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GOVERNING COUNCIL

EXECUTIVE SUMMARY

With more than two decades of focussed research towards the realization of controlled thermo-nuclear fusion through magnetic confinement behind it and the active support of Department of Atomic Energy for participation in ITER and rapid indigenous development of advanced nuclear energy options like fusion, the institute is now poised to make significant and accelerated contributions to plasma science, fusion technologies, ITER and industrial applications.

The current tokamak experiments in the institute, namely Aditya Tokamak and Superconducting Steadystate Tokamak-1 (SST-1), have been instrumental in gaining rich experience, understanding the advanced technologies and training manpower. Even after twenty years of operation, the Aditya tokamak is still a workhorse; a couple of more diagnostics have been integrated into the machine and are being tested; a new error field correction coil set has been added to the machine and the capacitor bank has also been upgraded. The exploration of the vast richness in physics of tokamaks has led to many new experiments and the compilation of interesting results obtained therein shows the presence of many unexplored areas accessible to Aditya tokamak.

With the problem areas in SST-1 having been identified in detail, the remedial action plans at the system and sub-system level are being executed with the support of experts and industries from within the country . After setting up a full-fledged test facility for the toroidal field (TF) coils, the spare TF coil was tested with 10kA load. In these tests, the joint resistance was measured to be hundreds of pico-ohms which is an appropriate value for satisfactory operation of SST-1. Through this testing, a valuable experience of all the relevant sub-systems has been obtained and also well documented. In the near future it is envisaged to test two coils jointly and efforts are on to extend the existing facilities to be able to do that. Meanwhile, the heating systems and diagnostics systems are getting tested either in Aditya tokamak or in mock-up setups at laboratories.

ITER-India is making steady progress towards preparing itself for fulfilling India's commitments to ITER. The technological development programme in the eleventh five year plan is progressing well, with many useful collaborations being established with various institutions and industries, present in different parts of the country. In this process new materials, new processing methods of materials and new applications of the processes and materials are getting developed. The relevant training of manpower during the course of these developments is also an expected value added feature of the programme. One of the most important potential promises of the power reactor based on controlled thermo-nuclear fusion is generation of very low volumes of long-lived radioactive waste. The activities of the newly set up neutronics group will be helping in realizing that promise.

While the new basic experiments started recently are getting to a mature stage, some more new experiments have also been started. Now the basic experiments are representing a vast spectrum of plasma physics from simple fluctuations measurements to low-medium temperature plasma physics to plasma wake-field acceleration physics. The work on the ever-interesting experiments like BETA, LVPD and non-neutral plasmas is being extended to new regimes of operation and physics by an appropriate upgradation of the machines.

Electron Magneto-Hydro Dynamics simulations and Gyro-Kinetic simulations have helped to understand many new physics problems. Simulation of Laser-Plasma interactions, in the collaboration with TIFR experiments, have explained many observed phenomena in the experiments. Molecular dynamics simulation with Yukawa potential is another new problem which has been initiated recently.

The number and variety of projects undertaken and delivered by FCIPT is an obvious sign of industries getting the benefit of plasma physics applications. The achievements of BRFST is really good – the number of projects sanctioned and the pan-India spread of the project recipients show that the community involved in the research and development of fusion physics and technology is growing very well.

Director,
IPR.

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April 1, 2008 to March 31, 2009

Since 1986 the institute has been excelling in plasma physics research with fast growing facilities and trained man power. Started with small tokamak experiments and basic plasma experiments, the institute has been acquiring expertise in all the relevant scientific and technological requirements for controlled thermonuclear fusion. The activities of the Board of Research on Fusion Science and Technology (BRFST) and the Fusion Technology Development Programme under the Eleventh Five Year Plan are giving the required growth for the capability to absorb the world's state-of-the-art technical knowledge of controlled thermonuclear fusion available through the participation of the country in the International Thermonuclear Experimental Reactor (ITER). At the same time basic experiments related to immediate plasma technology dissemination to industry through Facilitation Center for Indutrial Plasma Technology (FCIPT) forms an integral part of the programme.

A. SCIENTIFIC AND TECNOLOGICAL PROGRAMMES

Scientific programme of the institute can broadly be categorised in to five areas: 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 State of the device

In the last one year, various activities and experiments for upgrading tokamak have been carried out in Aditya. Capacitor discharges have been done for proposed experiments, like, (1) Measurement of plasma fluctuation using Mach-probe (2) Second harmonic ECR Pre-ionization / Start-up experiments in Aditya tokamak and (3) Trouble shooting of lately added magnetic diagnostics viz., Diamagnetic loop to calculate the stored energy, Sine –Cosine coil to measure the plasma position and Magnetic probe to measure the MHD activities. During this time Aditya was being operated at lower rating (30 kAmp, 30 msec) from capacitor bank. The main high voltage transformer for converter operation has been repaired and cold test has been already done. Testing with actual load is being done. Procurement of components for automation of capacitor bank power supplies including prototype electronics circuitry has been completed. Installation of new ICRH transmission line in Aditya has been completed.

A.1.1.2 Technological developments

Error field correction: Recently, a new 2-turn correction coil, with a proper external resistance, in parallel to the correction coils have been added to Aditya tokamak. This coil has been placed in series with ohmic transformer coils so as to produce and control the null position to be exactly at the inside centre of the vacuum vessel. An equivalent circuit with the correction coil is shown in the figure A.1.1.2.1.

A comparative study with different correction coil configuration viz. single turn, two turns alone and two turns with external parallel resistance has been made in capacitor bank discharges. Initial observations show significant improvement in pressure operation window and discharge characteristics. The formation position of the plasma and its subsequent evolution inside the vacuum vessel has been measured by monitoring the H-alpha line intensity at different major radius.

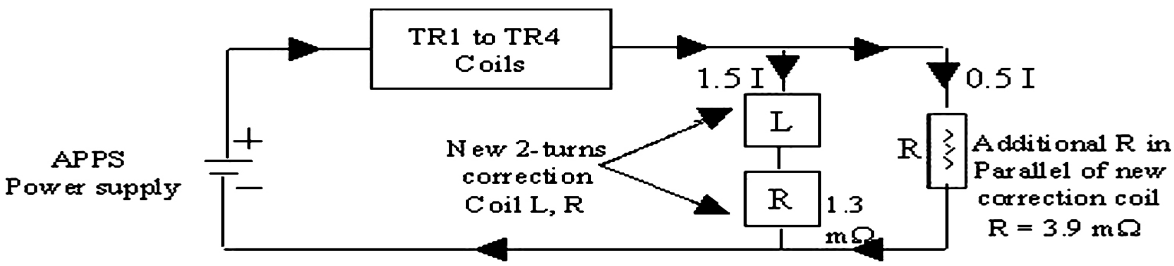


Figure A.1.1.2.1 Equivalent circuit for the correction coil

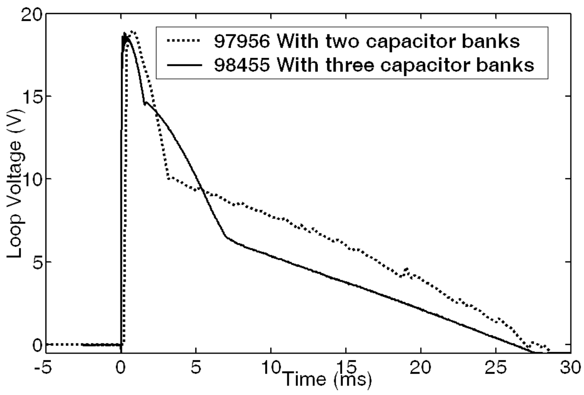
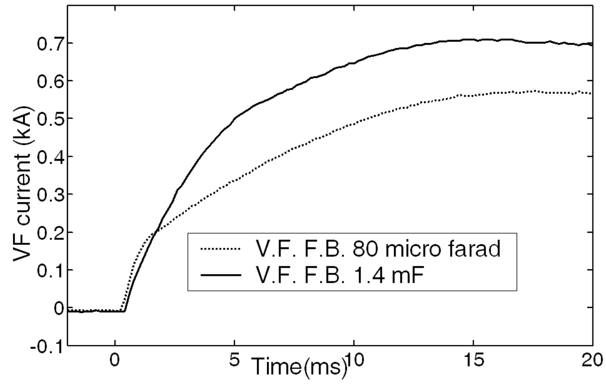


Figure A.1.1.2.2(a) Comparison of Loop voltage using old and upgraded capacitor bank



(b) Comparison of vertical field current

Upgradation of capacitor bank: Using normal capacitor bank, discharges are obtained with plasma current of 20 – 30 kA, of duration of 20 – 30 ms at lower operating pressure (~ 4 X 10^{-5} torr – 8 X 10^{-5} torr) (E/P ~ 400 -800 V cm^{-1} $torr^{-1}$). But these discharges were not repeatable at higher operating pressure (~ 1 X 10^{-4} torr – 2 X 10^{-4} torr) (E/P ~ 200 - 400 V cm^{-1} torr-[1]) because of huge increase in carbon impurity observed through CIII line radiation as observed in the figure A.1.1.2.3. Therefore at higher operating pressure it is believed that the insufficient burn-through of carbon impurities make discharges duration shorter (~ 10 ms). In order to get the discharges at higher operating pressure and lower E/P value, an additional capacitor bank (Slow Bank 1) of 3.2 mF / 10 kV is added in the Ohmic capacitor bank power supply. The performance of this additional bank was tested as shown in the figures A.1.1.2.2(a) and (b). It has provided additional loop voltage in the start-up phase which helped in producing successful discharges at higher operating pressure and lower E/P value as shown in the figure A.1.1.2.3(b). It has also led to significant improvement in the chord average electron density (increased from 5- 6 x 10^{12} / c.c to 1 x 10^{13} / c.c.).

A.1.1.3 Diagnostic developments

Spectroscopic Diagnostics

Wall reflection modelling for Tangential Image Tomographic Reconstruction (TITR) code: A tomographic reconstruction code had been developed for inferring the poloidal emissivity of tokamak plasma from tangentially acquired images. Modifications to the code have been carried out that account for any diffuse reflections from the surfaces of walls enclosing the plasma. As is well known, in a tokamak, it is very likely that the

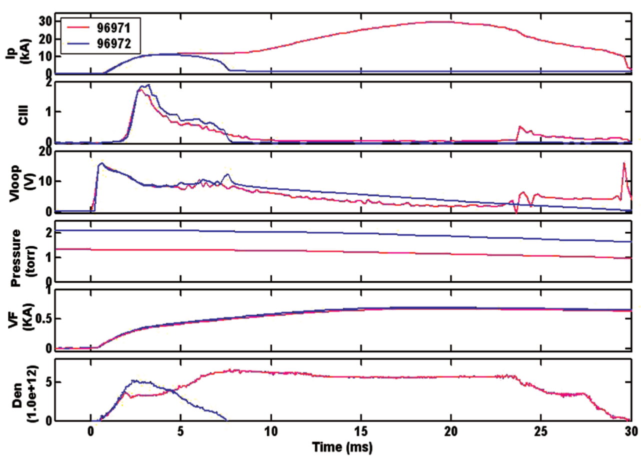


Figure A.1.1.2.3 (a) Failure of discharges at higher pressure. Insufficient burn through of CIII impurity at higher operating pressure. Red: low and Blue: high pressure

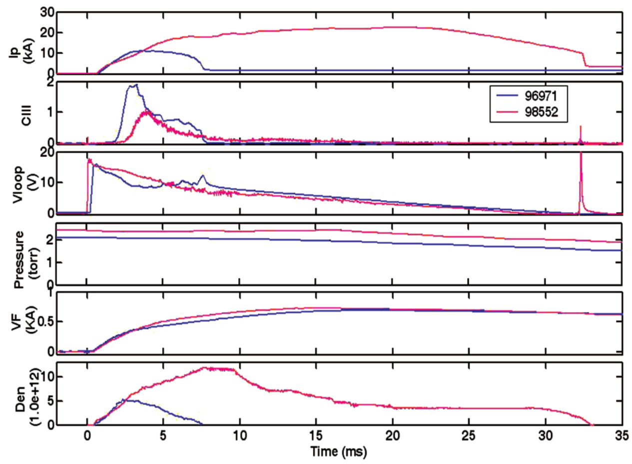


Figure A.1.1.2.3(b) Discharges at higher pressure with additional bank.: Red: high pressure (1.2x10^{-4} torr) with additional bank, Blue: without additional bank illumination on the camera pixels would also be receiving contributions from the plasma light scattered from the vessel wall. This may prove to be a major bottleneck for most optical diagnostics, but has not been addressed fruitfully till recently. A scheme has been developed, which accounts for the diffusely reflected light in a tractable manner, and has been included in the TITR code. Comparison of simulated images on the camera chip 'with' and 'without' wall reflections, smoothed over adjacent pixels are shown in the figure A.1.1.3.1. Here wall reflectivity is taken as 0.8. Also a surface emissivity, equivalent to 80 percent of the average light flux on the wall from the plasma, has been assumed. Under these conditions, the wall contribution seems to be amounting to 15 percent at the bright detectors, whereas, as much as 150 percent at the dark ones. This signifies that since the reflection from wall surface is not directly related to the amount of light received by each detector, this effect may play a huge spoilsport for the detectors starving on incident photon flux.

Noise stabilization for tangential image tomographic reconstruction (TITR) Code: It is generally recognized that such reconstruction codes are highly susceptible to noise in the data. In this work the sensitivity to noise has

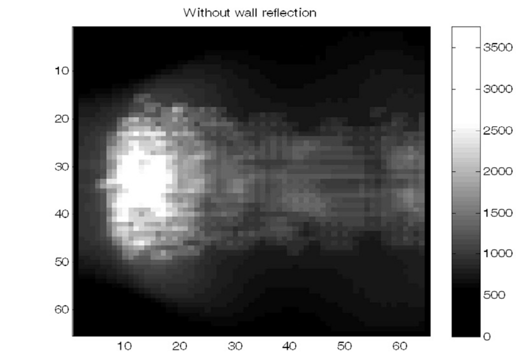
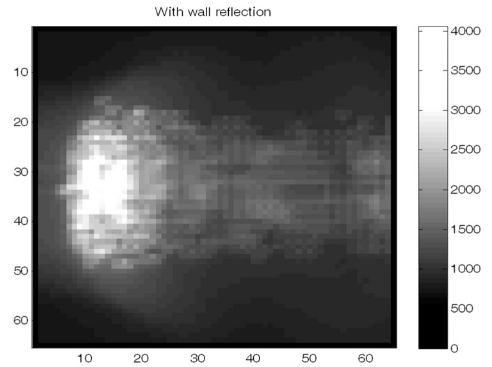


Figure A.1.1.3.1 Comparison of simulated images on the camera chip 'with' and 'without' wall reflections



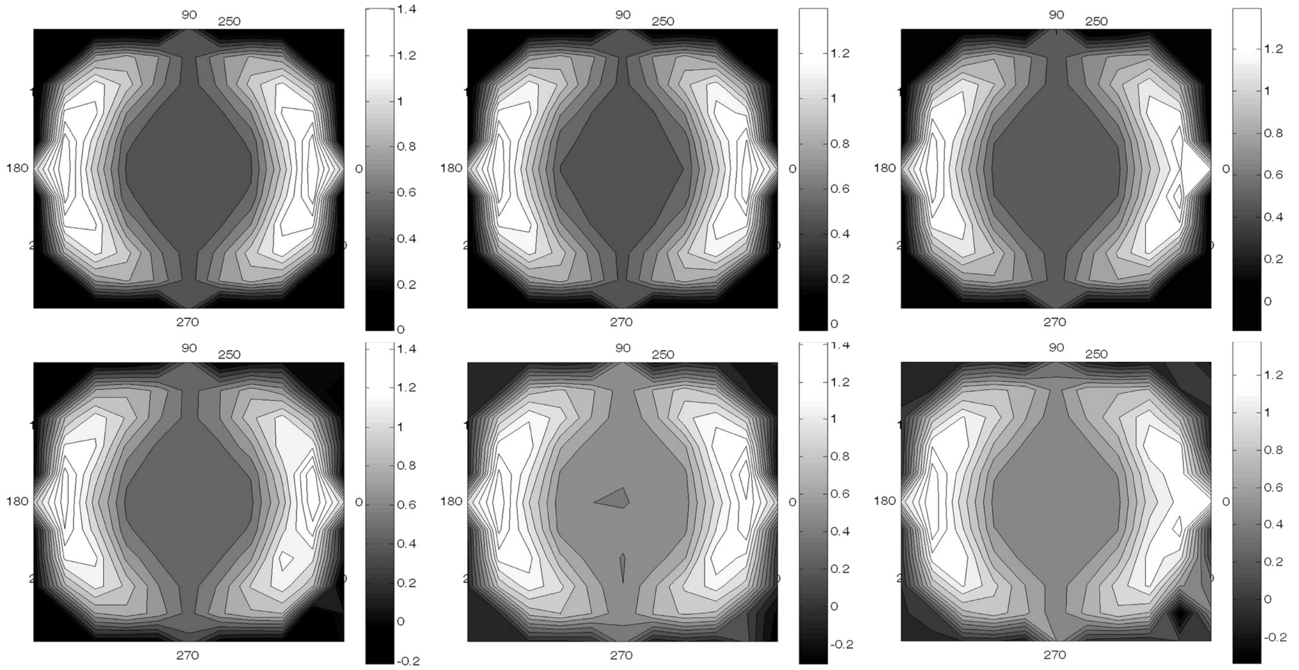


Figure A.1.1.3.2 Reconstructed emissivity profiles with increasing amount of shot noise in the input brightness and in the presence of wall reflection have been shown. Top row L to R: reconstruction with no noise, 5% ,10% noises. Bottom row L to R: with 15%,20% and 25% noise. Minor radius (=250 mm) of the model torus is depicted in the first quadrant of each panel.

been analyzed for varying degrees of over-determinism in the set of equations; Over-determinism is defined as the ratio of the number of detector signals available to the grid resolution of reconstruction. A tractable scheme for dividing the poloidal cross section into finite number of unknown sub-tori and voids, while still keeping the over-determinism high, is incorporated. Finally it is shown that noise level >20 percent can be handled with over-determinism achievable from present day detector array/cameras as shown in the figure A.1.1.3.2.

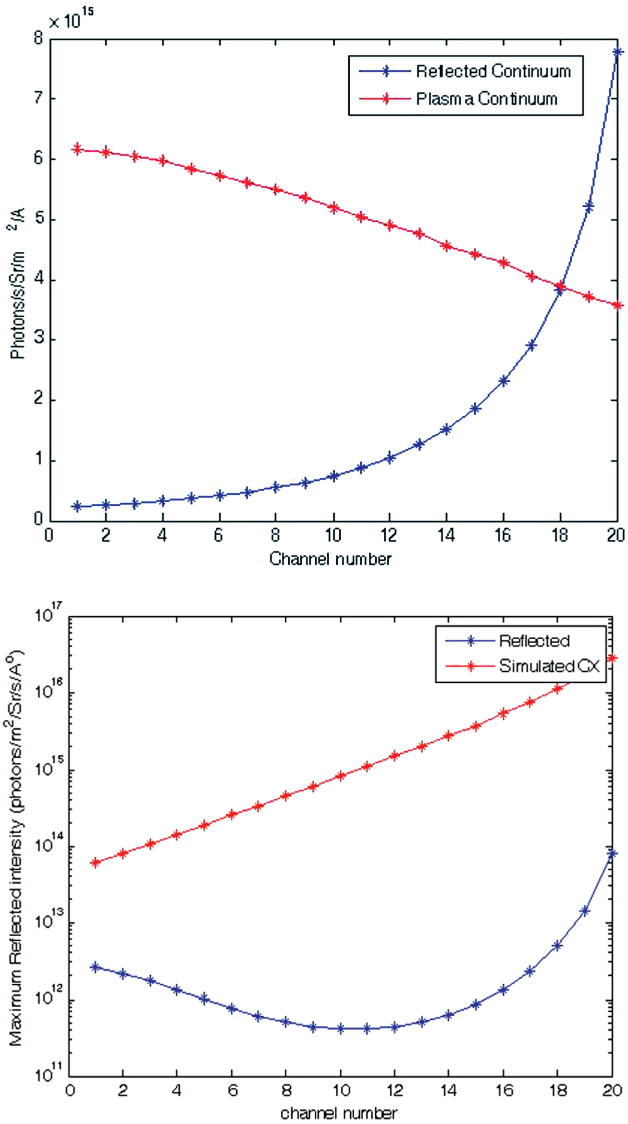


Figure A.1.1.3.3 Simulated and reflected continuum signals for ITER are shown in the top panel while both the CX signals are shown in the bottom panel.

Estimation of Wall reflection on CXRS diagnostics in Textor and ITER: This work has been carried out at Forshungszentrum Jülich, Germany, September-December 2008 in collaboration with FOM-Institut voor Plasmafysica, Rijnhuizen, Netherlands. A diffuse reflection model has been developed for estimating the reflected continuum in the charge exchange (CXRS) diagnostics in ITER and Textor. Continuum radiation in ITER in each channel is ~ 4×10^{15} photons/s/Sr./m^2/A^o. With an assumption of wall reflectivity to be 0.7, the reflected continuum radiation in each channel is of the same order after the first 9-10 channels. The Edge channels are severely affected with the 11th channel ~ 20% and the 20th channel ~ 200% as shown in the figure A.1.1.3.3 (top). Similar results are envisaged with Textor, but the contribution is much smaller here. Wall reflectivity of R=0.7 for the SS part and R=0.4 for the carbon limiter part are considered. Line integrated continuum level in Textor is ~3.5×10^{14} photons/s/Sr./m^2/A^o. Reflected continuum signal ranges from 1.5×10^{12} to 8.8×10^{12}photons/s/Sr./m^2/A^o. So the reflected continuum in Textor never goes beyond 5 % under the same considerations / model as of ITER. This can be attributed to the viewing geometry and the Bremsstrahlung profile of the two machines. For ITER upper port 3 the view is much like 'head on' in comparison to the tangential view for Textor. This may prove to be a major concern for the CXRS diagnostic for ITER.

For estimating the reflected charge exchange (CX) recombination signal for eachchannel, a full Bidirectional Reflectance Distribution Function (BRDF) model has been developed. Reflected CX signal has been estimated to about 1% of the original CX signal for Textor CXRS diagnostic channel. While in case of ITER (figure A.1.1.3.3.bottom), the reflected signal strength is estimated below 5% even for a high wall reflectivity.

Studies on First Mirrors for ITER: A new initiative has been taken this year to study the performance of ITER First Mirrors (FM) under erosion- and deposition- dominated conditions. For this purpose Mo mirrors are placed inside the Aditya tokamak. One mirror is being exposed to plasma discharges while the other mirror is being exposed to wall conditioning and plasma discharges. Pre-exposure Optical and surface characterization of the mirrors were carried out by University of Basel and Forschungszentrum Juelich, before putting them in the Aditya Tokamak. Post characterization of the mirrors will be performed when mirrors are taken out after exposing the mirrors for approximately 100 seconds equivalent of plasma discharges.

Neutral Particle Analyzer(NPA): NPA works on the principle of Charge Exchange reaction between hot energetic plasmas with the neutral atoms present in the core. The fast neutrals thus escaping out of plasma core are analyzed by using an electric field and/or magnetic field to separate the energy components.

The Aditya Charge exchange System has been upgraded for suppressing the Vacuum Ultraviolet radiations from plasma. Additional components were fabricated and added to the system and were successfully tested for vacuum down to 10^{-6} torr (figure A.1.1.3.4). Signal to noise ratio was also tested with standard VUV source and the results showed more than 98% of improvement in the ratio

The four channels of the System have been calibrated

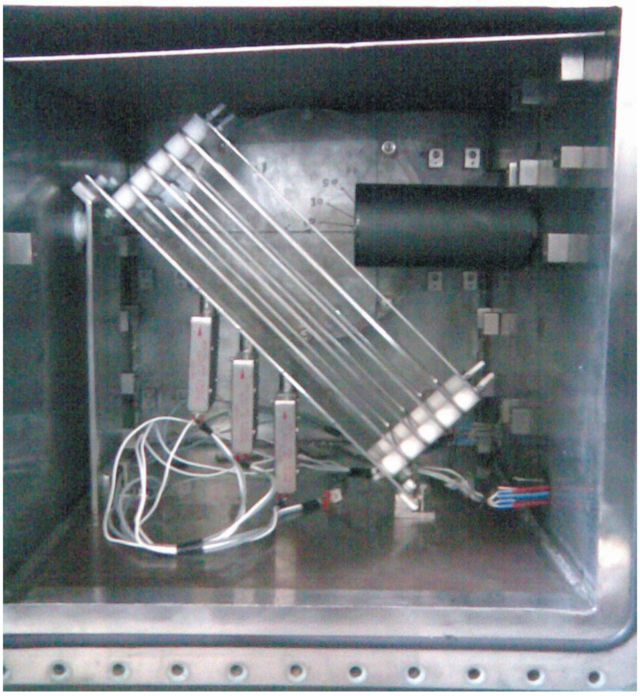


Figure A.1.1.3.4 Photograph of 45° Parallel Plate Electrostatic Energy Analyzer

using the Hydrogen ion source. Now the calibration data is available for all the four channels [CEMs] from 100 eV to 600 eV of H+ ions (figure A.1.1.3.5). The system is ready for testing the Signal to Noise ratio and for estimating the core ion temperature in capacitor shots and/or APPS shots of Aditya.

