessel and the Electron Energy Filter (EEF)

कृपया देखें A.3.1. निर्वात पात्र और इलेक्ट्रॉन उर्जा फिल्टर (ईईएफ) का परिच्छेदीय दृश्य

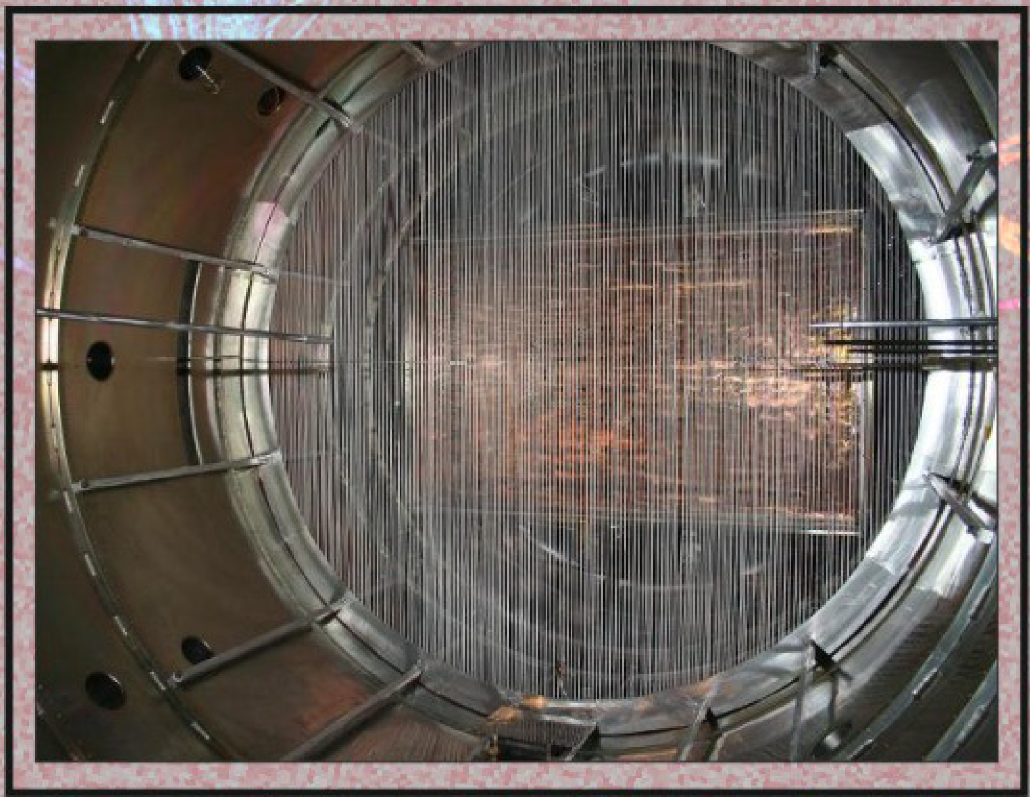


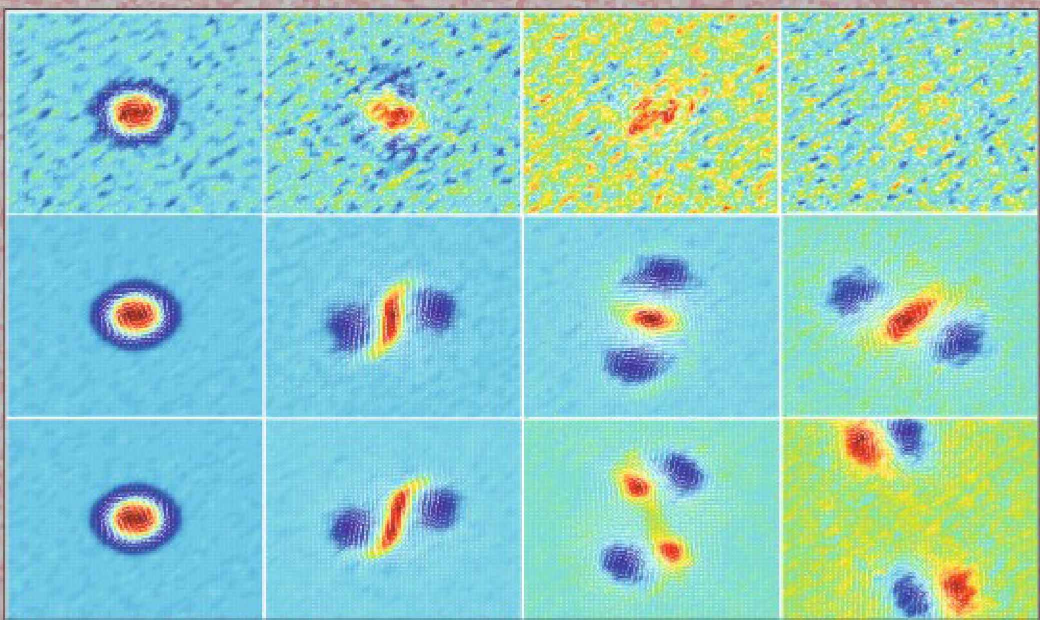
Please refer A 4.6 Time evolution of the vorticity profile

कृपया देखें A.4.6. भ्रमिलता प्रोफाईल का काल विकास

Participants at NWIT-2010

एनडब्ल्यू आईटी-2010 में सम्मिलित सदस्य





INSTITUTE FOR PLASMA RESEARCH

Bhat, Gandhinagar-382 428, Gujarat (India)

प्लाज़्मा अनुसंधान संस्थान

भाट, गांधीनगर–382 428, गुजरात (भारत)