Time of Flight Neutral Particle Analyzer: The Charge-exchange neutrals escaping from plasma are mechanically chopped into bunches and made to traverse through a sufficiently long path called a flight tube. They afterwards fall on a secondary emission surface and the secondary electrons are registered by a detector. As a result of energy spread in the incoming chopped beam, the neutrals hit the detector at different time i.e., the energies are resolved over time a time scale (~ µs). For a moderate core ion temperature of ADITYA (~ 50-80 eV), Time of Flight method has been adopted as an option.

Status: Conceptual design is over and preliminary parameters have been worked out (figure A.1.1.3.6). Engineering design and drawing is going on. Procurements of the components are in process.

A.1.1.4 Heating and current drive systems

Ion Cyclotron Resonance Heating System (ICRH): After upgrading the Aditya ICRH system it was felt necessary to improve the impedance matching range of

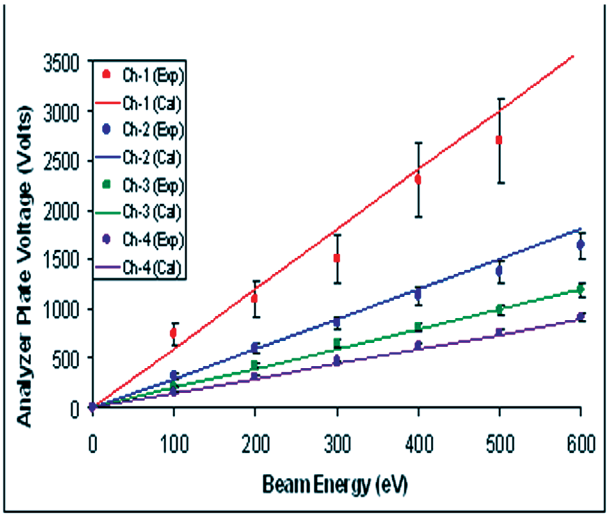


Figure A.1.1.3.5 4-Channel Calibration plot for 45° Parallel Plate Electrostatic Energy Analyzer

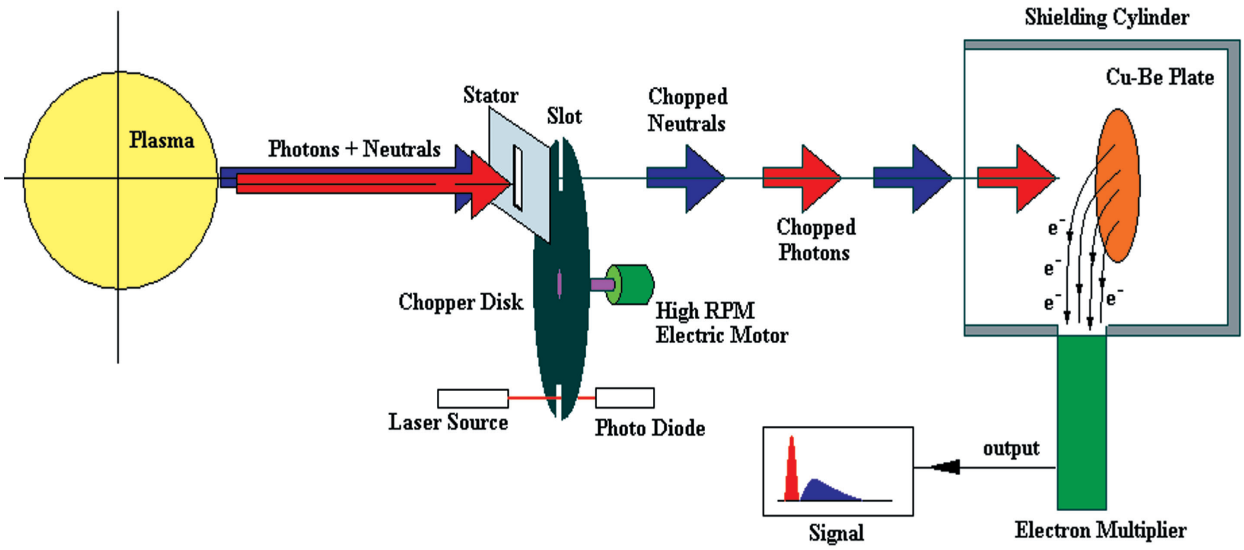


Figure A.1.1.3.6 Schematic of the Time-of-flight neutral particle analyzer planned for aditya tokamak

antenna plasma matching. Previously one phase shifter and one stub were installed in the line. Recently one more liquid phase shifter and liquid stub are added so that the system can cover wider antenna-plasma matching. Experiments of fast wave heating will start soon.

ECR Pre-ionization experiment: Second harmonic 'X' mode low field side launch pre-ionization / start-up experiments have been successfully carried out at relatively low microwave power ~ 1 to 2 kW / 2.45 GHz. with TE-10 output mode in Aditya tokamak.The operational window for consistent pre-ionization/start-up in Aditya has been explored. Further, low ohmic loop voltage (~ 1.6V/m) operation for a plasma current of ~ 10 KA has been successfully established. A lower ohmic loop voltage ~1.1V/m (without the aid of microwave power) did not yield to successful start-up in the tokamak. With microwave assisted pre-ionization and the aid of a vertical magnetic field of several *mT* at the plasma center, plasma current of ~ 100 to 350 A could be initiated.

A.1.1.5 Experiments

Measurement of plasma fluctuation using Mach-probe: The Mach-probe diagnostic has been installed during last vacuum vessel opening for direct measurement of plasma flow velocity along the field line. The probe is mounted on a movable shaft and can be placed up to 29 mm inside of limiter. At present it is oriented along the toroidal direction. After vacuum break it can also be oriented along poloidal direction. The fluctuation measurement with Mach probes is carried out with and without H_2 gas puff. This experiment was carried out by introducing a short puff of the working gas during the flat-top phase of the Aditya capacitor discharges using a Piezo-electric valve. The quantity of hydrogen gas passing through the valve was determined and found to be approximately 10^{18} molecules of hydrogen gas being introduced into the plasma. The pulse width timings and voltage level, time (T) for gas-puff to start, number of pulses and the time gap between the pulses as per experimental requirements was controlled and varied with pre-programmed gas-puff system. Plasma positions and plasma current float-top has been maintained to get the reliable data for fluctuation studies.

Comparison of plasma flow measurement by magnetized and unmagnetized Mach probes : A study has been carried out on comparison of plasma flow measurements in the scrape-off layer plasma of ADITYA tokamak by using magnetized and unmagnetized Mach probes. Such measurements are necessary to establish a relation between both measuring techniques. The general formula for the flow measurement is $M=k\log(I_{su} / I_{sd})$ where

M is the flow Mach number, I_{su} and I_{sd} are upstream and downstream ion saturation currents respectively and k is a model dependent constant. The model of magnetized Mach probe is widely recognized, but that of unmagnetized probe is not so well accepted. On the other hand, construction and use of magnetized probe in low magnetic field plasma experiment is difficult because the probe size becomes large. Therefore experiments were conducted in order to establish a relation between Mach numbers measured using magnetized and unmagnetized probes.

Figure A.1.1.5.1 shows a top view of a configuration for simultaneous measurement of Mach numbers using these probes. The magnetized Mach probe consists of a pair of tungsten plates of dimension 6mm X 4mm separated by boron nitride dielectric of 9 mm. The unmagnetized Mach probe consists of molybdenum wires of 1 mm diameter and 4 mm length and they are placed at a distance of 3 mm from the tungsten plates. These probes are biased at -100 V with respect to the signal ground in order to collect ion saturation currents. The present experiment is carried out during capacitor bank discharges of ADITYA tokamak. The discharge parameters are as follows: plasma current ~25 kA, toroidal magnetic field ~0.2 tesla, central plasma density ~6x10^{19} m-3 and plasma duration ~25 ms. The ion saturation currents are measured in a number of discharges when Mach probes are placed just behind the leading edge of the scrape-off layer plasma. The probe is ~530 mm away from the limiter in the ion drift direction and ~95 mm in the electron direction. The Mach numbers are estimated by assuming k=0.43 for magnetized probe (Hutchinson model) and k=0.25 for unmagnetized probe (Hudis model). Figure A.1.1.5.2 shows estimated values of Mach numbers from a large number of discharges. By combining data from several discharges, plasma flow measurements could be compared. The measurement shows that the magnetized Mach number range is from 0.1 to 0.55 and the un-magnetized Mach number range is from 0.01 to 0.17. From these measurements it can seen that the unmagnetized Mach number is ~1/3 times of the magnetized Mach number. Therefore it is concluded that sensitivity of unmagnetized Mach probe for plasma flows is less than that of the magnetized Mach probe. In the unmagnetized probe, the difference between the upstream and the downstream side ion saturation currents is not very large. On the other hand, this difference is quite large in case of magnetized Mach probe. A careful interpretation of the data in terms of flow dynamics and behavior of the two probes in flowing plasma is being considered at present.

Fluctuation suppressions : The suppression of fluctations by application of gas puff has been observed during the capacitor bank discharges also. In addition to that, the electron density also found to be peaking-up, the hard x-rays being suppressed and the plasma current becomes more flatter after gas pulse is applied.

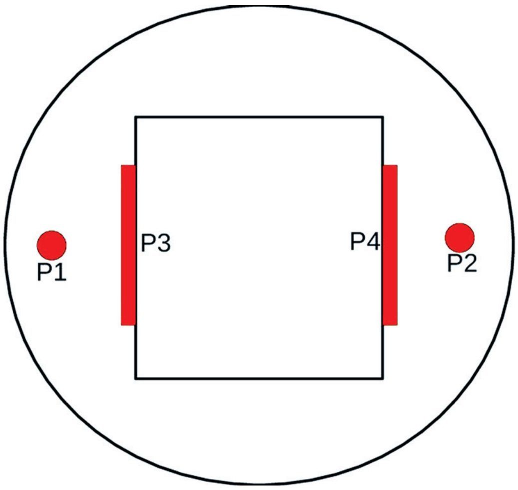


Figure A.1.1.5.1 Top view of the Mach probes

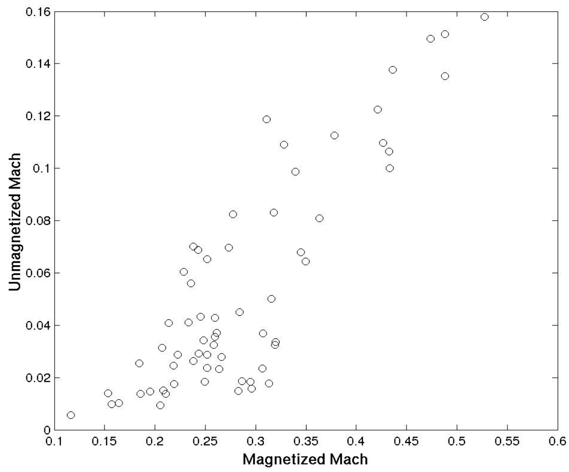


Figure A.1.1.5.2 Mach numbers measured simultaneously by the magnetized and unmagnetized Mach probes.

A.1.2 Superconducting steadystate Tokamak-1 (SST-1)

A.1.2.1 State of the device

SST-1 group 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 towards the refurbishment of the SST-1 machine leading to the first plasma by 2011. The problem areas in the SST-1 have been identified in sufficient details and have been reviewed by experts having domain knowledge on both sub-system and system level. Subsequently, remedial action plans have been put into places on various aspects such as process validation, technology development, testing, experimental prototyping etc. Some of the significant activities and progresses on SST-1 during 08-09 have been in the areas of spare Toroidal magnet test with new joints and terminations together with 10kA current leads in the experimental cryostat employing SST-1 cryogenic facilities, experimental validation of the new terminations and joints, cable-in-Conduit-Conductor (CICC) loop hydraulic characterization tests, Cold Circulator operations in the Cryo-facility as a first step towards the supercritical operations, 10 kA Current leads performance validation with extremely long pulses exceeding an hour, adopting novel concept at 80 K Thermal Shields in the SST Tokamak, process validations of the repair of the SST-1 vacuum vessel baking channels, attempts at commissioning of facilities for SST-1 baking system and designing the baking chamber, two TF coil and vessel sectors assembly trails as one-eighth of the SST-1 machine shell, developing a web based SST-1 Information Management System (SIMS), initiating integrated tests of the data acquisition systems with simulated diagnostics and control interfaces, Long operations of the Power Supplies with VME controls etc.

A.1.2.2. Technological Developments

Spare TF Coil Tests: A full-fledged TF spare Coil test facility has been realized in the Cryogenic Hall. The spare TF coil was tested in this facility with an aim at experimentally demonstrating leak tight low DC joint resistances between the CICC terminations of the winding pack at 10kA of transport currents. The campaign began in the summer of 2008 and was carried out twice. As a pre-requisite to these campaigns; the subsystems level demonstrations such as the low resistance measurements and related instrumentations, supporting vacuum facility establishment, electrical interfaces and instrumentations, communications protocols etc were also established. During these campaigns, it was also possible to pass 10kA of current in the winding pack and hundreds of pico-ohm of DC resistances was obtained in the joints of the winding pack. However, insulation related accident has necessiated a repeat of these experiments which will be done in a near future. The test facility and some of the essential components are

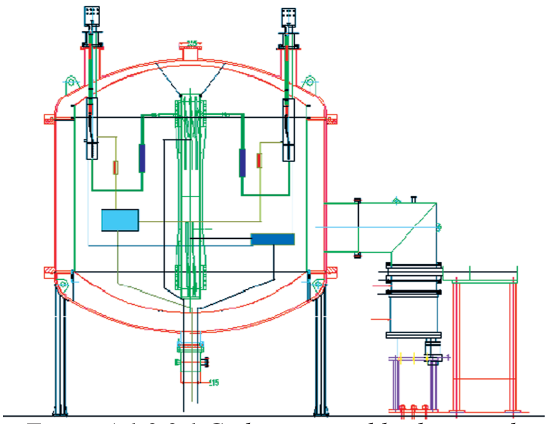
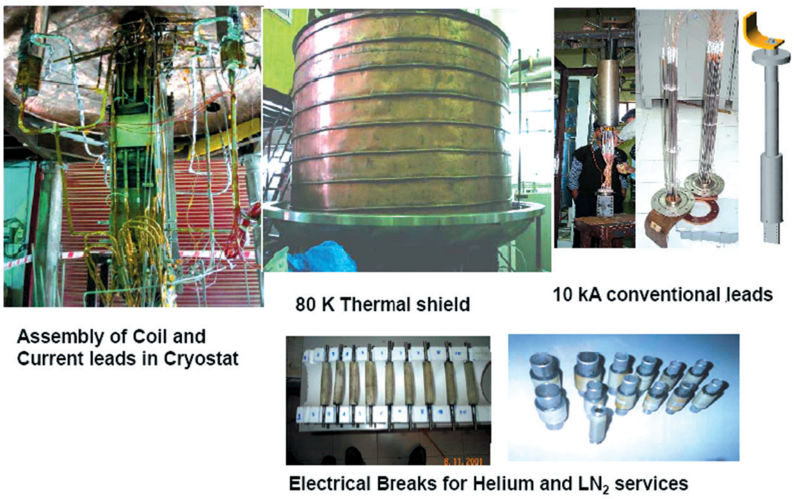


Figure A.1.2.2.1 Coil test assembly showing the current leads and vacuum system and some basic components



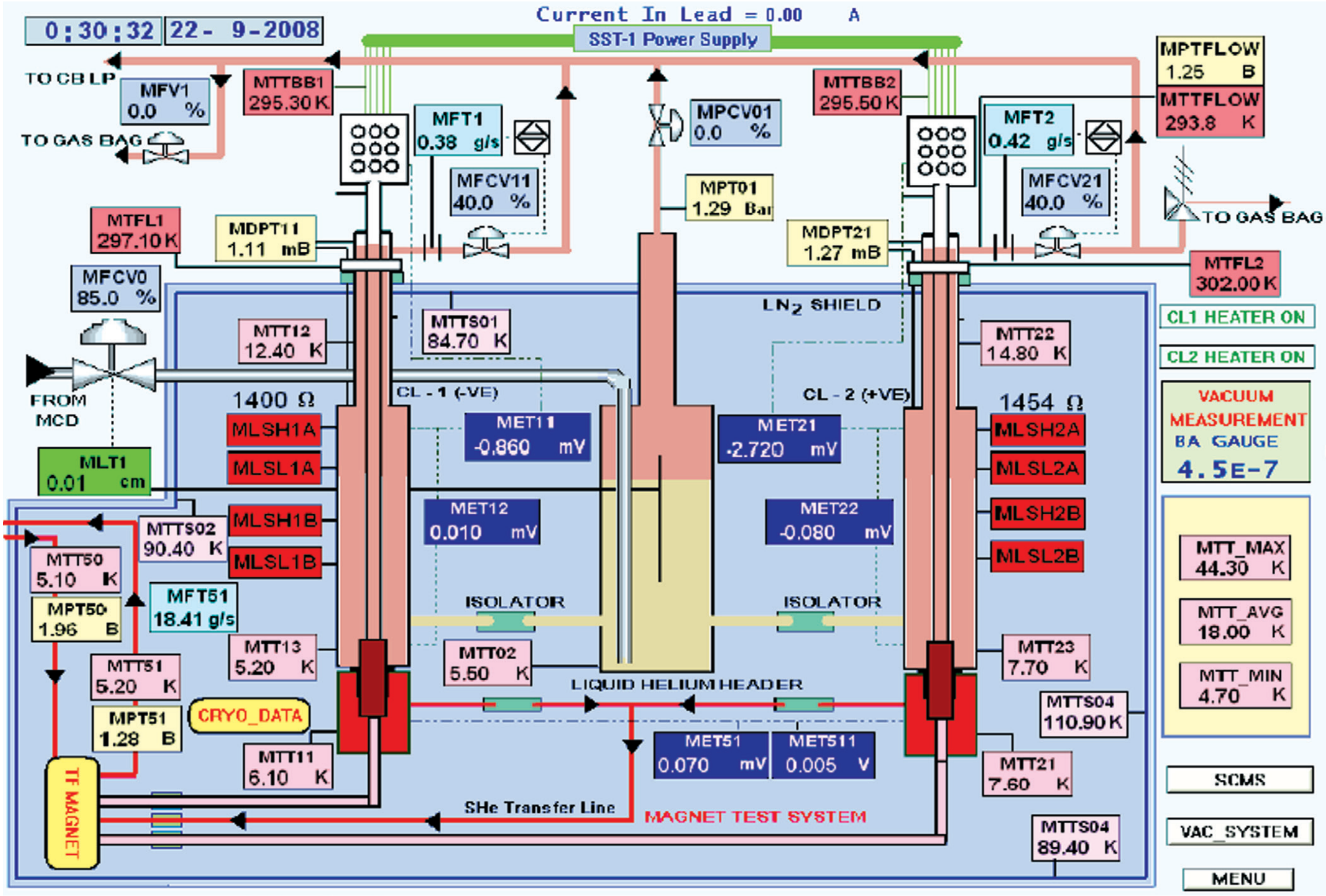


Figure A.1.2.2.2 MIMIC developed and used for the Current Feeder System during the test

shown in the figures A.1.2.2.1 .The mimic developed and used in these tests is shown in figure A.1.2.2.2. whereas the controlled cool-down, pressure is shown in Figure A.1.2.2.3.

Joint validation test assembly along with the current leads: Conduction cooled joints involving the SST-1 CICC have been tested successfully with 10kA of transport currents over 3600 seconds. Two such joints in a loop of SST-1 CICC were successfully cooled down using forced flow SHe at the inlets (figure A.1.2.2.4). Subsequently, the joints were successfully charged up to 10kA. The DC joint resistances were observed to be ~ 200 pico ohms and were very stable through out the current pulse.

CICC Loop Hydraulic Characterization Test: The hy-

Figure A.1.2.2.3 Controlled cool-down of the Spare TF coil during the tests

Figure A.1.2.2.4 Joint validation test Assembly in Test cryostat

draulic characterization test on a ~ 10 m long SST-1 CICC loop has been performed. The CICC loop was cooled down to about 5 K using supercritical helium. Hydraulic test for the loop were performed without charging any current. During this test, the cold circulator CC 409 was also successfully run for the first time after its commissioning.

80 K Thermal Shields for SST-1: The superconducting magnets of SST-1 operates at 4.5 K temperature whereas surrounding Vacuum vessel and cryostat remains in the range of 323 K – 523 K during normal as well as baking conditions. The whole cold mass is enclosed by 80 K thermal shield in order to minimize the radiation heat-in leaks from the ambient (300 K). 80 K thermal shield of SST-1 has been modified since last time in order to eliminate the non-uniformity in the temperature distribution and flow imbalances between various parallel branches. A concept of bubble panels with supercritical LN2 has been adopted as shown in figure A.1.2.2.5. Bubble panel specifications for LN2 shield of SST-1 are mentioned in the folowing table.:

Type of the panel	Bubble / pillow / embossed / dimple-t
Material of construction	SS304L / SS316L
Working temperature range	80K – 300K
Coolant to be used	LN_2
Cooling loop	Inlet/supply at bottom and outlet/return at top
Allowable temp. on the panel	≤ 85K (max.)
Allowable He leak rate	< 10^{-8} mbar-l/s at service conditions
Estimated Heat loads at 80 K	18.5 kW for Normal and 70.5 kW for Baking

Augmentation and modification of facilities: Towards the refurbishment of SST-1, several sub-system level and component level augmentation and modifications have been carried out. IFDCS (integrated flow distribution system) PLC control panels have been made dust-proof inside the control panel. In order to connect field I/O to PLC, an advanced TELEFAST module has been put in place. All the PLC modules have been rewired and configured as per actual connections.

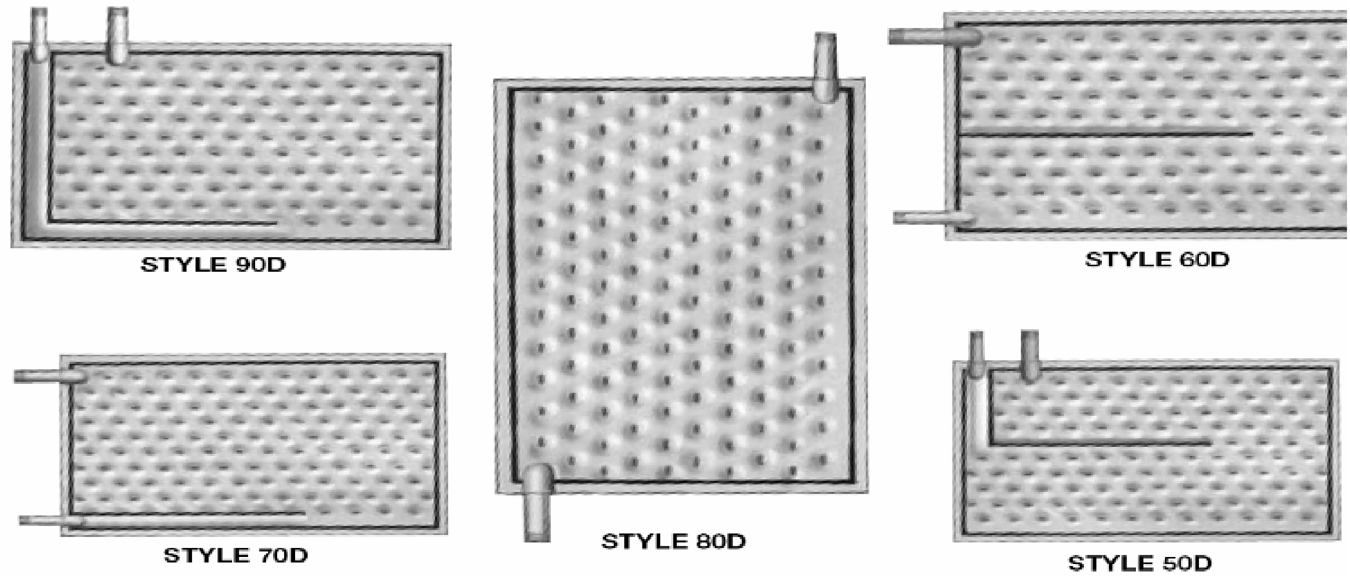


Figure A.1.2.2.5 Bubble pannel concept.

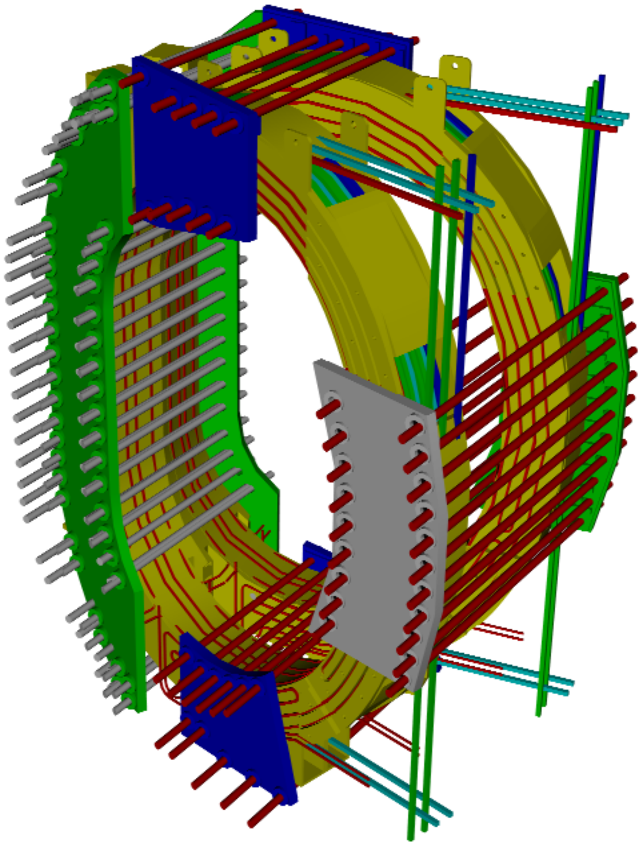


Figure A.1.2.2.6 Two Coils assembly

Enhancement Of Supervisory Control And Data Acquisition Systems (SCADA) Of SST-1 Cryogenic System : The Cryogenics System of SST-1 has various sub-systems such as Helium Refrigerator/Liquefier (HRL), Integrated Flow and Distribution Control System (IFDCS), Current Feeder System (CFS) and Nitrogen Management system. Each subsystem has dedicated control systems consisting of programmable logic controllers (PLC), Program Stations and Supervisory Control and Data Acquisition (SCADA) system. The SCADA of each sub-system is configured and communicated to individual PLC over serial or Ethernet link. Individual SCADA applications are developed in Citect and Wonderware software for interactive process commands, monitoring, control, data acquisition as well as data retrieval of various physical parameters. An application on Sequential Query Language (SQL) database of Wonderware software has been conceptualized, developed and commissioned. It involves configuration of different SCADA and PLC systems with their process parameters for establishment of communication over Ethernet network to centralized database with Object-linking and Embedding for Process Control (OPC) and proprietary protocols. The server based data acquisition and data retrieval system have been successfully operationalized during the coil tests.

SST-1 Magnets Tests: It has been envisaged to test two TF magnets of SST-1 together in an extended experimental cryostat in order to save the SST-1 refurbishment time. All necessary electromagnetic analyses and supports design towards the test of two assembled SST TF magnets have been completed. The experimental chamber augmentation has been designed. The 80 K shield for the experimental chamber with appropriate breaks has also been designed.

Hot Nitrogen Baking System of SST-1: The SST-1 vacuum vessel is designed to be baked up to 150^{o}C with the help of hot nitrogen. The hot nitrogen would flow inside the vacuum vessel baking channels, which have been laid and welded on the surfaces of the vessel sectors and modules. The hot ni-

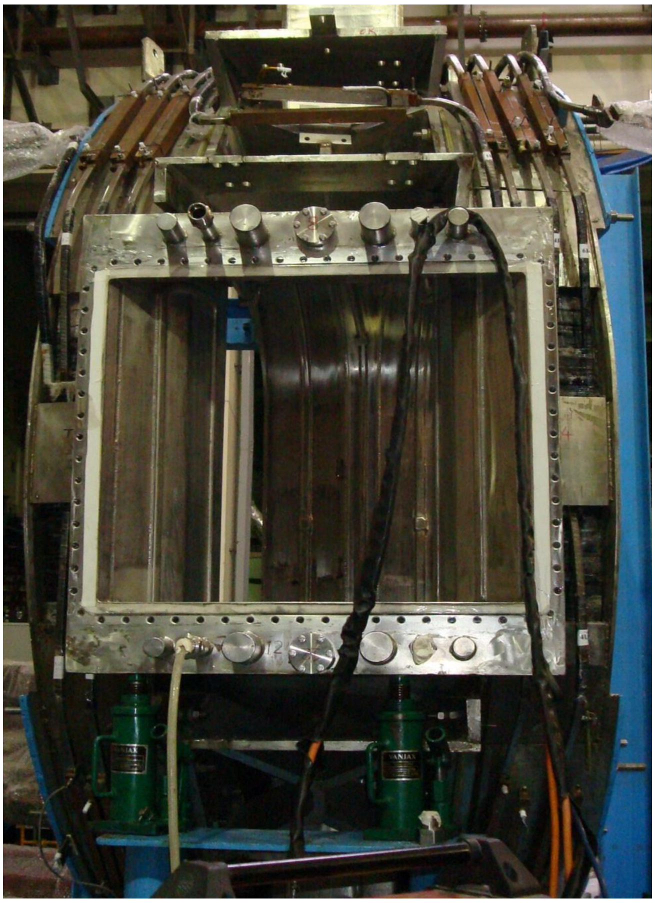


Figure A.1.2.2.7 SST-1 Module assembly trogen baking system of SST-1 has been commissioned with programmable control logics. The operation of this baking channel has been tried out on a vessel sector. A dedicated baking chamber has also been designed and is under fabrication where all of the vessel modules shall be baked and tested prior to their assembly on the SST-1 Tokamak.

SST-1 Operation & Control :SST-1 operation and control is the central control for several sub-systems during the operations such as SST-1 Magnets, SST-1 Cryogenics, SST-1 Vacuum, SST-1 Power etc which are based on heterogeneous platforms with varying sampling rates. Time synchronization of all these sub-systems prior to as well as during the plasma shots is essential. A GPS based time synchronization has been adopted. Feasibilities of these aspects have been carried out in several trials and are in the process of being implemented.

SST-1 Module Assembly: The re-assembly sequence of SST-1 has been worked out. It will be modular with a module consisting of a pair of prepared TF magnets, helium cooled TF case screens, 80 K bubble type thermal shields both towards the cryostat side and vacuum vessel side, a vessel sector and two interconnecting rings along with the top vertical port. A mock assembly has been carried out to work out the sequences of assembly, to measure the clearances between the TF coil cases and those of the shields etc. This module will be tested in the test cryostat prior to the assembly on the SST-1 machine.

SST-1 test instrumentations: SST-1 test instrumentations and improvements in measurement techniques have been one of the emphasized aspects of the SST-1 Mission activities. Reliable measurements of the low temperature with desired stabilities, reliable measurements of the pressure, flow, strain etc, reliable measurement of extremely low resistances of the order of nano-Ohms in tens of cryogenic environments apart from quench voltage measurements have been achieved. The quench detection system has been improved with stable reference generator, increase in counter size, input filter protection, opto-isolation between input and output sections and digital driver for driving quench signals.

SST-1 Data Acquisition: SST-1 Data Acquisition is responsible for catering to the data obtained during the SST-1 plasma shots for various diagnostics. The data acquisition system acquires the data in the desired formats from front-end signal conditioning units, processes it and then delivers the data in a desirable format for the diagnostics users. In the absence of plasma shots and engineering validation of the integrated testing of the data acquisition system for the minimum number of diagnostics of SST-1 has begun with simulated signals, signal conditioning cads outputs, necessary triggers from the central controls with the data acquisition modules. These integrated tests are planned diagnostics-wise as per their sampling rates in both fast and slow modes. These tests would validate the engineering aspects of the performances when all associated sub-systems are integrated.

SST-1 Auxiliary Sub-system: SST-1 has a pair of TF current leads and nine pairs of PF current leads. These current leads are guided through cryostat port sixteen and fifteen respectively to a dedicated current lead assembly chamber (CLAC). The CLAC is a very complex aspect of SST-1 as there are integration of low DC resistance joints, electrical isolations, cryogenics supply and return lines and a host of measuring devices and instrumentations. The CLAC has been modified with the objectives of accessibility in joint making, joints displacement, repair feasibility of the cryogenic lines and isolators and piping. The CLAC has been changed from a vertical geometry to a horizontal cylindrical geometry.

A.1.2.3. Diagnostics development

Subsystem developments and testing in SST-1 Thomson scattering system : Window testing: the UHV windows to be used in the transport line of Thomson scattering is to be tested for its transmission properties under different situations. The windows (rectangular, 250mmx140mm) were mounted on a test stand and measured the respective curvature and transmission properties under UHV condition.

Design and testing of control circuit for filter polychromator: A micro controller based controller circuit is designed and tested with one of the detector channel. The detector is set for high gain, so it is very sensitive to temperature fluctuations and background light. A constant monitoring of temperature and light levels are required for the safe operation of the detector. The developed controller circuit monitors the temperature of filter polychromator and detector using a RTD attached to it. The circuit also acquires the slow output of the detector and stores the data for the further analysis. The slow output is used for the timely calibration of detectors. The gain and biasing voltage of the APD are also set through the controller circuit. The capability of the circuit is to extend for the entire five modules of a filter polychromator and this work is in progress.

Developing the program for control and calibration of filter polychromator: SST-1 Thomson scattering system is designed for multi point imaging (8 to 27). The measurement from each point requires monitoring and data acquisition of five detectors. A Lab view based program is developed for monitoring, controlling and setting various parameters for all the detectors. The program communicates to designed controller circuit through the RS 232 port of PC. The program is integrated with the controller and tested for one detector module.

Design and testing of fast integrator for charge integration: A fast integrator (20 ns) is designed for measuring the intensity of scattered photon reaching each channel. The designed integrator is tested with a standard pulse generator.

A signal conditioning electronics for an IR enhanced thermoelectrically cooled Si-avalanche photodiode (Si-APD) module is developed and tested. Present design of signal conditioning electronics for the APD has fast (50 MHz) and slow (500 kHz) channels to measure scattered and plasma background light, respectively. Design analysis was performed for different stages. The performance of fast channel is analyzed for two different group delays, speed, linearity, and its cross-talk with slow channel. Temperature dependence of APD's responsivity is studied in the wavelength range of 900–1060 nm. A minimum detection of (25 photoelectrons with S/N=1) in the range of 5 to 25 °C is achieved at an APD gain of 75 in the present design (figure A.1.2.3.1).

A.1.2.4. Heating and Current drive Systems

ICRH System

Work for automatic on-line matching of SST-1 plasma impedance with antenna impedance has been completed successfully for both the lines and finally with hybrid coupler and both the lines simultaneously. Variable load impedance could be matched with the help of variable capacitors and stubs in less than 40 ms, which is better than that of many other tokamaks.

RF group is developing 180 kW, 1 MHz rf generators for NBI Group. The conceptual design has been completed. All the components are finalized and many important indents have been raised. The engineering design of the rf generator is in progress.

In order to make ICRH systems of Aditya and SST-1 tokamaks independent, many power supplies are required which were in the process of fabrication and procurement and most of the work is over now so that we can operate many systems simultaneously.

In order to have 1.5 T operation of SST-1, 45.6MHz at 1 MW is required. The development of 100kW rf generator is in process. The required power supply system is conceptualized and generated specifications for the supply system. Indent has been raised. and purchase process in progress. 2 kW stage fabrication and testing has been completed. 20 kW is being fabricated and fabrication work for 100 kW will start soon. Existing 1.5 MW stage will be tuned to 45.6 MHz to make complete system ready for SST-1 machine.

Development of 70kV, 22A HVDC facility for testing high power microwave devices is in final stages. It consists of 11 kV voltage variation system, solid state crow bar system and HVDC rectifier system. The 11kV Voltage Variation system of rating 2MVA has been tested successfully and installed at IPR. The solid state crow bar system is finalized and order will be placed soon. The HVDC rectifier unit has arrived at IPR and has been installed recently. The testing of the complete system will start after installation of control panel.

1 MW RF generator at 91.2 MHz is planned for SST-1 machine, which consists of 2, 20, 200 and 2 MW stages. The testing of 2 and 20 kW RF generators has been completed at full power. 200 kW stage is in progress. 2 MW tube has been tested at factory for full power and now the design of 2 MW stage is in progress, which includes simulation, fabrication of cavity, assembly and testing with dummy load. The procurement and the fabrication of all the power supplies for final stage has

been completed.

Rigid co-axial transmission line components like 6" TEEs, reducers, directional couplers which are to be used at 350 MHz, 120 kW power for BARC have been fabricated, tested and supplied to BARC, Mumbai.

Fast Ferrite Tuner for on-line antenna-plasma matching: During fast wave ICRH experiments on tokamak plasmas, large and fast plasma load changes may occur. Hence a device is needed to match antenna impedance to the generator impedance on a faster time scale for delivery of maximum power. In addition, power delivered by tetrode-based amplifier is a strong function of SWR at its position. Thus impedance matching plays very important role in ICRH scheme. Minimum response time achieved by using methods other than FFT is 40-50 ms. FFT is designed for input power of 600 kW, Insertion loss < - 0.15 dB, Return loss > 25 dB, Response time for matching (ρ <= 0.65) with active feed-back <= 6 msec. Its accessible mismatch region is reflection coefficient ρ <= 0.65 with all phases.

The complete yoke assembly along with inner and outer conductors arrived at IPR. FFT yoke is tested for 300 A current. The magnets are fixed to the assembly and now fixing of ferrites to inner conductor will start soon. For testing FFT one needs generator, stubs, pressurized transmission line, probe section, gas barriers and dummy load. All the components of the test-set-up are in the process of design. PLC based feedback control system is being developed. +-600 A current power supply to vary the current of electromagnet has arrived at IPR after successful factory testing and will be installed soon.

The design, development of 30 kW system to be supplied to IUAC has been completed. The 3" transmission line technology was developed at IPR and has been fabricated from the local vendors. Recently 30 kW system is supplied to IUAC, New Delhi. Final testing will be done at IUAC by IPR staff along with IUAC staff.

LHCD System:

The activities related to up gradation of the LHCD/ SST-1 system is in progress. The support structure accommodating four klystrons and its high power components have been fabricated and installed in LHCD area in RF-bay of SST-1. The cooling lines are being modified to cater the additional requirement of water-cooling. The magnet power supplies for additional two klystrons have been procured and tested for its performance. The filament power supplies are under fabrication. Activities related to designs and procurements for Data acquisition and control system for the new scheme has been initiated. The low power rf amplifiers; which would be used in driver stage for the klystrons have been tested. The contract for the procurement of two additional klystrons is signed.

Activities for the use of Regulated High Voltage Power Supply (RHVPS) for the four klystrons have been initiated. The RHVPS wire-burn testing up to 40kV, 1sec has been realized and preparation to qualify it for rated

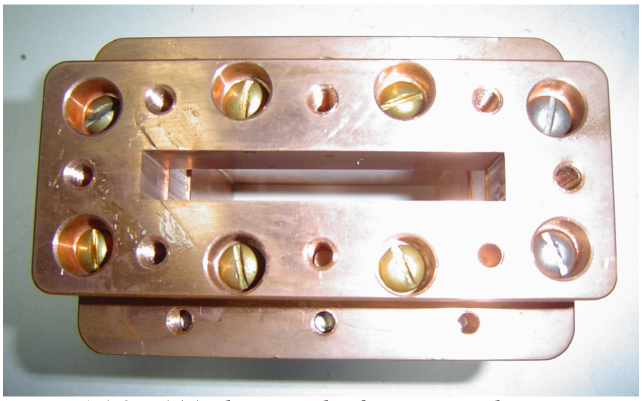


Figure A.1.2.4.1(a) photograph of proto-type three-step waveguide transformer

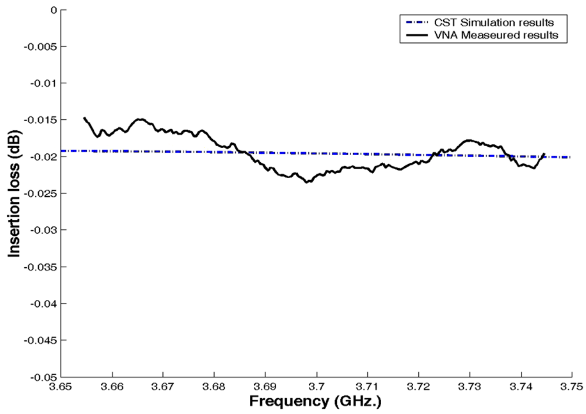


Figure A.1.2.4.1(b)The insertion loss measured using VNA is compared with CST simulation results for the proto-type waveguide transformer.

power is under progress. The civil work for installation of 11 kV regulator and high voltage DC power supply is completed. The 11 kV regulators have been installed. HVDC power supply has been received at IPR and is being installed. The procurement of solid-state crowbar system is under process

LHCD has transforming (outvessel) module in the LHCD/SST-1 to transform the standard WR-284 waveguide to non-standard 76X7 mm waveguide. The essential component of this system is Waveguide transformer. The transformer is designed to yield a Tchebycheff-type reflection co-efficient response over a desired bandwidth (3.6GHz – 3.8GHz). Further it is modeled, simulated and optimized using commercially available standard software, namely CST microwave studio simulation software. A proto type transformer is fabricated and its rf parameters are measured on Vector Network Analyzer (VNA), which shows good agreement with our design specifications. The photograph of the waveguide transformer and its CST result and measurement result is shown in the fig. A.1.2.4.1(a) and (b).

The design and analysis of 500kW, 1000sec high power water load has been carried out employing CST microwave studio software. Various models have been considered and are being analyzed. The activities to develop the high power load have been initiated.

A ramp generator circuit for probes diagnostics using micro-controller is designed and developed for remote operation. The various parameters like ramp-up rate, trigger mode, no of cycles etc. can be set through the PC using RS485 serial link so that edge parameters of the plasma near the antenna could be measured for different plasma durations by setting appropriate parameters remotely.

The performance of lower hybrid waves for SST1 plasmas has been studied using LUKE simulation code. The temporal performance of SST1 plasma, employing lower hybrid waves is also studied with CRONOS code to carry out predictive analysis of the plasma as it evolves from Ohmic plasma to fully non-inductively supported plasma using lower hybrid waves only. These studies were carried out in collaboration with CEA, France and formed the basis for transfer of above two codes, namely LUKE and CRONOS code, at IPR. These codes have been successfully installed at IPR for future studies.

ECRH system:

All the interlocks (fast and slow) for the protection of 82.6GHz Gyrotron are tested sequentially for their reliability. Additional interlocks for power loss in the gyrotron window and for silent working of the gyrotron are incorporated and tested for their reliability. The scheme of CVD window test is finalized and a SS mirror box is fabricated to test CVD window on water dummy load.

High voltage tests are carried out prior to gyrotron testing at IPR. The 10joule wire-burn test was performed at full operating voltage (~42kV) to ensure the safety of gyrotron.

The gyrotron is tested at IPR in pulsed condition as well as in CW mode. The burn pattern at the exit of gyrotron ensures good gaussian output from the gyrotron. In CW mode, gyrotron is tested for ~ 60kW power for 1000s.

New crowbar firing cards are designed, fabricated and tested for system reliability during high voltage operation. The DAC cooling software has been further upgraded for MDS plus based data visualization. The ignitron crowbar system is under development. A 3.0kV trigger module is developed for the system.

A.1.2.4. Neutral Beam Heating System

The major activity during the year 2008-2009 is readiness of NBI test stand for operation of Positive Ion Neutral Injector (PINI) ion source which would deliver 5 MW hydrogen ion beam power at 55 kV. Prototype ion source has been replaced by PINI ion source. Interceptor plate has been removed and V-target is placed inside the vacuum vessel. Differential calorimeter is placed behind the V-target. The other important activities are up gradation of gas feed system, water and electrical connection to the beam line components. Wire burn test has been done for Regulated High Voltage Power Supply (RHVPS) designed for PINI ion source.

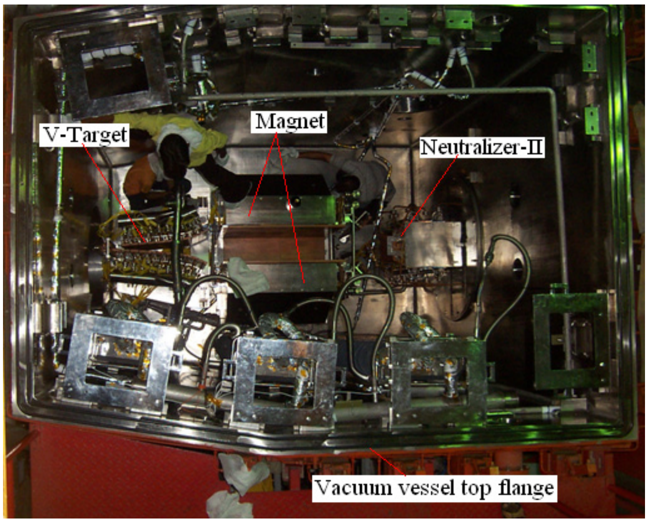


Figure A.1.2.4.2 View of the NBI components placed inside the vacuum vessel.

Neutral beam line commissioning: During prototype ion source experiment, the extracted hydrogen ion beam profile was measured by an interceptor plate placed behind magnet. This plate has been removed and V-target is placed is shown in figure A.1.2.4.2. This would measure the horizontal beam profile and a differential calorimeter is placed after V-target for measurement of vertical beam profile. All the beam line components are aligned with the PINI ion source mounted with gate valve attached with vacuum vessel. The view of magnet liner, neutralizer and earth grid is shown in figure A.1.2.4.3. The vacuum vessel is pumped with turbo molecular pump of pumping speed of ~ 3000 l/s and vacuum of 10^{-5} Torr is obtained.

PINI Ion source: After assembly of the PINI ion source at clean room of NBI laboratory, activity has been carried out for transportation of the PINI ion source to the location of Gate valve connected of the vacuum vessel and mounted. Various tools and fixtures needed for this work have been procured. Transport jigs (sent by vendor) have been modified to use the same for mounting purpose. First dummy mock has been carried out for confirmation of safe transportation and mounting scheme. Then actual PINI has been transported to the specified location of the vacuum vessel and mounted is shown in fig.3. Non conducting water hose pipe (figure A.1.2.4.4) has been procured to supply pressurized deionized water to PINI ion source and work for cooling connection is under progress.

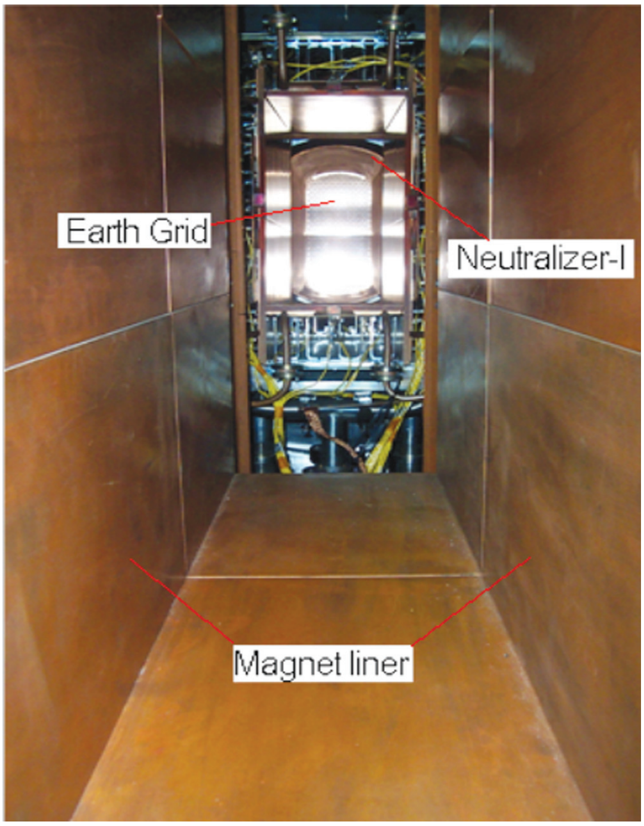


Figure A.1.2.4.3 View of magnet liner, neutralizer and earth grid.

Gas feed system: The gas feed system for ion source and neutralizer is upgraded from the present 5 torr-lit /

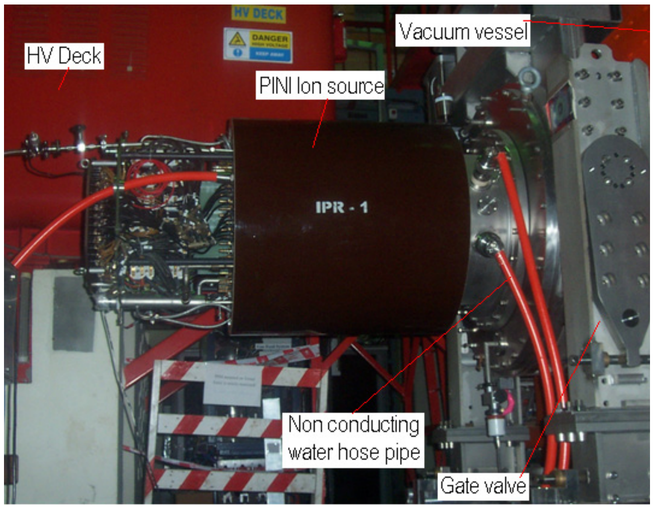


Figure A.1.2.4.4 PINI ion source is mounted on vacuum vessel sec to the PINI requirement of ~ 80 torr-lit/ sec. Certain modifications were made in the fiber optic trans-receiver of this system for improving its stability and ruggedness. Integration of this subsystem with PINI is completed.

NBI Cryoplant: The NBI team operated the 3.8 K LHe cryoplant independently and LHe was produced in the Dewar. Internal cryogenic lines of the vacuum vessel were checked for leaks. Work related to electrical isolation of cryogenic system from vacuum vessel has been completed. Besides, maintenance and up gradation of the 3.8 K LHe cryoplant was also carried out.

Wire burn test for RHVPS : Wire burn test is mandatory for any low stored energy power supply to prove the level of energy.

Regulated high voltage power supply (RHVPS) is applied to ion source and RF loads (Klystron, gyrotron and tetrodes). These loads demand a low stored energy from power supply in case of fault. Fast turn off at short circuit like faults at the output of RHVPS as well as very low energy delivered in load is to be tested. Wire burn test is the proof of principle for the low stored energy for RHVPS. A test setup was made for this is shown in figure A.1.2.4.5. Test results showed energy deposited in fault less than 10 Joules. A short circuit is made at output of RHVPS and power supply output is turned OFF within 1 microsecond.

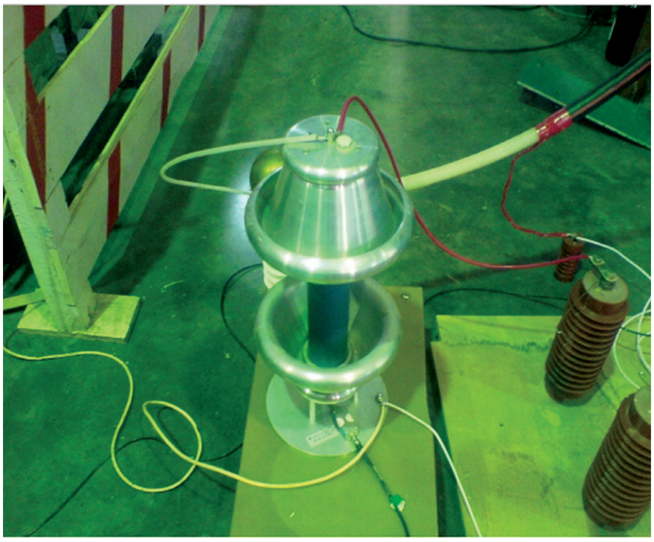


Figure A.1.2.4.5 Experimental set up for wire burn test for RHVPS

Data acquisition and control system: An experiment was devised to study the effect of conduction and electromagnetic radiation noises on the thermal sensors (diagnostics), their cables and signal conditioning units. It was found that the noises could be eliminated by (a) improving the EM radiation shield of the thermal sensor cables and (b) by introducing optical isolation in the first stage of the signal conditioning unit. Both these steps are now being implemented on the thermal diagnostics.

A detailed analysis was performed on the data obtained from spectroscopic diagnostics. It was found that excited states with long radiative life times and presence of water vapor (impurity) affect the spectral analysis. These effects have been taken into account in the analysis algorithm for improving the accuracy of measurement of ion and neutral species ratios

Safety measures related to electrical systems and hydrogen handling is being implemented. Safety protocols are being built into the operation sequence. Following this the operation of PINI shall be taken up.

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A.2 Fusion Technologies Development under XIth Five Year Plan

A.2.1 Prototype Divertor Cassette Development for Fusion Grade Tokamaks

Prototype Divertors Division of IPR deals with design and development of divertors for fusion grade tokamaks. Major activities carried out by the division during 2008-09 are oriented towards developing fabrication technologies for divertor targets and dome. Technical discussions are also carried out to fabricate divertor cassette body, development of new tungsten based materials, NDE/NDT techniques for study of materials and joints. Other activities included procurement of tungsten and Carbon-Fibre-Composite materials, procurement of 3-D coordinate measuring equipment and procurement of pressurized water supply system.

Details of activities are as follows:

(a)***Divertor target development:*** Development of technologies for fabrication of divertor target elements has been initiated. A MOU titled - '*Development of fabrication technology and prototypes of divertor target elements using W+1%La_2O_3 tungsten alloy in mono-block geometry for plasma facing components of fusion grade tokamaks*'– is signed between IPR and NFTDC (Hyderabad) in Sep-2008. Work has been started on joining tungsten alloy monoblock with CuCrZr copper alloy tube using two different techniques viz. Hot-Isostatic-Press (HIP) technique and High-Temperature High-Pressure sinter bonding technique. Preparations for joining of materials including fabrication of fixtures, cutting and machining of raw materials, micro-structural and ultrasonic inspection of raw materials are completed.

(b)***Divertor Cassette Body Development:*** Engineering design & analysis and fabrication of divertor cassette body is a major technological challenge due to complex 3-D structure of divertor cassette body (made of SS316L(N) material weighing 7 - 8 tons approximately) to be designed for different types of loads in a tokamak environment (e.g. thermal, hydraulic, structural, electromagnetic, gravitational, neutronic loads). Three-dimensional drawing of divertor cassette body is generated. Technical discussions are held with some of the relevant external parties to know capabilities for undertaking engineering design and/or fabrication of cassette body and technical inputs required by them for such tasks. Documents containing relevant technical inputs (concepts, engineering and technical inputs, scope of work, etc.) are being prepared for detailed engineering design and fabrication of divertor cassette body.

(c)Tungsten Material Development: Indigenous development of tungsten based materials for divertor target application has been initiated. A MOU titled - *'Powder metallurgical processing of tungsten and tungsten-based alloys for ITER-like divertor components'* – has been finalized between IPR and IIT-Kanpur. Tungsten-Copper Functionally Graded Materials and Tungsten-Alloy materials without and with addition of suitable additives for tokamak divertor applications will be developed using powder metallurgy. In addition to sintering using conventional furnace, alternative sintering process using microwaves will also be attempted t produce the tungsten based materials.

(d)Remote Handling System: Experience is gained by a mechanical engineer of the division in the field of remote handling systems for in-vessel components of ITER Tokamak by participating in various activities including design study of Baseline Transporter Systems for ITER Divertors (such as Casssette Multifunctional Mover (CMM), Cassette Toroidal Mover (CTM) and In-Vessel Transporter (IVT) systems) and ITER Remote Maintenance Management System. This experience will be useful for indigenous development of divertor system.

(e)Procurement of materials and equipments:

(i) Procedures for purchase of different types of tungsten and CFC materials are completed. Received materials are subjected to relevant characterization tests.

(ii) Equipment for precision 3-D coordinate measurements – Portable Arm- is procured.

(iii) Pressurized water supply system suitable for high heat flux tests of test mock-ups is procured.

(iv) Technical specifications of Ultrasonic flaw detector system, IR-Pyrometer and IR-Camera are prepared after

Figure A.2.1.1 Test mockup with (a) Graphite tiles brazed to CuCrZr copper alloy heat sink; (b) with Tungsten tiles brazed to CuCrZr copper alloy heat sink; (c) Comparison of temperature distribution on NAL test mock-up (top) with reference test mock-up (bottom) during transient IR-Thermography at t=20sec after switching from cold water (28^{o}C) to hot water (85^{o}C).

technical discussions with relevant experts at IPR and other DAE units. Procurement of these equipments is in progress.

(f)Brazing technology development: Development of brazing technology for plasma facing components is being carried out at National Aerospace Laboratories (NAL, Bangalore). Test mock-ups fabricated by NAL (see Figure A.2.1.1(a) and (b) are being evaluated using NDT techniques i.e. IR-Thermography and Ultrasomnic flaw detection. Infra-Red Thermography division of IPR carried out transient thermography of test mock-ups by switching flow of water through test mock-ups from cold water loop (28^{o}C) to hot water loop (85^{o}C). Figure A.2.1.1(c) shows comparison of temperature distribution on a reference graphite test mock-up with the test mock-up received from NAL. Non-uniformity in temperature distribution indicates variations in thermal contact conductance at brazed joints. Absorption of heat energy by test mock-up also adds minor non-uniformity of temperatures across inlet and outlet as seen in case of the reference sample.

(g)Development of high heat flux facility: Development of cascaded thermal plasma torch as high heat flux source for thermal performance test of plasma facing components is being carried out at Center of Plasma Physics (CPP, Guwahati). Plasma torch along with mechanism for thermal cyclic loading of targets is made operational. Heat flux from torch is presently limited to 3MW/m^2 (as measured by a calorimeter of 50mm diameter are) due to limitation of DC power supply current rating. Efforts are being made to install DC power supply with higher rating so that heat flux can be improved to desired level of 10MW/m^2. Measurement of 2D heat flux profile of plasma torch is in progress.

A.2.2 Fusion Relevant Prototype Magnet Development

This Project has achieved several significant milestones during the current period. IPR Magnet Division and Atomic Fuels Division (BARC) in a joint initiative made significant progress on realizing the fusion relevant 30 kA NbTi based cable-in-conduit-conductor (CICC). The stage-wise cabling facilities have been developed in-house, the cabled conductor insertion inside the conduit through the pull through techniques have been realized on long lengths, the final swaging and roll forming of the cable on long length has been achieved successfully during this period. As a final outcome of these initiatives, a sixty meter long 30 kA NbTi based cable-in-conduit-conductor has been indigenously realized on Feb 28, 09 having over 500 strands twisted in four stages on a final dimension of 30 mm X 30 mm in square cross sectional shape (Figure A.2.2.1). This CICC would be subjected to several room temperature, cold temperature and electromagnetic validations during the period 09-10. With these achievements, indigenous NbTi based superconducting technologies appropriate for fusion relevant magnets have been realized in the country.

In parallel, green strands of Nb3Sn have been fabricated after suitable optimization of the processes involved through Internal Tin route. The heat treatment sched-

Figure A.2.2.1 30 kA CICC indigenously developed by IPR-AFD(BARC)

ules are presently being worked out. Purification of Niobium (Nb) by solvent extraction processes as seed material for cabothermic reduction towards achieving Hi Ho Niobium has been successfully achieved in a laboratory scale. On the testing and characterization front, a working critical current Jc measuring facility up to 12 T for strand characterization has been commissioned. Towards the development of novel superconductors, up to tens of centimeter long strand and tapes of MgB2 have been realized. A novel radiation resistant Bisphenol F and Cyanate Ester based insulation impregnation system with accelerators of Manganese Acetyl Acetonate in co-catalyst of nonyl phenol have been initiated. Once successful, this insulation system shall be extended to the prototype magnet winding packs. Modifications on SS 316 LN towards a stronger conduit material in laboratory scale have been tried out and the characterizations are in progress. Pre-engineering concepts have been developed for a special purpose winding machine for prototype magnet winding. Fabrication of the experimental cryostat for prototype magnet testing has begun. Engineering design of a vacuum pressure impregnation facility for laboratory testing of insulation and winding pack samples has been completed. Conceptual development of a 30 kA, 30 V power supply for prototype magnet has been completed. A 1000 A power supply for testing the short samples developed has been commissioned. Partial testing up to 1 kA High Tc current leads has also been done.

Validations of 30 kA CICC, several special purpose machines including winding set-ups, experimental cryostats, insulation system development and appropriate materials development are envisaged during 09-10.

A.2.3 Prototype Vessel Sector, Cryopump Development and Pellet Injector Project

Development of a cryosorption cryopump : Good vacuum and good surface conditions are very critical for the performance of a Tokamak. The typical base pressures of 10^{-8} mbar (fuel dominated) between pulses and 10^{-10} mbar for no-fuel components are essential. Considering the aspects such as quantitative recovery of Hydrogen isotopes, operation in time varying magnetic and electric fields, extremely high pumping speeds, Cryosorption pumps operating at 4.2 K meets all the requirements. Prototype Cryosorption cryopump development Project has been taken up under XI plan. Pumping speed aimed for this pump is 50,000 lit/sec. The pumping surfaces or cryopanels of the pump are covered on both sides with activated charcoal adsorbent material which is fixed to the metallic substrate of the panels by inorganic cement. In the pumping mode the panels are cooled with supercritical helium (SCHe) to 4.5K and the radiation shield by liquid Nitrogen at 80K. CAD model of Cryopump has been generated. The model will be used as an input to MOVAK3D

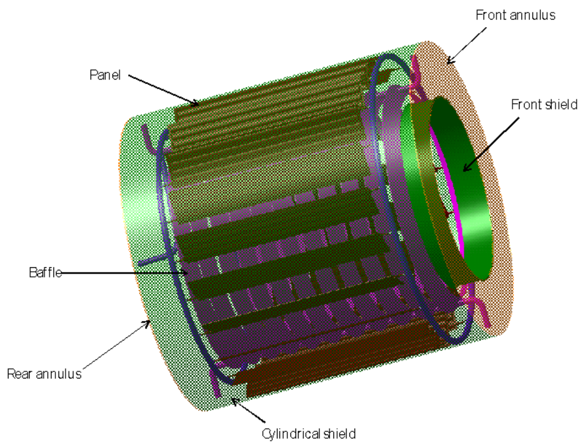

Figure A.2.3.1. Multipanel Cryosorption cryopump

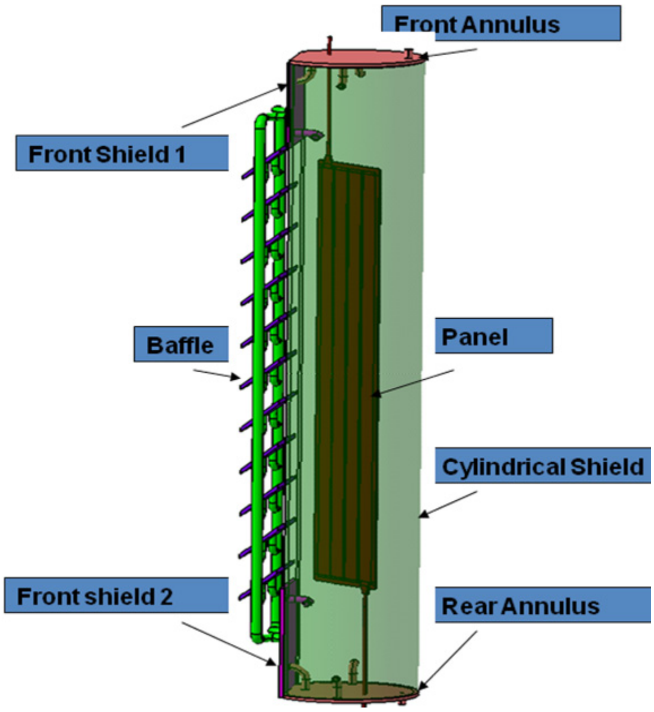

Figure A.2.3.2 CAD model of Cryopump

code. CAD model of Cryopump was generated from the baseline model, drawings of the prototype pump including all the components Cryopanel, baffles, and shields has completed. Heat transfer analysis of the baseline Cryopump and thermal shield assembly was done to find the temperature distribution for given load cases. To test the various concepts of cryopanel and experimentally study the thermal hydraulics and pressure drop and regeneration scheme a test stand has been conceptualized. The design was optimized to meet required structural design criteria. Study of adsorption isotherms at liquid helium and liquid nitrogen temperatures has been carried out. Methodology for thermal hydraulics was developed.

Prototype vacuum vessel: Fabrication of one sector of a double wall vacuum vessel for fusion grade machine satisfying all stringent fabrication challenges is the main aim of this project. The primary function of the vacuum vessel is to provide a high quality vacuum for the plasma as well as the first confinement barrier of radioactive material. The decay heat of all the in-vessel components can be removed by the water in vacuum vessel primary heat transfer system. The vessel supports the in-vessel components and their loads during normal and off-normal operations. The ferromagnetic material in the vacuum vessel reduces the toroidal field ripple. Through the development it is expected to learn and gain experience of the following: to achieve specified tolerances in welding of high thickness plates, to produce required weld quality in all-position, to increase the speed of welding deposition rates and to re-

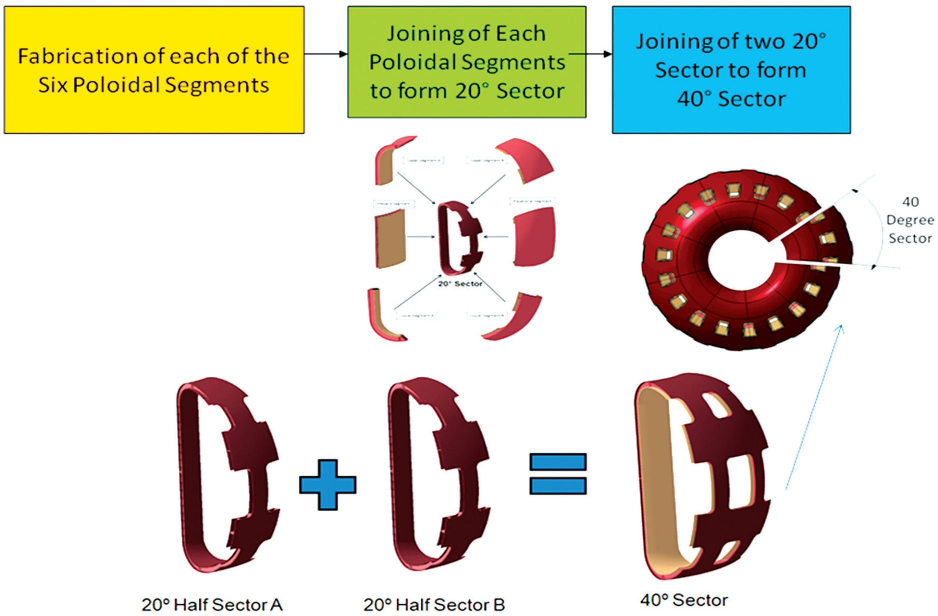

Figure A.2.3.3 Plan for fabriction of 40° sector duce the deformation, to be able to test the fabricated sector to given accurate dimensions, to gain Confidence in Fusion Reactor vacuum vessel, validation of the fabrication feasibility, step by step, with bracing assembly jigs and beams to simulate the rest of the VV, evaluation of welding feasibility and restraints, application of non-destructive examination (NDE) on weld joints, measurements of welding distortions and shrinkage and assessment of final achievable tolerances, preparation as a mock-up for Intersection cutting and welding operations, validation of finite element numerical analysis methods of calculating welding distortion. Deliverables of the project are Fabrication of Large Vacuum Vessel, Welding R&D, Proof of Concept- Mock Up and Reactor Vessel Design – Confidence. The drawings of the concept have been completed. As the vessel will have to sustain and undergo various load conditions, a case study was done to establish methodology for the design analysis of double wall vacuum vessel for structural and electromagnetic loads. The study also included design analysis for vertical displacement events and mid plane plasma disruption for vessel of the existing experimental reactor eg ITER. Procurement related to R&D works in fabrication initiated.

A.2.4 Test Blanket Module

It is well known that India is one among the seven full partners of International Thermonuclear Experimental Reactor (ITER). One of the ITER missions is that "The ITER should test tritium breeding blanket module concepts that would lead in a future DEMO fusion reactor to tritium self-sufficiency, the extraction of high grade heat and electricity production". ITER is a unique opportunity to test the blanket mock-ups in real fusion environment. All ITER Parties have defined DEMO breeding blanket designs in both solid and liquid type blankets and are performing R&D program leading to the fabrication of blanket mock-ups, called Test Blanket Modules (TBMs), and to their installation and testing in ITER. India is also developing its own blanket concept, namely, Lead-Lithium cooled Ceramic Breeder (LLCB) (half-port size). This TBM concept consists of lithium titanate as ceramic breeder material in the form of packed pebble beds. The structural material is ferritic steel and is cooled by helium gas.

The preliminary engineering design of the LLCB TBM concept has been developed and its review-able engineering design report was prepared along with the involvement of BARC experts. Neutronics design and Analysis for the TBMs are under progress to improve the further performance of the concept. Following the thermal hydraulics analysis, the thermo mechanical analysis and structural analysis for LLCB DEMO and TBM was continued and completed. Based on this work, like every other ITER partners, India also prepared the first version of Design Description Document (DDD) and submitted to ITER Team during April 2008. The ITER-Test Blanket Working Group (TBWG) has reviewed the concept and accepted the Indian proposal for testing in ITER. In this connection one-half port of ITER has been allotted to Indian TBM program.

In parallel, the Helium Cooled Solid Breeder TBM design was initiated with minor variation in the existing concept. The preliminary results on DEMO blanket thermal hydraulics calculations have been completed. The scientists and engineers from BARC, Mumbai and IGCAR Kalpakkam are actively involved in the development of the R&D required for the development of TBMs and its associated technologies. The major R&D areas that are identified are : Liquid metal technologies, Thermofluid MHD, Lithium Ceramics, Beryllium pebbles, Structural Materials, Fabrication Technologies, Tritium extraction technologies and Remote handling technologies.

The development of structural material Reduced Activation Ferritic Martensitic Steel (RAFMS) has been initiated at IGCAR with MIDHANI, Hyderabad. The chemical composition and impurity level has been achieved. The microstructure requirements, mechanical properties and fabricability of the material are under progress. Tritium extraction systems for TBMs, the design and preliminary layout have been completed jointly with the BARC experts. The required R&D for the Tritium extraction from Lead-Lithium is under planning stage. The tritium measurement systems R&D has been initiated and are obtaining the initial results.

The interface requirements with ITER machine are of prime importance. The TBM assembly, piping arrangements, auxiliary equipment units in ITER building has been worked out to a first level of information. Presently the Process Integration Design (PID) is under progress. In liquid metal technologies, a mercury loop of ~ 1.5 ton (closed loop) is being set-up at IPR. This loop will be used for studying the thermofluid MHD effects in ¼ size of LLCB TBM under high magnetic field (~ 2 Tesla) environment. This design and development is being done jointly by BARC and IPR. The corrosion effects in ferritic steels and SS 316LN in Lead-Lithium environment is of a great importance for TBM development. Presently a dozen numbers of small-scale lead-lithium loops are being planned at IPR to study the corrosion effects and generate a data base for ITER qualification.

The TBM related R&D activities on each area has been identified and developed as work packages with definite deliverables in order to meet the ITER milestones. These work packages have been developed along with BARC and IGCAR experts. Based on this, a Draft Memorandum Of Understanding (MOU) has been prepared and a discussion meeting was arranged at BARC on 15th September 2008 with the Chairman, DAE and the Directors of BARC and IGCAR along with the experts. The finalization of the MOU will be done as per the guidance provided during the meeting. Presently the LLCB Breeding Blanket design and analysis for DEMO relevant mock-ups will be further investigated and their performance is being improved. In parallel, the design and analysis for Helium Cooled solid breeder TBM is under progress.

A.2.5 Negative Ion Beam Source

The first step in the Indian program on negative ion beams is the setting up of Negative ion Experimental Assembly – RF based, where 100 kW of RF power shall be coupled to a plasma source producing plasma of density ~5 x 10^{12} cm^{-3}, from which ~10 A of negative ion beam shall be produced and accelerated to 35 kV, through an electrostatic ion accelerator. The experimental system is modelled similar to a RF based negative ion source, BATMAN presently operating at IPP, Garching, Germany. The mechanical system for Negative Ion Source Assembly is close to the IPP source, remaining systems are designed and procured principally from indigenous sources, keeping the IPP configuration as a base line. The complete realization of the –ve ion experimental facility has been divided in two phases (a) Phase -1: Plasma production and (b) Phase -2: Beam extraction and acceleration. Following are some of the major activities initiated in this front:

(i) Procurement of BATMAN type source: BATMAN type ion source has been ordered on M/s PVA, Germany. The delivery will be in two parts, where the first part will include RF components, Plasma Box, Back Plate, Magnets, Dummy grids required for the Phase-1 of experiments and the following part will include Main insulator, post insulators, Plasma Grid, Extraction and Ground grid; required for the Phase-2 of experiments. The manufacturing of the components, which are deliverable in part 1, is over and the factory acceptance tests are presently being conducted at M/s PVA whereas major fabrication and manufacturing work for the second deliverable parts is presently going on which is expected to be over by Feb 2010.

(ii) Procurement of 100kW, 1MHz, RF Generator: Since the source is RF driven, a 100kW, 1MHz RF generator is procured from M/s Himmelwerks Germany. This is a tube based oscillator based RF generator and is built in two units (1) Unit -1: Power supply, control and monitoring unit and (2) Tube based oscillator unit.

The PLC controlled generator can be operated locally through the LCD based HMI console provided on power supply unit or else can be operated remotely by interfacing it with the central DAC system via FO links. The generator is procured along with a water cooled 100kW resistive dummy load. The factory tests were successfully performed in May 2009 and the generator has been delivered recently to IPR. Preparations are on for installation and commissioning of RF generator.

(iii) Training Sessions at IPP, Germany: Two major training sessions involving (a) Information exchange on BATMAN negative ion system and experimental layout generation at IPR & (b) Operational know-how BATMAN source have been concluded successfully and have led to the realization of experimental hardware, consolidation of diagnostics, control and Data Acquisition configuration and finalization of scheme for integration of mechanical electrical hardware.

(iv) Cs oven design : Cs oven experiments have been initiated at IPR. The design of Cs oven with flow control is presently going on in collaboration with RFX (Padova) for implementation in BATMAN type source and also for its adoption in ITER DNB tests.

(v) Vacuum system : Hardware for vacuum pumping system supported by a TMP and a cryo sorption pump, are in their final stage of procurement.

(vi) Design and procurement of Power distribution system: To cater the utility and experimental requirements, a 800A distribution system has been designed.

The complete system includes:

(i) 3-ph, 440v, 50Hz, 800A Main distribution system housed in LT panels as per IS 8623.

(ii) Incomer feeder @ 800A with ACB with Microprocessor based Protection Unit having overload, Short-circuit and Ground Fault Protection as per IS 2516

(iii) Outgoing feeders (5 Nos.) @ 400A (1 No.), 200A (1 No.), 100A (3 No.), MCCB with integrated static releases for protection against Short circuit, Overload, Earth Fault, Over-voltage and Under-voltage as per IS 2516

(iv) AC Distribution Cable - Copper conductor, 1.1kV, XLPE Insulated, Cables, As per IS:7098

(v) Cable routing through Hot dipped Perforated GI cable trays as per IS 226 and IS 2629

The installation and commissioning contract has been placed with Ahmedabad based M/s Laxmi Engineering. The fabrication of MDP and SDPs is nearly complete and the first phase of factory inspection has been recently concluded.

(vii) Procurement of Heating and Bias power supplies: Heating and bias power supplies are required for control the experimental parameter during Plasma production and beam generation. The specifications of various heating and bias power supplies have been gen-

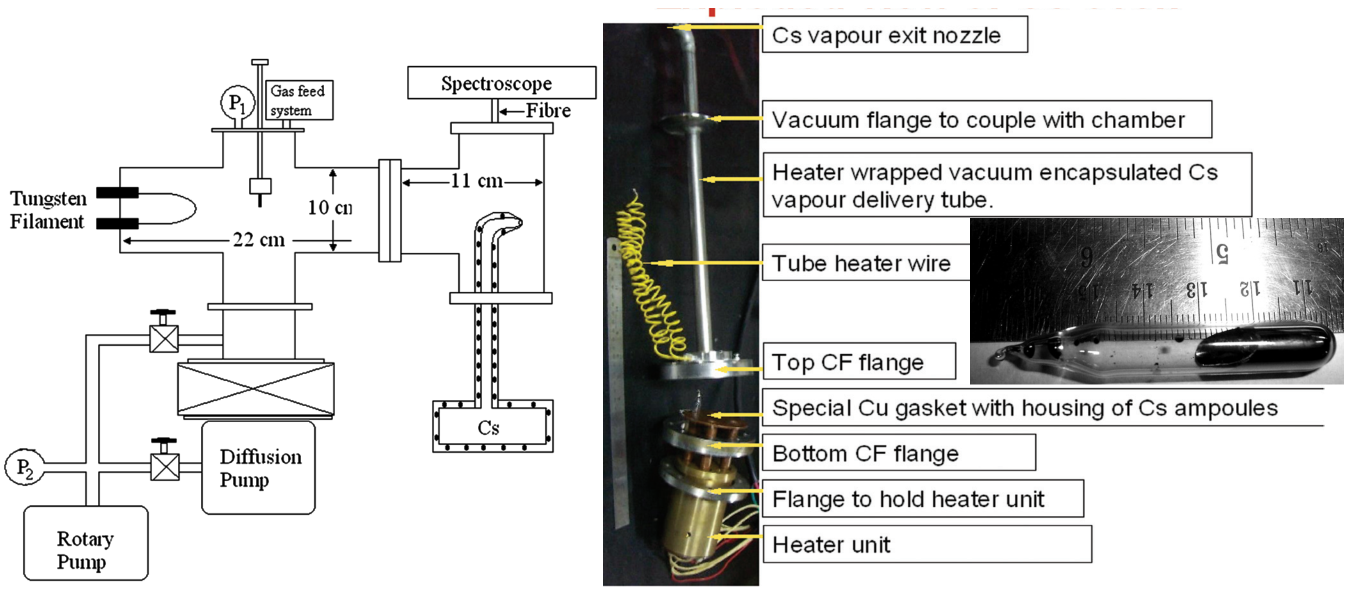

Figure A.2.5.1 Experimental setup of Cs oven experiments at IPR erated and procurement process initiated. Many of these power supplies (listed below) have already been tested and kept ready for commissioning.

No	Power Supply	Rating
1	Filament Heater	0-16V DC, 10A
2	Filament Bias	90VDC, 0.5A
3	Grid bias	30VDC, 66A (programmable)
4	Grid heating	65V, 10A (programmable)
5	Cs oven	40V, 12A AC

(viii) Procurement of 50kV DC Isolation transformer: 50kV DC isolation transformer is procured for feeding the power to the sub-systems connected to the source potential. The transformer is epoxy cast and is easily portable over wheels. The transformer is manufactured by Baroda based M/s Arya Transformers. The factory and site acceptance tests are performed successfully for the specified ratings.

(ix) Development of Control and data acquisition system: Successful operation of the negative Ion system requires strict & automatic - control and data acquisition systems. There are approximately 150 analog and 200 digital control and monitoring signals required to perform a complete control of the system. About 130 essential parameters are required to be stored or acquired for post experimental analysis and to ensure healthy operation of the system. Since the source essentially floats at a high (~ 50kV) potential, a proper signal isolation and communication mechanism also needs to be implemented, which forms one of the decisive parameter for the control and monitoring strategy. Various schemes (PLC based, PXI based, mix of PLC-PXI, Distributed vs. separated DACS and control) for control and Data acquisition system are explored for the Negative Ion System at IPR. Based on their system compatibility (with existing system at IPP), availability of various hardware and software tools, merits and demerits; a Siemens PLC S-7- 400 and PLC S-7 300 based control system is proposed for control system and a PXI based DAQ system with fiber optics isolation in each channel is proposed for Data Acquisition system.

(a)Control System: Control system consist of S-7 400 master control PLC system, S-7 300 vacuum control PLC system, Step 7 PLC programming software, WinCC SCADA software and Workstations. Specifications of all the above PLC hardware and software have been generated, Purchase orders for the same have been placed and all the components will be delivered in by the first week of august 2009. Required workstations for both data acquisition and control system are already delivered, tested and are ready for commissioning.

Front-end electronics is required for the control signal conditioning and isolation. For the digital signals Relay modules, with 2.5 KV isolation level, will be used and for the analog signals, analog signal conditioning modules, with 2.5 KV isolation level will be used. Specifications of both types of front-end electronic, has been generated and are presently in procurement phase. Procurement process for the Relay modules has been initiated and the material is expected to be delivered in IPR by first week of August 2009. Purchase order for the analog signal conditioning modules is expected to be placed by August 2009 and the material is expected to be delivered by the end of September '09.

Other essential items like racks, connection cable, connectors etc are also in procurement stage and are expected to be delivered by middle of August 2009.

(b) Data Acquisition System (DAQ) : The Complete DAQ system is a combination of PXI system, DAQ program, workstation computers and fiber optics modules. Specification of the PXI based Data acquisition system with software development has been generated and the indent has been raised and the system is in procurement phase.

It is expected to be delivered by September 2009. For the 1st Phase of operation of the negative ion source, fiber optic links have been received and tested. Specifications of fiber optics links needed for the 2nd phase of operation have been prepared and the Indent has been raised. In addition to this, in-house activities for the

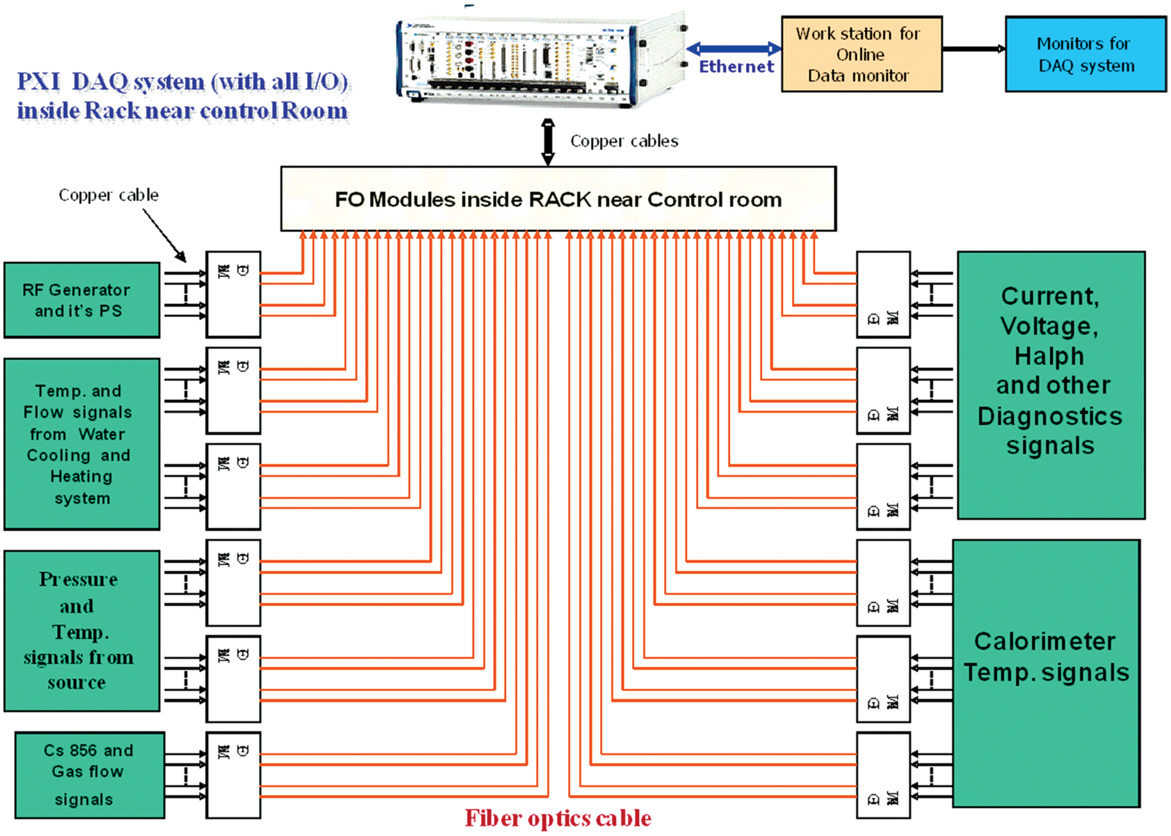

Figure A.2.5.2PXI based Data Acquisition system with fiber optic link in each channel

indigenous development of similar fiber optic links is presently going on. The prototype modules have been successfully developed and the full-scale development is expected to be over by 1st month of January 2010.

(x) Infrastructural development activities: To provide the basic and advanced needs for the successful commissioning of –ve ion source and related sub-systems, various infrastructure developmental activities have been initiated. Some of the major activities have been listed below:

(a) Design of laboratory layout and construction of enclosure: A laboratory layout has been designed keeping in mind the needs of the experimental system and the availability of space. The laboratory is in Utility building, 1st Floor of IPR. The total floor has been divided in two areas (a) Experimental area consisting of ion source, RF generator, power supplies and (b) Working area consisting mainly of vacuum system, main power distribution system and DAC system. In order to attenuate the radiations generated in the experimental area, Aluminium mesh based shielding scheme has been implemented. The laboratory will be constructed using Syntex boards framed on MS channels. The lab construction work has already been initiated by the civil and maintenance group of IPR.

(b) 2-Ton EOT crane: To cater the needs of ion source assembly and disassembly and for the movement of heavy components within the lab, the specifications of 2Ton EOT single girder crane has been generated and the purchase order has been placed to Ahmedabad based crane manufacturer M/s Japs Projects for the design, installation and commissioning of the same. Since the laboratory is in Utility building, where the existing RCC pillars are not designed for taking dynamic loads; a separate steel support based mounting scheme has been designed, which transfers the total crane load on existing RCC beams instead of RCC pillars. The commissioning of crane is expected to be over soon.

(xi) Instrumentation developmental activities : To assist in commissioning, testing and development various electrical and electronics instruments are under procurement phase. Major instrumentation includes:

i. High voltage insulation tester
ii. Earth tester
iii. Digital hygrometer
iv. IR thermometer
v. Precision calibrator
vi. True RMS AC/DC Multi- and clamp-on meters
vii. High voltage, High bandwidth HV dividers
viii. High Voltage handheld HV probe
ix. High current probes
x. Oscilloscopes – DSO and Floating channel
xi. Arbitrary function generator
xii. Handheld RF radiation meter

(xii) RF Generator development: As part of the indigenous developmental activities, a 200kW RF generator is currently being developed. Indenting activities of all the major components is almost completed. Many equipments and parts have already arrived. The fabrication of the RF Generator is initiated and the fabrication of RF Transfer line is started.

A.2.6 Neutronics

A.2.6.1 Experiments with 14MeV neutrons

◊ Fast neutron flux measurement with foil activation Al, Cu & Fe a flux of 2.3×10^{10} at the outer surface of the neutron tube.

◊ Irradiation of Li_2TiO_3 + BeO discs for material qualification for use as a tritium breeding material in the solid blanket concept. BeO was added to increase the breeding ratio but presence of Al impurity in trace quantities in Lithium Titanate absorbs neutrons excessively. (BARC Collaboration)

◊ Biological shield design calculation was performed using the MCNP code. The shield design includes the sky-shine effect. The thickness of the shield obtained was 1 m concrete wall all around the laboratory. The shield wall construction shall be started after the AERB regulatory approval.

◊ Neutron activation calculations were performed for the structural materials such as floor activation, soil activation, concrete activation, neutron generator activation, air activation etc. These calculations were performed using the EASY-2007 package.

◊ Neutron dose has been measured using the LB 6411 neutron area monitor at different locations to assess the radiation hazard due to operation of the neutron generator. It was found that a biological shield is essential for the safe operation of the neutron generator.

◊ A safety report has been prepared and submitted to Atomic Energy Regulatory Board (AERB) for approval. The technical presentation is scheduled to be held on 24th June 2009 at AERB.

◊ **Development of Fast Neutron Radiography Technique:** A new radiography technique has been developed using the 14 MeV D-T neutron generator in collaboration with Rocket Propellant Division, VSSC, ISRO, Thiruvananthapuram. The Neutron Radiography (NR) imaging of plastic explosives packet in missile nose of the rocket was done by moderating the fast neutrons to thermal energies and then the image was recorded using Dysprosium screen. The measurement with Indium foil activation showed a thermal flux of 10^6. The initial experiments with the water moderator could not produce sufficient activity in the Dysprosium screen and the imaging attempts failed. Subsequently an indigenous method has been devised for moderation with polypropylene sheets initially with 20cm thick and later reduced to 15 cm and very good image of density in the range 1.5 to 2.5 was recorded. The images of plastic numbers kept close to the plate cast sharp images but that of thicker objects are blurred. This is mainly due to the very low L/D ratio possible in the present arrangement. Proposed Moderator: Modified design of the moderator is to be made with HDPP of thickness 15cm very close to the tube having an input aperture of 8cm x 5cm and output aperture 15cm x 10cm with a length of the collimator 1.2 m. The expected L/D ratio will be more than 10. This improved design is expected to achieve fine-definition images and good spatial resolution. The optimization of the moderator and collimator design using the MCNP code is underway. Once proved this will be the first Fast Neutron facility for NDT application. (VSSC Collaboration)

◊ Measurement of reaction cross sections at 14MeV neutron energy on some elements of fusion reactor interest (TIFR Collaboration)

A.2.6.2 Simulations and Computation

Proposal for neutronics analysis of ITER components: Neutron and gamma-ray fluxes, energy spectra and radiation doses are evaluated for different location taking into account plasma neutron source.

The analysis is focused on areas of the Vacuum vessel (VV) port, blanket, upper ports (specifically port no # 9 x-ray spectroscopy), port interspaces, bioshield and port cell areas. This includes all diagnostics systems from blanket shielding module down to port cell areas.

MCNP modelling of the generic diagnostics upper port plug:

- Upper port plug nuclear heating
- Helium production and nuclear damage in the port plug and vacuum vessel and port
- Toroidal and poloidal field coil and insulator heating, dose, and fast neutron flux
- Two different blanket options (to be determined and specified by IO)
- Port interspace doses
- Safety calculations—induced radioactivity and decay heat calculations VV port, Remote handling, diagnostics and test facilities.

Task break-up:

- Collecting CAD models of the system from ITER-IO
- Incorporating the CAD model into a common model, identifying clashes, following, if any and informing the ITER-IO and the corresponding parties.
- Definition of neutronic assessment models and analysis on upper port #9

Tools & standards to be employed: MCNP-v.5, ITER-MCNP alite model (40 degrees), cross section library FENDL 2.1 and plasma neutron source scenario to be used. (BARC & IGCAR Collaboration)

A.2.6.3 Diagnostics for Burning Plasmas

Diagnostics for characterizing Burning Plasmas (BP) are being developed as part of our long term planning for SST-2 Tokamak. These systems will undergo few preliminary tests on the SST-1 Tokamak.

Fusion product diagnostics deals with diagnosing plasma parameters using emission of neutrons, alpha particles and gamma rays from a BP. Activity has been initiated to test the neutron activation system with multi-foil irradiation technique to determine neutron energy and flux. This is undergoing tests with the 14MeV neutron generator. A set of NE-213 spectrometers is being tested for determining ion temperature by measuring neutron flux and energy spectrum.

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A.3 Basic Experiments

A.3.1 Basic Experiments in Toroidal Assembly (BETA)

Experimental determination of fast electron characteristics using RFEA in BETA : BETA is primarily for understanding fluctuations and transport in simple magnetized currentless toroidal plasma. In the present experiments argon plasma is produced using hot 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. However as the measured floating potential close of filament locations dip approximately to the discharge voltages, this could indicate the presence of fast electrons on corresponding filament location spreading throughout the torus. To nail down experimentally the characteristics of this population, two Retarding Field Energy Analyzers (RFEA) have been constructed: 1. one to observe the fast electron spread in a poloidal plane; 2. other to obtain electron energy distribution in bulk plasma. Various stages in RFEA are entrance slit, ion repeller (to repel all positive ions), electron discriminator (to selectively transmit electrons) and collector. First three stages are made of SS mesh and collector is made of SS plate. The open aperture of mesh (or grid) is to be chosen comparable to Debye length. However the Larmour radii were also comparable or larger than the mesh aperture and consequently reduced transmission is observed. Correcting for transmission as a function of incident parallel energy, the derived temperature is compared to Langmuir probe measurements.

Triple Langmuir Probe has been constructed. Using this probe electron temperature and ion saturation current can be obtained without any sweep voltage. In future work, we expect to compare these results to single Langmuir probe data

A.3.2 Large Volume Plasma Device (LVPD)

This Device (LVPD) provides an active research platform for the studies primarily focused on two fronts, namely 1) high beta ($\beta \geq 1$) electron temperature gradient (ETG) turbulence and 2) plasma transport in the Scrape-of-Layer (SOL) region of high beta plasma .

Electron Temperature Gradient Turbulence :The capability of producing high-density plasma at very low applied ambient field has made possible, the first experimental measurement of ETG instability in Large Volume Plasma Device (LVPD). The origin of turbulence is found to be in electron temperature gradient instability. A control on electron temperature gradient was envisaged as an important milestone for further exploring ETG turbulence in a controlled manner. Our efforts were focused mainly for the realization of control on electron temperature gradient in LVPD.

In pursuance of exerting a control on electron temperature gradient, a Low Energy Electron Source (LEES) was designed, augmented and tested for vacuum compatibility in LVPD[Figure A.3.2.1(a)]. To change electron temperature and its gradient, the possible methods are to carryout local/ global electron heating/ cooling. Experimental investigations have carried out with both the methods for controlling electron temperature in LVPD. A prototype LEES (10 nos. of filaments, arranged vertically over an area 4.5cm x 10 cm) is installed [Figure A.3.2.1(b)] before actually venturing for the activation of large LEES to its full emission capability. It was decided to carry out some proof of principle experiment from a prototype LEES. The prototype LEES has same confinement scheme as that of LEES but has a difference that it contains only 10 numbers of filaments in comparison of 48 in LEES. The total current delivery capacity of prototype LEES is ~ 50 A. This is approximately one eighth of the total discharge current of the plasma in which the LEES is immersed.

Preliminary investigations are carried out for energy exchange using prototype LEES, when used as an electron emissive source. An electron emissive source is usually realized by tungsten or thoriated tungsten heated to the necessary temperature (white glow). Investigations using prototype LEES when biased with

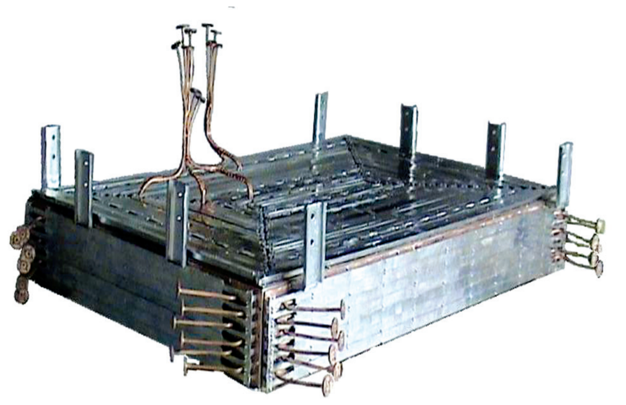
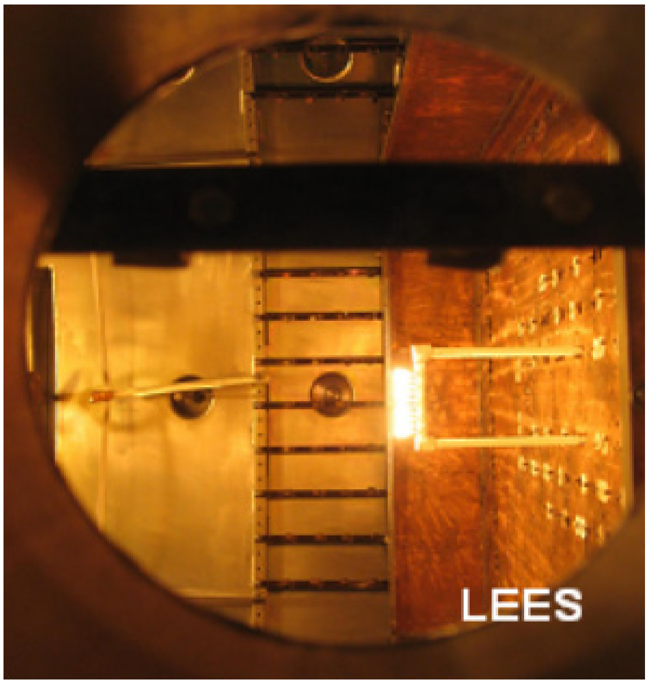


Figure A.3.2.1 The view of (a) assembled LEES and (b) the filament assembly of the prototype LEES.

respect to grid indicate that there is evidence of exchange of electrons between the emitted electrons and the bulk electrons of the plasma. This is seen from the measurement of bulk plasma temperature when LEES is hot and cold. It is found that the temperature of the bulk plasma reduces when the LEES is in emissive mode. The effect of plasma cooling as shown in figure A.3.2.2(b) is visible only along the axis of the device and is limited to an extent of Δz = 35 cm, the region where the plasma density also exhibits a depletion [Figure A.3.2.2(a)]. Preliminary observation shows that there is no variation of density and temperature in the radial direction. This is surprising and needs further investigation by proper configuring of LEES filaments.



Plasma Transport in Scrape-of-Layer (SOL): Another set of experiments undertaken in LVPD is focused towards understanding of plasma transport in the regions of sharp density gradients. A high beta, ($\beta \geq 1$), high density, ne ~ 3 x $10^{11} cm^{-3}$ plasma is produced using a narrow source. The frequency ordering of the plasma produced is $\omega_{ci} << \omega << \omega_{ce}$, where ω_{ci} and ω_{ce} are the ion and electron gyro frequencies,

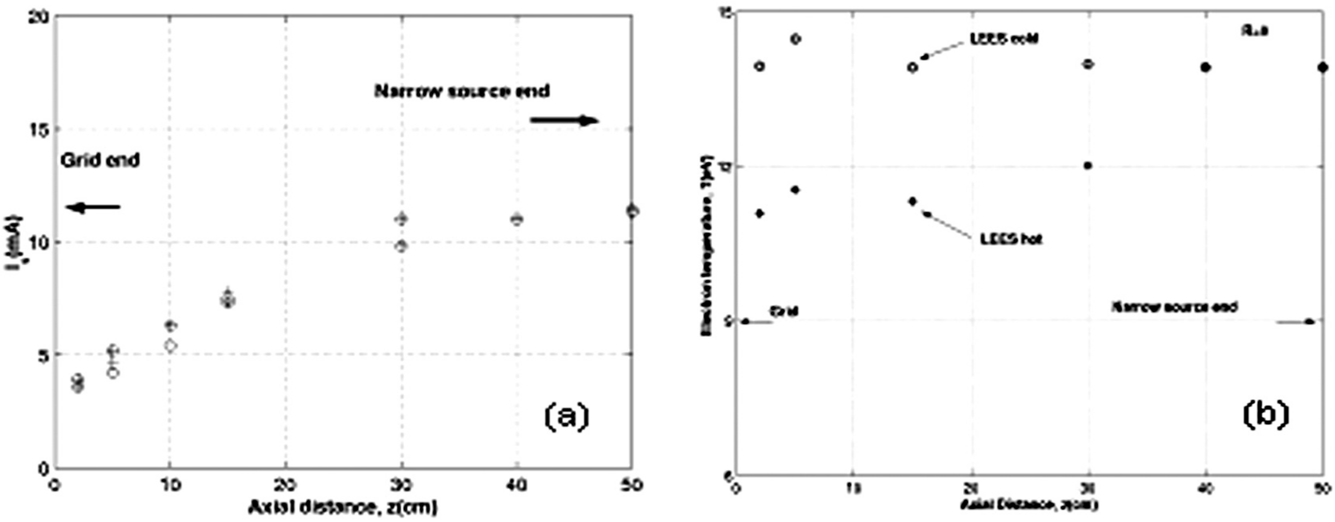


Figure A.3.2.2 The axial profile a) ion saturation current, mimicking plasma density and b) the electron temperature

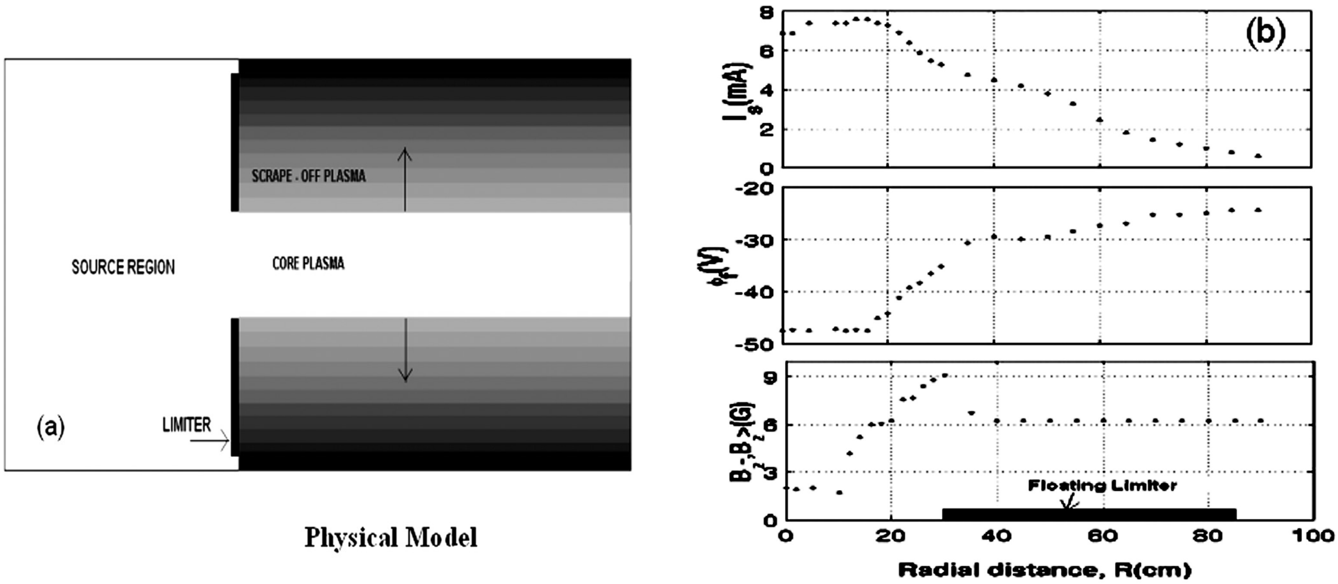


Figure A.3.2.3(a) Schematic showing different regions of plasma in the presence of a floating limiter; (b) the radial profiles of mean plasma parameters, density (top), floating potential (middle) and field expulsion (bottom) in the source and SOL region.

therefore the plasma dynamics is governed by EMHD, where electrons are magnetized and ions remains un-magnetized. A floating metallic ring of (ID=60cm, OD =180cm) is inserted in the plasma. The plasma produced is primarily divided into two regions i.e., the source region and the Scrape – of –Layer (SOL) region.

The mean plasma parameters exhibits setting up of a sharp density gradient in the SOL region with a characteristic density scale length, L_n ~ 45 cm. A radial electric field, E_y ~ 80V/m is developed in the region 18 cm < R < 40 cm. The radial profile of floating potential indicates that plasma rotation exists in the core region because of E X B. On the other hand, the SOL plasma has prominently the effect of density gradient. The radial profile of magnetic field shows significant expulsion in the core plasma. The field expulsion is absent in the SOL plasma where plasma beta, β~1.3 is observed. Further investigations and the analysis of the turbulence from the data collected is underway and will be reported next year.

A.3.3 Non-neutral Plasmas

SMARTEX-C upgraded : SMARTEX-C was plagued by several limitations that ultimately limited the lifetime of the plasma. The device has been now successfully upgraded. Vacuum during filament operation was limited to 1.0 x 10^{-7} mbar. Unwanted and unknown source of Hydrogen was observed in Residual Gas Analyser (RGA) and possible causes viz., in-sufficient baking and in-vacuum copper were identified. Viton O-ring seals were replaced with aluminum wire seal thus enabling high temperature baking of the vacuum vessel to 250° C (previously limited to 150-175°C). Copper strips used to power tungsten filament were replaced with stainless steel strips thus reducing the unwanted Hydro-

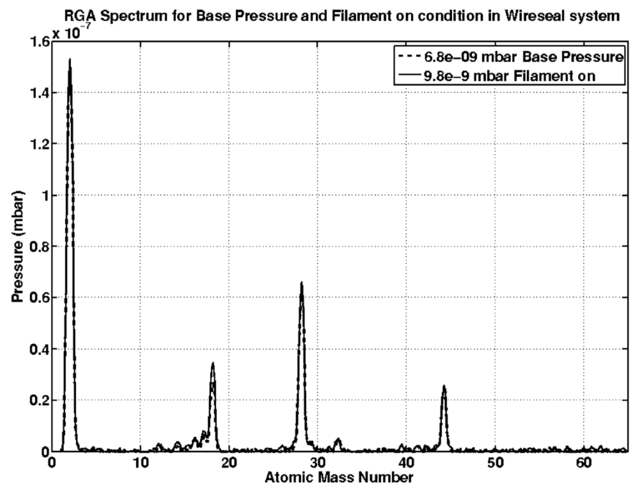


Figure A.3.3.1 RGA scan for Aluminum Wireseal (Solid line: Filament on, Dashed line: Base pressure)

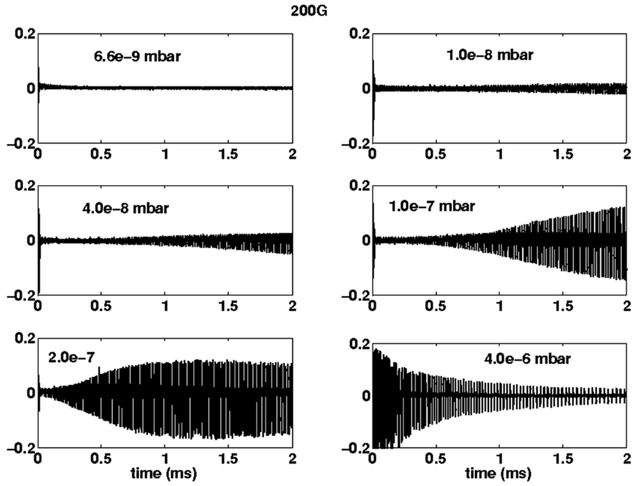


Figure A.3.3.2. Suppression of diocotron mode by lowering pressure

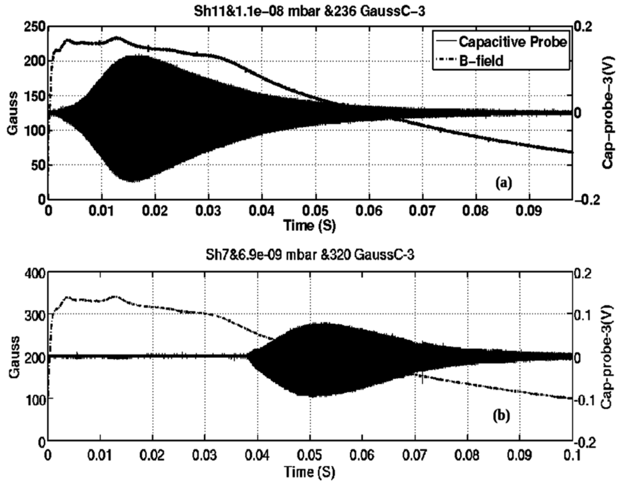


Figure A.3.3.3. Improved confinement time with a vacuum 6.9 x 10^{-8} mbar at 325 G

gen gas load from ordinary copper at high temperature. These measures brought the base vacuum down to 4.0 x 10^{-9} mbar. Further, during filament operation pressures were successfully held at 5.5 x 10^{-9} mbar. RGA analysis also confirmed the control of Hydrogen and Water Vapor during filament operation (Figure A.3.3.1).

Prior to Upgradation, magnetic field pulse length was limited to 4 ms (1.2 ms flat top) only and this was one major limitation that precluded long time confinement. A new Pulse Forming Network (PFN) was modeled in PSPICE and designed for 10 ms flat-top. This was further upgraded to 30 ms steady state and used for our experiments.

b. Control over Ion resonance instability demonstrated

Destabilization of diocotron mode due to resonance with residual ions was reported in SMARTEX-C before. Instability driven transport can cause a significant loss of confinement. Controlling the growth rate of the instability was demonstrated by introducing gases with different ionization cross-section and different energies of the injected electrons. The growth of the mode was also arrested for several hundred microseconds by appropriately increasing the B field to 500 Gauss. Higher pressures however did not allow a complete arrest of the instability. Following upgradation, neutral pressure densities were reduced substantially in SMARTEX-C. A complete quench of the instability for ~ 40 ms (as long as the magnetic field was steady state) at moderately high magnetic fields and 6.9 X 10^{-9} mbar has been demonstrated (Figure A.3.3.2). The arrest of the instability has significantly reduced loses and increased the confinement time.

Upgraded SMARTEX-C greatly helped us to improve confinement time by several orders of magnitude. With the reduction of neutral densities and successful control of diocotron instability electron plasmas were lasting for more than 70 ms with an extended B field. A plasma shot taken at 6.9 x 10-9 mbar and 325 Gauss has diocotron oscillations lasting >90ms (Figure A.3.3.3), well into the decay time of the B field. The trap now merits a steady state B field which can extend the lifetime to well beyond hundred milliseconds.

c. Scaling laws of confinement for toroidal electron plasma

Confinement of electron plasma has been increased by several orders of magnitude in SMARTEX-C. Scaling of the confinement is not simple as the charge loss from the plasma may be caused by a complex interplay of different mechanisms. The primary causes can be thought to be electron-neutral collisional charge losses, ion-resonance driven charge losses and losses due to the decay of the confining magnetic field itself. For any kind of scaling it is necessary to identify the range of parameters where one of the several loss mechanisms is dominant.

The amplitude envelopes of the mode evolution show that the mode after having a slow, linear (small amplitude) start grows to large amplitudes. Once the instability saturates and reaches a peak amplitude, the amplitude starts falling. For all those evolutions when the instability saturates and starts decaying within the flat-top of the B field, the evolution and decay is influenced largely by the instability driven losses. However when the growth rates are very slow, for example, at lower pressures and/or higher B fields, the mode has not fully saturated before the B field itself starts decaying. So the losses and

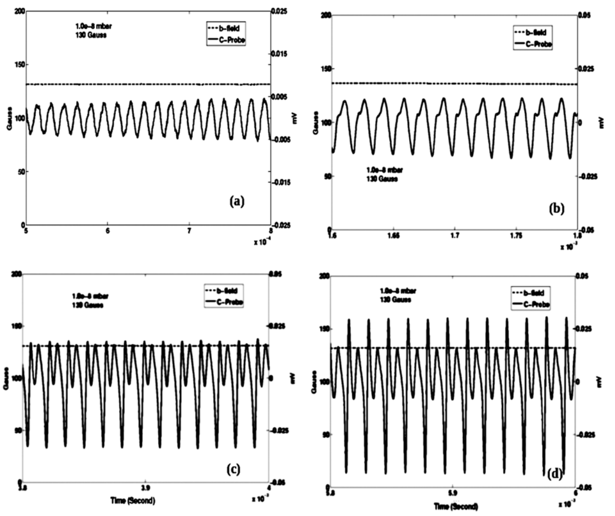


Figure A.3.3.4. Transformation of mode from Circular (Sinusoidal) to Elliptical (Double-peak) mode during the plasma shot. (a) Sinusoidal oscillation of charge cloud (b) slow conversion of sinusoidal to elliptical oscillation (c) More elliptical oscillation (partial toroidal) (d) Complete elliptical oscillation (Toroidal oscillation)

lack of confinement may have more to do with the decaying B field. At very high pressures, however the loses are expected to be dictated by the collisional processes. Parametric studies and careful investigation of the evolutions led us to the correct pressure and magnetic field range where only ion-resonance driven charge losses appear dominant. For pressures ranging from 1.0 x 10^{-8} to 1.0 x 10^{-7} mbar and magnetic field between 100G to 250G, the decay rates are same and the instability alone seems to be primarily responsible for the loss of charge. Upon investigating the plasma evolving under the influence of ion-resonance instability we observe the following: confinement time increases exponentially with pressure and linearly with magnetic field (figure A.3.3.4).

d. Observation of sinusoidal (Linear Devices) to double peak (Toroidal devices)

Periodic, double peak and large amplitude oscillations were hitherto observed in SMARTEX –C representing the nonlinear vortex evolution. With the arrest of the growth rate of the instability small amplitude, sinusoidal oscillations can be observed during the initial evolution of the plasma. For the first time the transition from small amplitude to large amplitude has been beautifully captured at very low pressures and/or high B fields. This represents transformation of the trajectory of the vortex from circular orbits to elliptical orbits (Figure A.3.3.4).

A.3.4 Interaction of Low Energy Ion and Neutral Beams with Surfaces

An auxiliary heating system has been incorporated which can be used to raise the sample temperature to the operating temperature (400°C to 600°C) of the specially constructed R&D samples (of various steel grades). This is specially important for the neutral beam experiments since neutral beam alone can not heat the R&D sample enough to raise its temperature to the operating temperature for surface treatment. A few steel samples (of various grades) have been treated with ion (plasma) beams (figure A.3.4.1) as well as neutral beams (figure A.3.4.2).

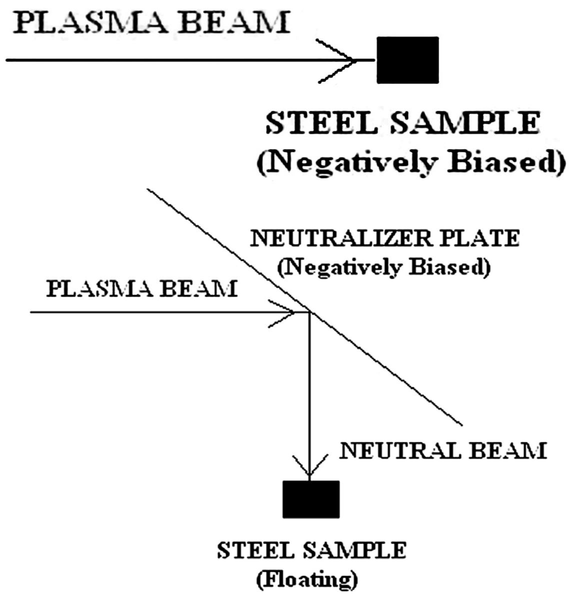


Figure A.3.4.1 (a) A steel sample being processed by plasma (ion) beam ; (b) being processed by neutral beam

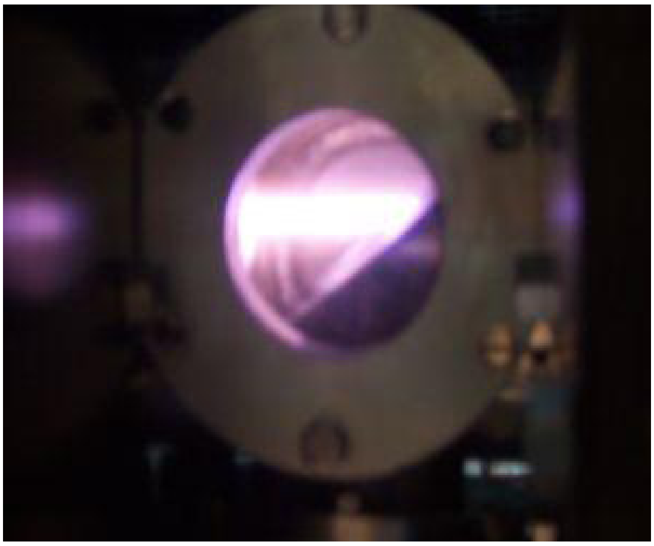


Figure A.3.4.2 Plasma (ion) beam falling on 45° reflector plate

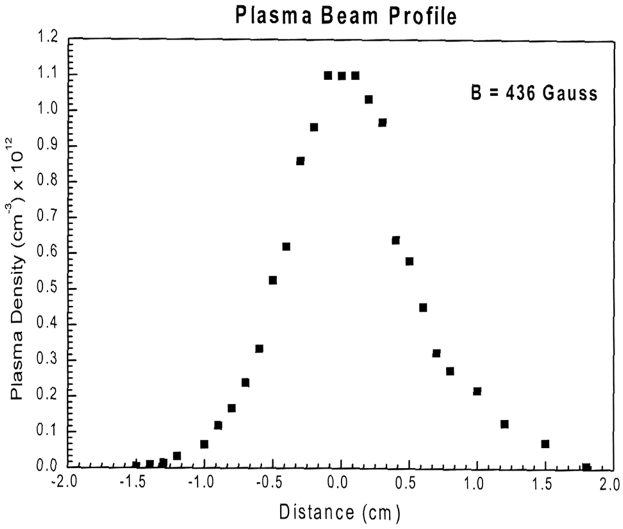


Figure A.3.4.3 Plasma density versus distance from the center of the beam

The treated samples show typical nitrided colour. A more efficient cooling system has been designed and incorporated for the electromagnet. In the past water got as hot as 50°C after a few hours of operation. With the present cooling system, water temperature could be limited to 42°C even after six hours of continuous operation. The present cooling system has added radiator cooling mechanism. Standard radiators (rated 3 KW) available in the market were used. Three of them were used to radiate away 8 KW of power used for the present electromagnets. A more powerful and energy-efficient electromagnet is being looked into for the future. The present electromagnet produces 436 Gauss by supplying 225 A of current (8 KW of power). With the new electromagnet, it will be possible to increase the magnetic field by a factor of four or higher employing only 7 KW of power (90 A). Since it is known that the plasma density goes as square of the magnetic field (for such plasmas), it will be possible to increase the plasma density by at least a factor of sixteen.

Figures A.3.4.2 and A.3.4.3 show plasma beam falling on 45° reflector plate and plasma beam profile (with present electromagnet), respectively.

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

The fabrication of the plasma chamber has been completed and is currently being integrated with the heater and vacuum systems. The vacuum testing as well as temperature profiling of the oven of the plasma chamber will be carried out. The purchase proce-

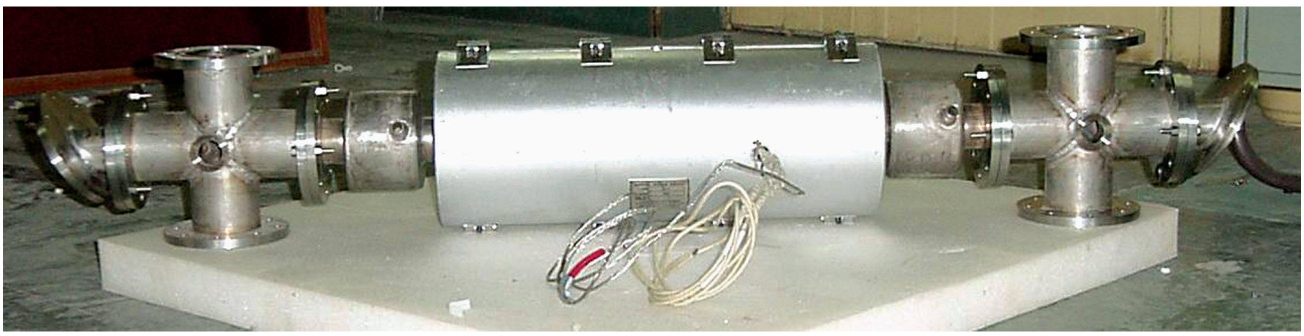


Figure A.3.5.1 Plasma chamber for PWFA being tested dures for most of the required hardware for the experiment have been completed and purchase orders have been placed. The laboratory is also being made ready to set up the experiment for generation and characterization of the photo-ionized lithium plasma.

A.3.6 System for Microwave Plasma Experiments

Objective of the experimental project on “High Power Microwave – Plasma Interaction” has been discussed in the last year’s report. An account of the critical criteria that the microwave source and the plasma should meet was also described along with description of system SYMPLE, being developed for this experiment.

While the Pulse Power Group of IPR is developing VIRCATOR based microwave source in various prototype stages, the developmental task of building the plasma system capable of fulfilling following plasma parameters has been taken up : plasma density in the range 10^{12}-10^{13}/cm^3, uniform axial and radial extent of 1m and 10 cm respectively, and a steep axial gradient having scale length ~ $\lambda_{microwave}$ at the region where the microwave-plasma interaction occurs.

For this a washer gun based plasma system has been setup consisting of 1) a vacuum chamber (~1.5 m long and 0.5 m diameter), 2) a washer gun, 3) a gas puffing assembly, 4) a capacitive discharge set up consisting of the charging circuitry, an ignitron switch and associated driver circuit along with a pneumatic bleeding arrangement, 5) an electronic trigger circuitry that carries out, a) opening of the piezoelectric valve with a pre-set voltage and pulse duration time as well as b) triggering of the ignitron driver circuit for discharging the capacitor at a pre-set delay time, and a 6) Langmuir probe based diagnostics and the associated electronics. Prior to operation of the integrated system, individual components/assemblies have been independently tested for their performance using dummy loads. Figure A.3.6.1 shows the photographs of different components.

As a subsequent step washer gun system was tested for plasma production and a plasma discharge of ~ 25 μs duration could be obtained with the following param-

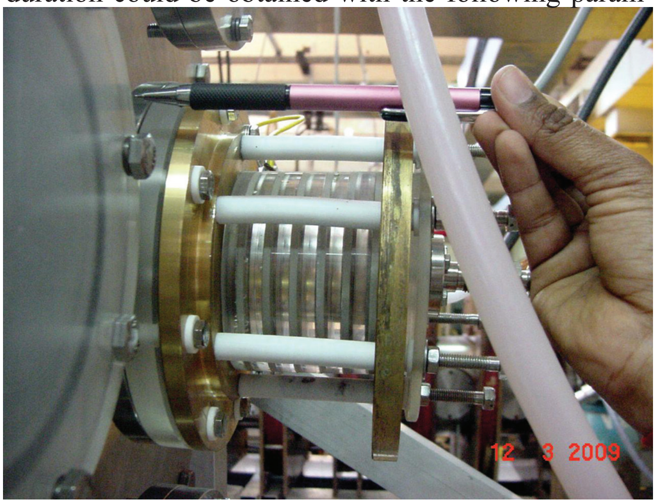
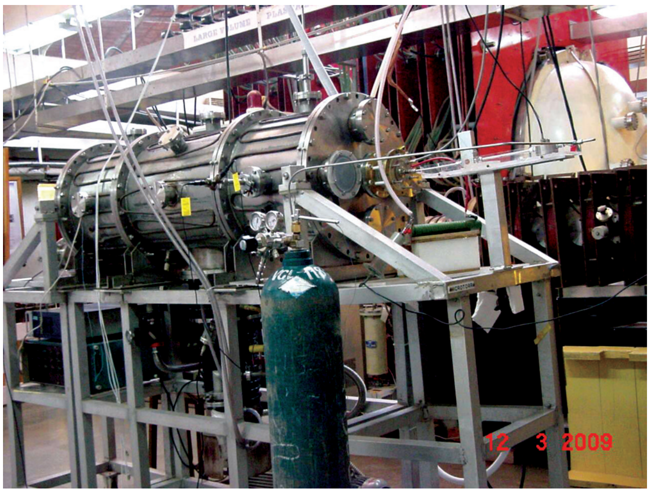


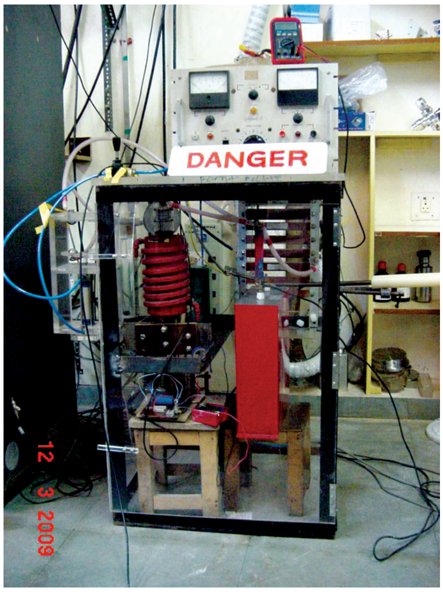
Figure A.3.6.1

(Top)
The washer gun

The capacitive discharge scheme (Right)

Infant stage of SYMPLE (Left)





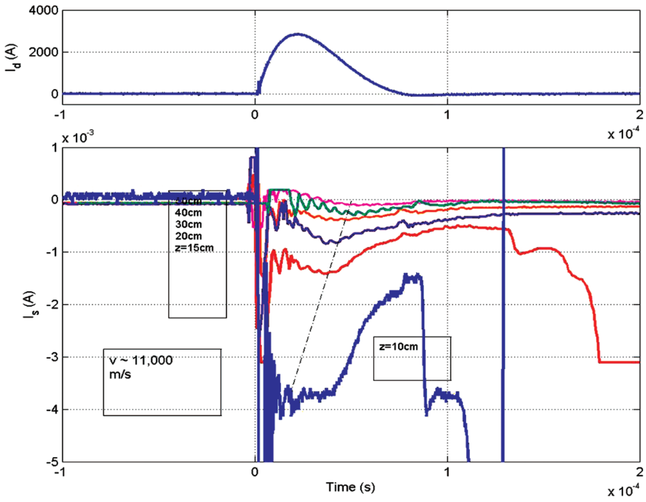


Figure A.3.6 2(a): Is vs Time at various z locations

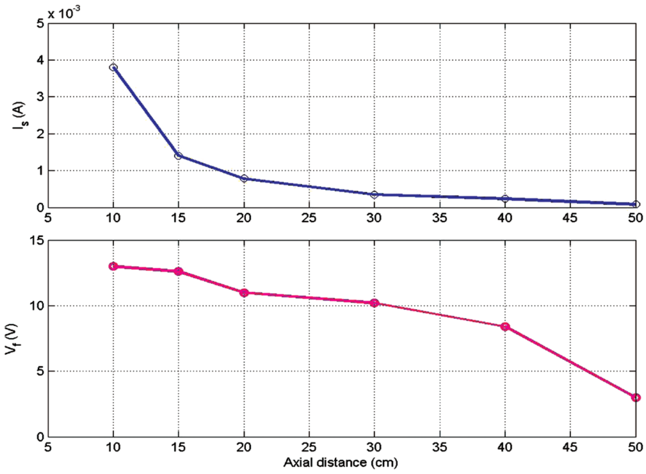
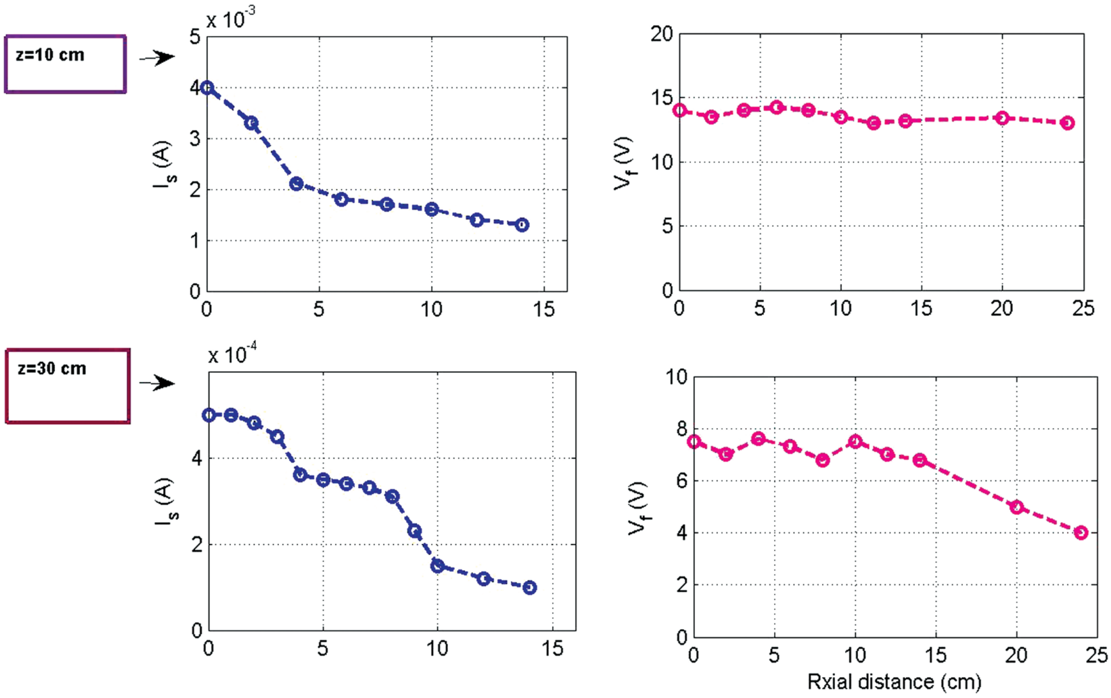


Figure A.3.6 2(b): Axial profiles of density (top) and floating potential (bottom)

eters: discharge voltage ~ 4 - 5 KV, discharge current ~ 3 KA, working pressure ~ 10^{-1} – 10^{-2} mbar. Various issues were encountered in subsequent stages of experiment involving probe measurements and corrective measures including choice of most appropriate grounding scheme, setting up of a DC plasma arrangement (filamentary) to enable cleaning of probes etc, were adopted at different stages. Plasma density ~ $1x10^{12}$ /cm^3 is obtained applying maximum possible (permissible by power supply and capacitor ratings) Vd across the gun. Te estimated at two axial positions revealed 20 eV and 11 eV at distances 10 cm and 30 cm respectively from the gun. The axial ion saturation current (Is) profile was generated from temporal plots of Is at various z locations as shown in Figure A.3.6.2(a). The axial profile of density and floating density is shown in figure A.3.6.2(b) where-

Figure A.3.6.2(c): Radial profiles of density and floating potential at two 'Z' positions



as Radial profiles generated at z = 10 cm and 30 cm is shown in Figure A.3.6.2(c). An axial gradient of scale length ~ 10 cm has been obtained. As the wavelength of the microwave required in this investigation (frequency range 2 – 10 GHz) lies in the range 3 – 10 cm, the density gradient obtained can be considered steep enough to carry out initial investigations on microwave – plasma interaction. However the plasma density needs to be enhanced and the plasma also needs to extended in both axial and radial extents. To achieve this, it is planned to implement the following improvisations: 1) using a pulse forming network to produce the sustain the discharge for about 100 μs, 2) applying weak magnetic field for confining the plasma and 3) using more guns. These activities will be taken up next year.

A.3.7 Flowing Plasma Experiment

Plasma expansion in a diverging or converging /diverging magnetic field leads many interesting phenomena in space and lab. Examples are; double layer, supersonic and super-Alfvenic flow generation, detachment and reconnection. Present study concentrates only about double layer. A Double Layer(DL) is a non-neutral region inside the plasma away from the boundary and having a spatial spread of the orders of Debye length. Energetic ions, important signature of DL existence, are confirmed by Laser Induced Fluorescence.(LIF) measurement. DL position is observed just downstream of max B gradient. Correlation between the strength of magnetic field and magnitude of potential drop across DL is also observed. This experiment aims to understand the following: (i) the parameters those control DL strength; (ii)the role of magnetic field and/or its gradient; (iii) the role of neutrals in DL formation; (iv) any role of Helicon in producing fast electron population; (v) any instabilities; (vi) the contribution from area expansion and (vii) parameters affecting the location of DL formation.

The main chamber is made of two parts. One glass chamber of length 70 cm and dia 10 cm where plasma will be produced by helicon antenna with 2 kW of power at 13.56 MHz. Then the plasma will allowed to expand in a metal chamber of length of 70cm and of diameter of 20 cm. Magnetic field (0.1-1 kG) in the main chamber would be produced by electromagnets. Magnets are individually powered with controlled field gradient at the junction between glass and metal chamber. Chamber would be evacuated to have base pressure around 10-6 torr and argon gas will be introduced at a pressure ~ 0.4-25 mTorr. Expected plasma parameter in the sources chamber would be Ne=10^{12} cm^{-3}; Te=4 eV; Ti=0.1 eV. In the experiment a helicon plasma will be created. Plasma will be characterized with Langmuir and magnetic probes, Retarded Field Energy Analyzer, Triple Langmuir probe and The role of magnetic field gradients will be investigated by varying magnetic field gradient and by studying the threshold of B-gradient in formation of DL. Later on, the role of chamber expansion will also be investigated by varying the chamber expansion location. And by looking for correlation of chamber expansion location and DL formation location. Finally, the role of helicon plasma for DL formation will be studied by creating plasma with different antenna.

A.3.8 Multi-Cusp Plasma Device

A new experiment has been proposed to study the natural fluctuations of a a real quiescent plasma. In this experiment, Q-machine like cesium plasma will be confined in a multi-cusp magnetic field. It is well known that in the Q-machine configurations studied in the 1960s, the source of the fluctuations was the axial magnetic field being perpendicular to the radial density gradient. It is expected that in the new multi-cusp configuration the fluctuations would be really natural since the axial field is close to minimum in the center. The cesium ions will be produced by impinging collimated neutral atoms on a hot tungsten plate. The temperature of the tungsten plate will also be made high enough such that it will also contribute electrons to charge neutralize the plasma. The magnets are being designed such that in the multi-cusp configuration 0.2 eV ions are unmagnetized in a finite region extending radially and all along the axis. This experimental set up is expected to be completed by 2010.

A.3.9 Laser Blow Off Plasma Experiment

In continuation with the characterization of LBO plume under the different experimental condition, the main emphasis in this duration was on imaging spectroscopy of expanding plume which can provide information on the local structure, dynamics of the constituent particles, and geometrical aspects of the plume. The time resolved images, of the visible plume luminescence were recorded by an ICCD camera having variable gain and gating time. The effect of experimental parameters (e.g nature and pressure of the ambient gas, laser fluence, presence of external magnetic field, etc.) on the expanding plume with regards to the shape, size and structural formation have been studied. Enhancement of the plume emission and change in size and shape occurs on introducing ambient gases/magnetic field and these changes are highly dependent on the nature and composition of the background gas as well as the applied magnetic field. On making a comparison with the results (expansion against the background gas/ magnetic field) available in the literature for conventional LPP experiments, some new features have been observed with some significant differences. One of the most important observations of the present experiment is the strong focusing (lateral confinement) of the LBO plume, which persists for longer times without any noticeable divergence. The strength of the focusing depends on the nature/pressure of the background gas used (it more pronounced in the heavier background atoms). Also, a strong oscillation in the delayed portion of the LBO plume in vacuum was observed by Triple Langmuir probe. This is an important observation because oscillations/instabilities in the expanding plasma plume are normally observed in the presence of magnetic field or ambient gas. At present these observations (focusing and oscillations) remains unexplained by earlier proposed model and therefore more investigations in this regard are required.

A.3.10 Electron-Positron plasma

1)Paul Trap parameters have been worked out for creation of Electron – Positron Plasma. This included:
(a)Analytical estimation of trap voltages that depend upon choice of Pseudopotential well depth of the trap;
(b)With the peak positron density, estimation of dimensions of the trap, the frequency of RF field at the trap electrodes and the average E-field in the trap region;
(c)Deduction of characteristic dimensions of the plasma based on the density profile in a Paul Trap

2)Following were the parameters estimated for a pure positron plasma in a Paul Trap:
(a)Expected plasma temperature = 0.5 eV
(b)Maximum space-charge limited plasma density = 5 $X10^6$ cm^{-3}
(c) Debye length = 0.23 cm;
(d)Expected plasma dimensions (r1, z1) = (0.8 cm, 0.4 cm)
(e)Expected plasma volume = 1.63 cm^3
(f) Number of positrons expected to be trapped = $8X10^6$
g) Axial Length of the trap 2zo = 5.08cm
(h)VRF = 242 Volt
(i)RF frequency = 71.2 MHz
(j)Stability parameters in Matheiu equation (az, qz) = (0, 0.66)
(k)Pseudo-potential well depths (Radial Dr, Axial Dz) = (10V, 20V)

3)Flux and buffer gas retardation and collisional cooling (with N_2 and CO_2) as well as Bohm diffusion calculations of the plasma in a Paul Trap with axial magnetic field ~ 1.6T

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A.4. Theoretical and Computational Plasma Physics

A.4.1 Laser Plasma Interactions

TIFR Collaboration: A one dimensional model proposed earlier (Phys. Rev. E 73 036409, 2006) to describe the temporal evolution of self-generated magnetic fields in ultra-short (100fs) ultra-intense (~10^{16}W/cm^2) laser-solid interaction, has been extended this year to include thermoelectric effects. This new theoretical model has been used to explain the measured magnetic field in a new set of experiments performed at TIFR, using two set of targets viz. 1μ thick coating of Cu and Ag on BK7 glass. These targets were irradiated with a laser pulse (100fs, 10^{16}W/cm^2) and temporal evolution of the magnetic field generated near the critical surface was measured with femtosecond time resolution using polarimetric methods.

Work on Nonlinear theory and Simulation of large Amplitude plasma Oscillations/Waves in a Cold Plasma: Spatio-temporal evolution of large amplitude plasma oscillations and waves in a cold plasma is a topic of intense investigation because of its application to several areas of current research viz. laser/beam induced particle acceleration, Fast ignition, Plasma heating etc. Amplitude of these nonlinear waves is limited by a phenomenon called wave breaking which occurs when neighbouring electron orbits cross. It is well known that a sinusoidal standing wave with a definite wave number "k" breaks when $keE/m\omega_{pe}^2 \sim 0.5$. Here we have investigated both analytically and using 1-D PIC simulation, the spatio-temporal evolution of a wave with multiple wave numbers.

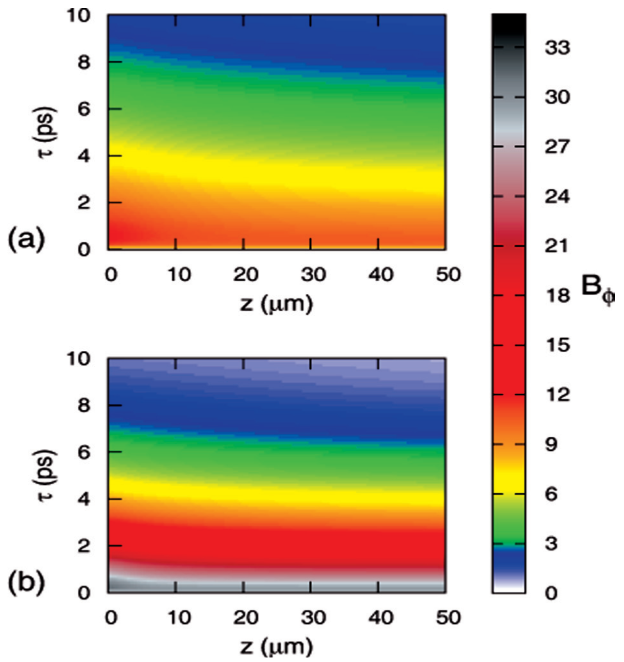

Figure A.4.2.1 shows the spatio-temporal evolution of the magnetic field in the two targets obtained using our new model.

A.4.2. Electron Magnetohydrodynamics (EMHD)

Fast Ignition related: The scaled down Fast Ignition (FI) experiments at ILE (Institute of Laser Engineering) Osaka showing the stopping of energetic electrons (with energy as high as 15 MeV) propagating through dense target core but free propagation through the low density corona region was interpreted. A novel EMHD mechanism of shock formation and the associated energy dissipation in the inhomogeneous plasma encountered by the electron pulse while propagating through the dense core region was invoked for this purpose. The quantitative estimate for the electron energy loss showed excellent agreement with the experiment.

Simulations of G-EMHD:Numerical simulations of Generalized Electron Magnetohydrodynamic (G-EMHD) equations were performed to investigate the role of electron inertia on the formation of EMHD shocks when the electron current pulse encounters a sharp density inhomogeneity. It is observed that the shock structures are sharper in the presence of electron inertia related terms. It was shown explicitly that the energy dissipation of the electron current pulse in such shock structures are independent of the magnitude as well as the nature of the underlying dissipation in the system. This offers an important collision-less dissipation mechanism in plasma.

Role of Whistler wave in the Kelvin Helmholtz instability in EMHD: The role of whistler waves in the electron velocity shear driven Kelvin Helmholtz (KH) instability was investigated in detail. It was observed that the presence of whistler waves reduces the growth rate of the instability. Furthermore, the numerical simulations in the nonlinear regime of the instability show a considerably reduced effective anomalous viscosity in this case.

Strongly Coupled Plasma: A numerical simulation code was developed to simulate a strongly coupled plasma system in one dimension using generalized Hydrodynamic fluid model. The code is currently being tested for known exact results.

A.4.3 Non-Linear Phenomena

Kinetic Vlasov simulations of collisionless plasmas

Studies on collisionless plasma shocks: Large scale kinetic Vlasov simulation of a collisionless hot plasma, resembling stellar and interstellar space plasmas are performed using the code KSLab. The analysis of long lasting stable laminar electrostatic shocks has long been subject of considerable interest in the modern astrophysics because of the capability of plasma shocks to accelerate cosmic ray particles to the observed velocities. The simulated shock structures show characteristic particle acceleration in the region upstream to the collisionless plasma shock. Unlike the long standing predictions, the low Mach number laminar collisionless shocks are also found to propagate stably for considerably longer durations. A mechanism, involving the supersonic particles which drive a wave particle instability in the collisionless shock front, is identified to provide the extended stability to the observed shock structures.

Finite temperature effects on wave breaking and phase mixing processes in nonlinear plasma oscillations: Large amplitude nonlinear electron plasma oscillations are simulated in a fixed ion background finite electron temperature plasma, using the kinetic code KSLab. For larger wave numbers (smaller phase velocities), finite electron trapping and formation of nonlinear BGK modes is observed.

For smaller wave numbers a finite electron temperature is seen to accelerate the process of wave breaking, which is characterized by the traces of formation of slow moving coherent structures and corresponding modification in the associated frequency spectrum.

A.4.4. Gyro-kinetic Simulations

Simulation of non-adiabatic passing electrons: A linear global electro-magnetic gyro-kinetic model (EM_GLOGYSTO) applicable to large aspect ratio circular tokamak is used to study the temperature gradient driven class of micro-instabilities, for example, ion temperature gradient driven mode (ITG), trapped electron coupled ion temperature gradient mode (ITG-TEM), electron temperature gradient driven mode (ETG) and trapped electron mode (TEM). Usually the ITG mode is studied with a tacit assumption that electrons will necessarily be adiabatic at the mode frequency of the ITG. Later, inclusion of trapped electrons revealed that, these trapped particles, indeed have strong effect on the ITG mode, leading to substantial rise in the growth rate as well as mode frequency of the ITG instability and the concomitant ion transport. Passing electrons, nonetheless, were considered adiabatic in those studies.

The effect of inclusion of the passing non-adiabatic electrons was studied with all the kinetic effects from FLR effect of all orders to various kinetic resonances, radial and poloidal couplings, true ion to electron mass ratio, profile variation with the electrostatic version of the code. This allows one to perform a comprehensive study of the class of temperature gradient driven micro-instabilities, which is believed to be the plausible candidates for the loss of particles and energy from a magnetically confined plasma, in the presence of fully non-adiabatic passing electrons. To accommodate the physics of the fully non-adiabatic passing electrons in the time dependent linear and non-linear simulations has been an uphill task in the presence of full ion dynamics with true ion to electron mass ratio in terms of the consumption of the computational time. These particles are therefore considered either adiabatic or non-adiabatic with reduced ion to electron mass ratio.

In contrast to the earlier speculation, strong effect of these non-adiabatic passing electrons has been seen on the modes such as ITG ITG-TEM and TEM . The linear growth rate of these modes are altered significantly in the presence of passing non-adiabatic electrons. Especially, near the mode rational surfaces where parallel wave vector tends to zero, the drastic rise in the phase velocity of the mode, makes the passing electrons to respond sluggishly. Thus, the rise in the potential and hence EXB drift changes the growth rates as well as the real frequency of the mode. The mode structure, near mode rational surfaces, breaks up to finer length scales. The observed breaking of the mode structure near these surfaces in the case of ITG-TEM is shown in the Figure A.4.4.1 and also with a close-up view. The first one is the ITG with the electron species fully adiabatic, second one is ITG with trapped electrons but with adiabatic passing electrons and the third one is the ITG with trapped electrons and non-adiabatic passing electrons. The change in the mode structure is clearly visible in the picture.

Simulation of fast particles on ITG: Role of energetic ions is another area that has derived much attention in the fusion community. Presence of these particles are inevitable in the fusion grade plasmas, because of the various auxiliary heating schemes and fusion produced alpha particles. Study of the influence of these energetic ions on the kinetic ballooning mode (KBM), toroidal Alfven eigen mode(TAE) is very much important. These particles can give rise to the unstable modes on their own, for example, energetic particle modes (EPM). These particles are thus capable to quench the fusion process. As a first step, a second species of ions have been incorporated, which is hotter than the usual ion component, to the background model and has been studied its effects on the ITG modes. These energetic ions are observed to stabilize the ITG mode strongly. The same model also enables one to study the influence of the impurity ions on the various modes.

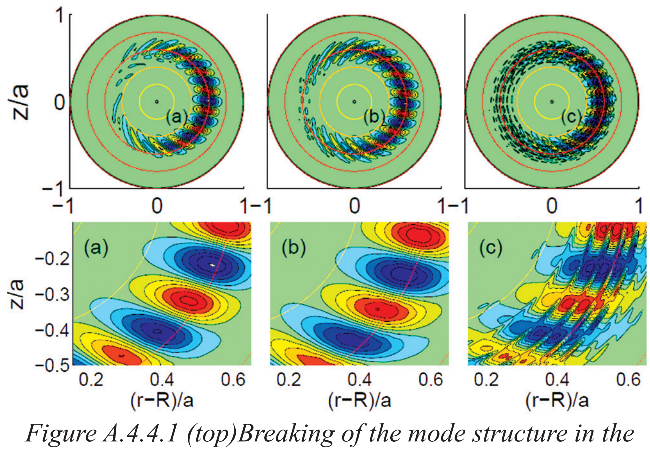

Figure A.4.4.1 (top)Breaking of the mode structure in the case of ITG-TEM (bottom)with a close-up view

Gyro-kinetics of ETG and effects of ion non-adiabaticity: Electron temperature gradient (ETG) mode, even though, has very fine scale length, can give rise to significant loss of energy, via the non-linear formation of streamers. So, the mode is now believed to be a potential candidate of electron transport. We have therefore, extended our study from ion scales of ITG, ITG-TEM and TEM modes to the electron scales of ETG. With the inclusion of the space charge effect in the form of Debye shielding, the model enables one to study the pure ETG mode in the presence of fully non-adiabatic ions and can elucidate the effect of ions scale on the ETG mode.

Multi-scale Turbulence using GTC : A recent series of investigations on ion temperature gradient (ITG) drift instabilities based on multi-scale gyro-kinetic particle simulation have been carried out to address the questions concerning 1) the interactions between the global zonal flow modes and the mesoscale ITG turbulence, 2) the interplay between these instabilities and the resulting profile modifications and 3) the numerical noise issue in long time simulations. Results obtained were used in understand various open issues in steady state transport of ITG turbulence.

Molecular Dynamics Simulation of 3D Yukawa Systems

Development of the new 3D Molecular Dynamics Code : MPMD (Multi Potential Molecular Dynamics) is a parallel molecular dynamics code for simulating Yukawa and Coulomb systems. The code has been exhaustively bench marked against known results. This code can handle inter-atomic potentials of Yukawa systems, Lennard Jones and Tersoff-Brenner. Ewald sums are employed to handle long ranged forces in the Yukawa system in the presence of periodic boundaries.

MPMD can simulate various thermodynamic ensembles such as NVT, NVE,NPT by employing a Gaussian thermostat and an Andersen Barostat. Using this code the following physics problem has been addressed.

The study of a weak external drive has been done on strongly coupled 3D Yukawa systems. For this we have developed a 3D Molecular Dynamics code called MPMD. The external drive is applied on a Yukawa solid (BCC) and both non-equilibrium and equilibrium studies are done. The magnitude of external drive is small compared to average interparticle potential energy. We observed melting of strongly with the application of external drive. A critical value of external drive (Vc) was found below which there is no melting. The mechanism of heating in the transient state is attributed to the local heating of the system where the forces are maximum. It is shown that these local hot regions dissipate heat into surrounding regions ultimately leading to a uniform temperature throughout the system.

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A.5. Facilitation center for Industrial Plasma Technology (FCIPT) Activities

A.5.1 EXTERNALLY FUNDED PROJECTS

Development of Atmospheric pressure plasma system for treatment of activated carbon used in water purifiers: Activated carbon surface properties are both hydrophobic and oleophilic. Due to its hydrophobic nature certain pressure is required to pass the water through it. Generally for municipal water treatment plants, electric pumps are used to generate desired pressure. In some cases, a water tank of few meters height is also capable to produce necessary pressure. But when it comes to provide clean water to small villages where they lack both of these facilities i.e. electricity and desired heights of water tank then this method does not work. Due to these constraints it can not be used in remote villages.

To improve the water absorbing property of carbon powder, FCIPT took a challenge to develop a plasma based technology which could use gravity pressure to filter water for drinking purpose. The aim of this work was to improve the water absorption property of coconut charcoal, thus facilitating hydrophilic nature of the carbon filter. Keeping the industrial use of the plasma system in mind, it was felt that an atmospheric plasma system would be suitable choice. A prototype lab scale atmospheric pressure plasma system was designed, fabricated and installed at M/s Filtrex Technologies Pvt. Ltd., Bangalore in February 2009 and has been functional thereafter.

Langmuir Probe diagnostics system development for Rajasthan University: Rajasthan University, Physics Department is developing an ECR plasma system which would require a langmuir probe system to diagnose the ECR plasma. FCIPT will be developing and demonstrating a Langmuir Probe system for Rajasthan University, Jaipur by the end of September 2009.

Anti-wear coatings developed for LPSC: A project had been undertaken by FCIPT with LPSC, ISRO via an MOU for developing TiN coatings specific for rocket applications over 440C grade steels. A successful TiN coating has been

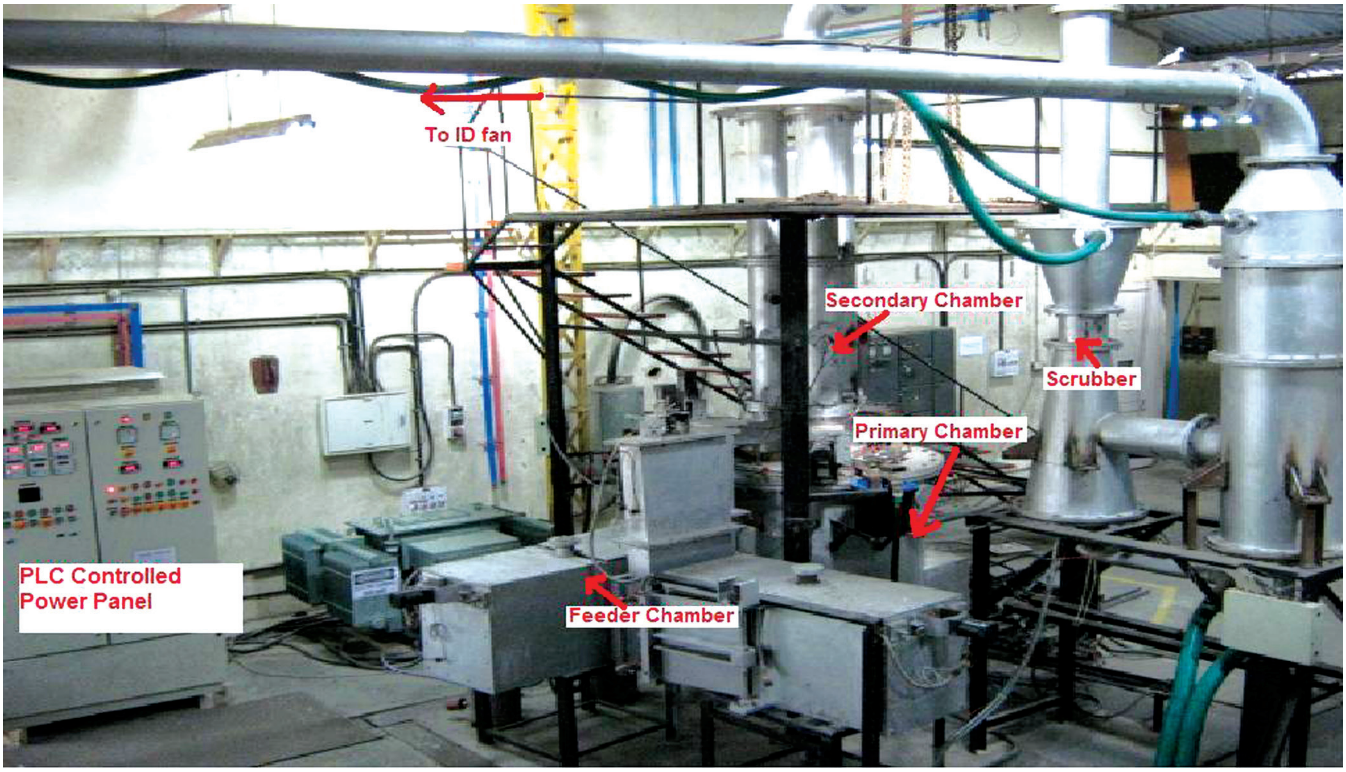

Figure A.5.1.1 Higher capacity plasma pyrolysis system as demonstrated and tested at FCIPT.

developed by FCIPT and such coated 440C test coupons has been successfully tested at LPSC, Trivandrum.

Higher capacity Plasma Pyrolysis System tested for emissions: A higher capacity (50 kg/hr) and more efficient Plasma Pyrolysis system for medical and plastic waste which had been funded by DST, New Delhi under Technology Systems Programme has been successfully tested for emissions. The gas emissions analysis reveal lowest emissions compared to that of conventional incicnerators and are well below the specified limits of CPCB. This has paved the way of an eco-friendly waste processing in India. Further more, an innovative design modification in this system made it an energy efficient system. An International Patent (PCT) has also been applied for this system which is shown in the figure A.5.1.1.

Industrial Scale Plasma Nitriding System Installed and Inaugrated at IGTR, Ahmedabad: An Industrial Scale Plasma Nitriding System had been installed and inaugurated at Indo German Tool Room, Ahmedabad on 12th November, 2008. The 25 kW plasma Nitriding system has been made open for utilization by industries on job work basis.

A.5.2 INTERNAL PROJECTS (UNDER IPR FUNDING)

Development of Hot Dip Aluminide coating for Indian TBM: The Test Blanket Module Programme of India has an LLCB concept which uses both solid and liquid breeder concepts. The LLCB design needs specific surfaces (coatings) which can tackle various phenomena encountered during operation such as MHD, Erosion-Corrosion from Pb-Li flow, Tritium permeation etc. FCIPT has undertaken this activity in a project mode, to develop a hot dip aluminide coating for the above application along with the TBM group of IPR. Preliminary trials on hot dip aluminized coatings on M.S samples have been done and the effect of melt composition, temperature and sample surface fluxing are being investigated. The Design of a suitable HDA system has been completed and indented so as to install the system in September 2009 at FCIPT. The experiments on optimization of the coating shall follow.

Hydrogen permeation studies for Tritium Permeation Barrier properties: Tritium inventory and control is one of the essential criteria in the fusion technology for its operational implications. The interaction of tritium with the structural materials is crucial for safety considerations because of high probability of tritium permeation through the materials during high temperature operation. Hence, the study related to permeation of hydrogen & tritium through RAFMS (coated and uncoated) has emerged as a validating tool. FCIPT along with TBM group of IPR has undertaken a project to study the permeation rates of hydrogen through structural steel (RAFMS) for the TBM applications. This study will help develop, characterize and optimize a suitable hydrogen/ tritium permeation barrier.

Erbia Coating on RAFMS: As one of the candidate coatings for the Test Blanket Module, Erbia is emerging as one of the promising coatings which provides Tritium Permeation Barrier Properties, MHD insulation, resistance to corrosion against eutectic Pb-17Li etc. As an attempt to develop this coating for the Indian TBM (IN-LLCB), a project has been worked out jointly by FCIPT & TBM Group, in which Er2O3 coatings on Reduced Activity Ferritic Martensitic (RAFM) steels shall be developed using RF magnetron sputter deposition process. The optimization of the coating shall be done by extensive characterization and testing and shall be further validated for the LLCB application requirements.

Mixed Phase Hydrogenated Silicon (Si:H) thin film deposition by VHF-PECVD: The Very High Frequency-VHF (55 MHz) Plasma Enhanced Chemical Vapor Deposition (PECVD) system with Silane (SiH_4) gas distribution has been developed in-house for the deposition of device grade hydrogenated silicon (Si:H) thin film. Langmuir probes have been used for the detail comparison of VHF (55 MHz) with RF (13.56 MHz) Hydrogen (H_2) plasma using multi-hole cathode (MHC) shower head. Radial profiles indicate a higher ion density (Ni) and lower electron temperature (Te) for VHF as compared to RF plasma, here the lower Te for VHF plasma known to give better quality Si:H films whereas higher Ni in case of VHF as compare to RF would result in a high deposition rate (Figure A.5.2.1 (a) & (b)). Further, Ni dependence on power indicates ohmic (collision) nature of the plasma, while Te is essentially constant (Figure A.5.2.1 (c)). Amixed phase, microcrystalline + amorphous hydrogenated silicon thin films have been grown using a MHC shower head geometry and a low substrate temperate of 60 C by VHF PECVD. The deposited films were characterized by Atomic Force Microscopy (AFM) and High Resolution Photoemission Spectroscopy (PES), AFM revealed the mixed phase in the deposited films, showing micro-crystallites of 500-600nm embedded in the a-Si:H matrix (Figure A.5.2.2 (a)) and (b) shows a line profile across two crystallites. PES of Si 2p core level measured with the high resolution of 0.15 eV confirmed the two types of Si species: microcrystalline and amorphous, present in the mixed phase Si:H thin films (Figure A.5.2.2 d) whereas figure A.5.2.2.c shows PES for reference crystalline silicon sample.

1 MW Peak power Solid State IGBT based power supply developed: The demand for new materials and layer structures has lead to development of more advanced sputtering systems. Applying high power pulses (of the order of few MW) to a magnetron is a relatively new method to produce thin films, and is called High Power Impulse Magnetron Sputtering (HIPIMS). In HIPIMS the peak power on the target surface can be as high as several kW/cm^2. Such high power pulses are capable to produce highly ionized plasma with a high degree of ionization of the sputtered material, which results in better wear capability, better corrosions resistance, higher transmittance for light, better electrical conductivity, smoother film surfaces etc. Considering its vast future potential, FCIPT is developing an indigenous HIPIMS facility i.e. 1 MW (peak power) solid state IGBT based pulsed power supply for this HIPIMS facility. The pulsed power supplies consist of 3 sections: a DC power supply, a pulse unit and an intelligent arc protection unit. As a next course of action this system will be tested and integrated with a plasma reactor to evaluate its performance for various applications. Once if this technology is successfully developed it can be helpful for various surface coating industries in India

Plasma Enhanced Jet Vapour Deposition (PEJVD) process for Zinc free coatings: FCIPT undertook preliminary studies on development of zinc free coatings on steel by PEJVD technique. The experimental setup has been built and the initial trials are being carried out. The necessary differential pressures have been created for obtaining the critical velocity of the jet. The concept of JVD has been successfully tested at sample level, by starting with the deposition of low boiling point elements. Deposition rates as high as 42 micron per minute have already been achieved. Further, certain studies have been carried out to see the effect of nozzle-target distance on the deposition rate and the morphology of the deposited coating. Further, we have also successfully created the plasma in the JVD setup so that the metallic vapors would pass through the plasma and get modified and ultimately change the characteristics of the deposited coating. Studies to find the role of plasma on the enhancement of coating characteristics is going on.

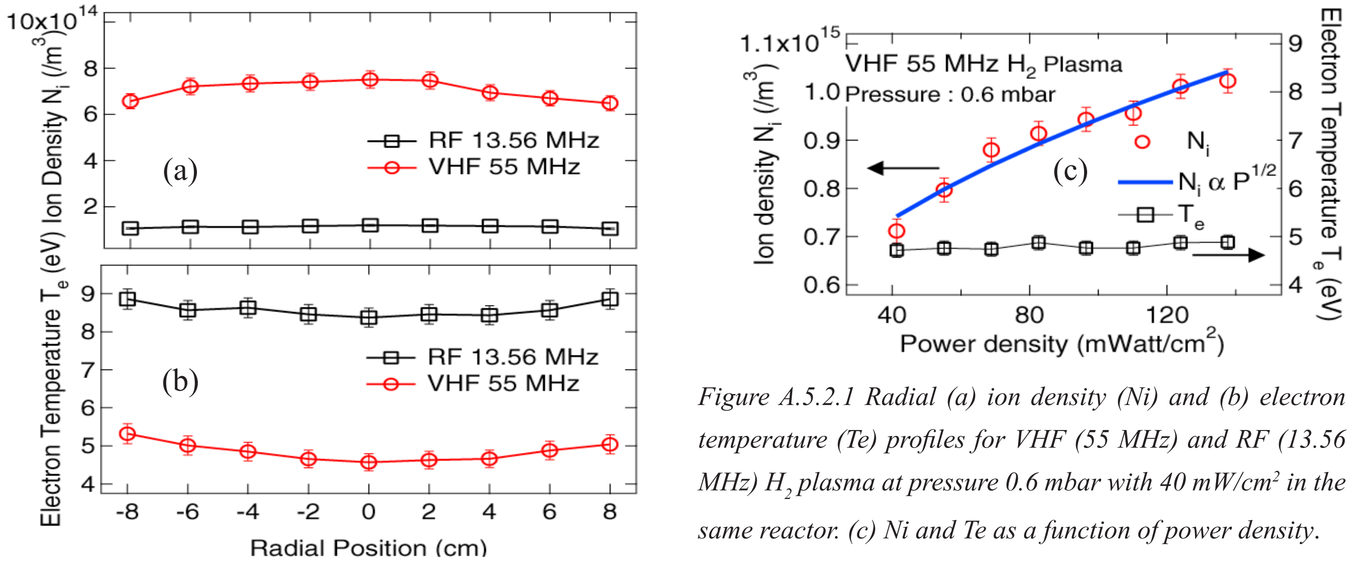

Figure A.5.2.1 Radial (a) ion density (Ni) and (b) electron temperature (Te) profiles for VHF (55 MHz) and RF (13.56 MHz) H_2 plasma at pressure 0.6 mbar with 40 mW/cm² in the same reactor. (c) Ni and Te as a function of power density.

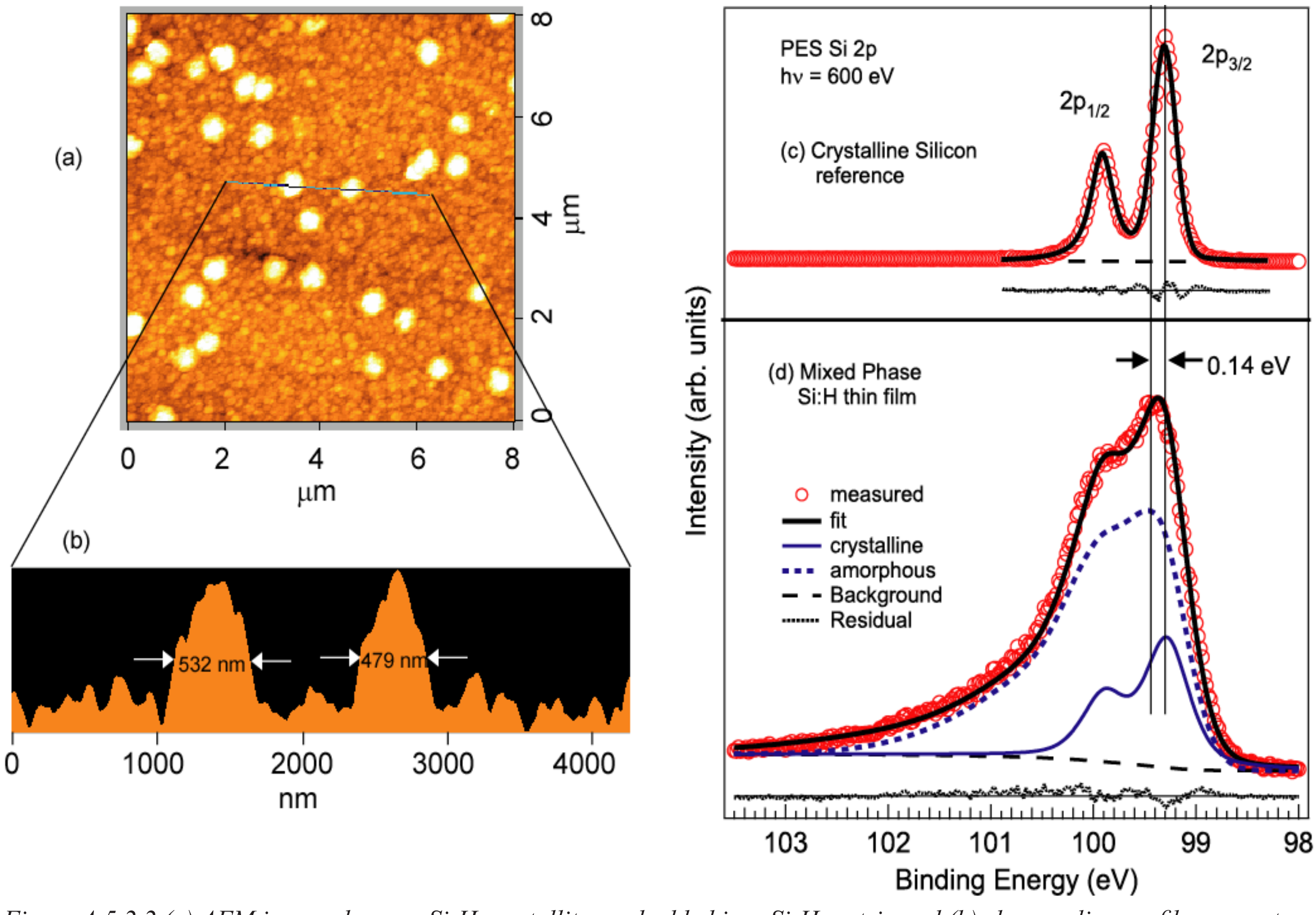

Figure A.5.2.2 (a) AFM image shows µ-Si:H crystallites embedded in a-Si:H matrix and (b) shows a line profile across two crystallites. Si 2p core level PES for (c) crystalline silicon reference sample and (d) mixed phase Si:H thin film.

Synthesis of nanomaterials using thermal plasma: Preliminary work to study and control the size distribution of nanomaterials synthesised using thermal plasma has been undertaken. An existing chamber was modified to make it suitable for nanoparticle synthesis. Preliminary experiments on TiO_2 nanoparticle synthesis have been done and its analysis is being carried out. TiO_2 nanoparticles have numerous applications, especially in the textile industries for photocatalyst for degradation of dirt particles (self cleaning textiles), antibacterial properties, for UV protection etc. and such applications are explored to be exploited using plasma technology.

A.5.3 SURFACE CHARACTERIZATION LABORATORY

The activities of the surface characterization laboratory at FCIPT are as given below:

Commercial: Characterization and analysis of materials have been carried out on commercial basis to address diverse problems of different customers.

Grazing XRD analysis on Ferritic-Martensitic T-91 steel with heat treatment and micro-structural stabilization followed by He and Ni irradiation with varying dose at varying energy, was carried out for a NFP project of Mumbai University. The project is aimed at studying the effect of heavy ion (Ni) dose to the steel after He incorporation. Detailed study reveals that He incorporation tends to expand the steel matrix, whereas post irradiation with Ni brings it back to the equilibrium volume. Detailed morphological and elemental characterization was also carried out using SEM and EDAX.

Preferentially oriented (0 0 2) reactive magnetron sputter deposited AlN film on Fused Silica and Alumina substrates were prepared by Space Application Centre for their SAW device application. On observing relatively rough surface morphology of the film on Fused Silica substrate, they approached us to investigate the possible difference between the two films. High resolution XRD analysis indicated that the film on Alumina contained significantly less micro strain as compared to that on Fused Silica, suggesting higher defect density in the later case. The elemental composition on morphologically different pockets observed on both the films but more on Fused Silica substrates, shows no difference as compared to normal film surface.

Root canal treated human tooth sections and dental sections were analyzed with SEM for checking the effectiveness of the Glyde file prep during root canal instrumentation.

Moreover, various analysis such as polymorph identification, inclusion and failure analysis of alloys, growth, size and shape analysis of organic single crystals etc. were carried out on commercial basis for diverse organizations and industries such as PRL, SAC, Gujarat University, S P University, Sahjanand Laser, Shah Alloys Ltd., Viraj Alloys Ltd., Dental College Civil Hospital Ahmedabad etc.

Internal Projects and Research support: XRD, SEM and EDAX characterization and analysis for crystalline phase identification, preferred orientation, surface morphology, micro-structure and quantitative elemental analysis, were provided for various internal projects, research, process and technology development activities such as of following :

◊ Cu-TiN composite coatings on Si wafer and SS304 with varying concentration ratios, by dual planar magnetron sputtering.

◊ Cu and TiN planar magnetron sputter coatings on Si wafer and SS304 substrates with varying DC bias voltage (0 - 120 V), varying pulsed bias voltage (0 – 5 kV), varying deposition angle (0 -90 ^{o}C) and varying substrate temperature (0 – 500 ^{o}C).

◊ Transparent Conducting Oxide SnO_2 coating on Si, SS304 and glass by thermal evaporation and annealing in Oxygen pressure. Tin metal evaporated in a high vacuum and a thin film of few-micron thickness deposited on substrates at 350 ^{o}C. The film was analyzed with XRD and SEM for its phase, crystallinity and surface morphology before and after the annealing.

◊ Zinc deposition on Si wafer by Jet Vapour Deposition process.

◊ Heat treatment and plasma nitriding of AISI 52100 Bearing steel.

◊ Hot Dip Aluminization of mild steel; characterization of aluminum diffusion and phase formation in steel.

◊ Hard friction-less Teflon-like and TiN coatings on 440C steel using planar and cylindrical magnetron.

◊ Ageing effects on High temperature superconductor Bi(Pb)SrCaCuO, an M. Phil. Project under the Cryogenic group, IPR.

◊ Morphological and thickness analysis of Protective transparent SiOx coating on Si wafer using Plasma Enhanced Chemical Vapour Deposition.

◊ SEM analysis of pyrolytic products of Plasma pyrolysis of polyethylene and cotton: Residue (carbon soot) formed at different temperatures and collected from primary chamber were separated and examined under SEM for the particle morphology (size and shapes) found to be in shapes such as spherical, polygonal, tubular etc.

◊ Tungsten/tungsten alloy (La_20_3) plates to be used as particle target in fusion reactor were analyzed for its chemical composition for the Cooling group, IPR.

◊ Copper alloy (Cu-Cr-Zr) and stainless steel joints brazed with TiCuSil alloy for first-wall application were analyzed using SEM and EDAX for joint quality and elemental redistribution after the joint.

ISO 9001:2000 SURVEILLANCE AUDIT OF FCIPT

A surveillance audit of FCIPT for it's conformance to ISO 9001:2000 standard had been conducted by the certification body TUV SUD. FCIPT had been certified compliant to the standard and the QMS practice had been well appreciated by the auditors.

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B. OTHER ACTIVITIES

B.1 Board of Research on Fusion Science and Technology (BRFST)

During the period a total number of 30 research projects were granted by BRFST. Of this, four were awarded to collaborative research proposals with industry. The Board conducts review of project twice in a year (February and August). This is to ensure that the waiting period between submission and award of project is less than a few months.

Major Activities of BRFST : Some of the achievements of BRFST are listed below graphically. A total number of 30 projects have been sanctioned under NFP during this period with a committed budget of approximately Rs.686 Lakhs. Research projects in several areas of research important from the point of fusion science & technology have been sanctioned to both academic as well as industrial establishments.

The board also supported over 17 conferences/workshops that were related to fusion science & technology. Fourteen students from various streams of science & engineering were awarded fellwowships under the NFP internship scheme.

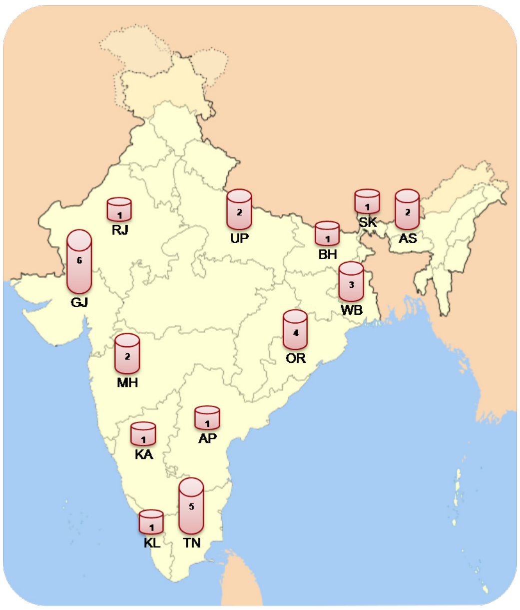


Figure B.2.1. Demographic distribution of the projects sanctioned under NFP

BRFST also began the series of contact meetings which is aimed at propagating the activities of BRFST and evoking interest in fusion science & technology based R&D. The first in the series was held at NIT Hamirpur in November 2008. Two other meetings in Cochin and Kolkata are in the pipeline.

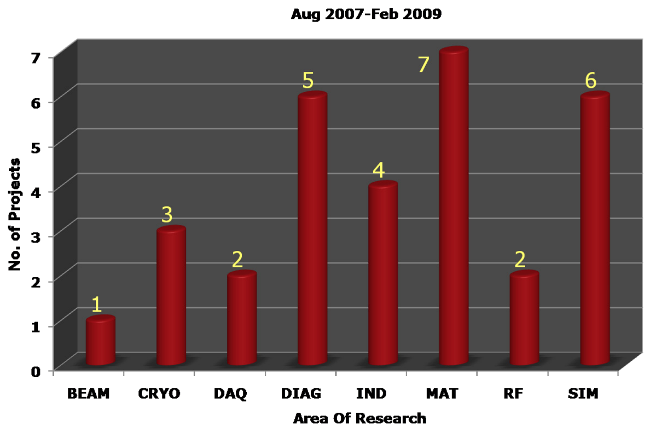


Figure B.2.2. Areas of research that have been funded under NFP.

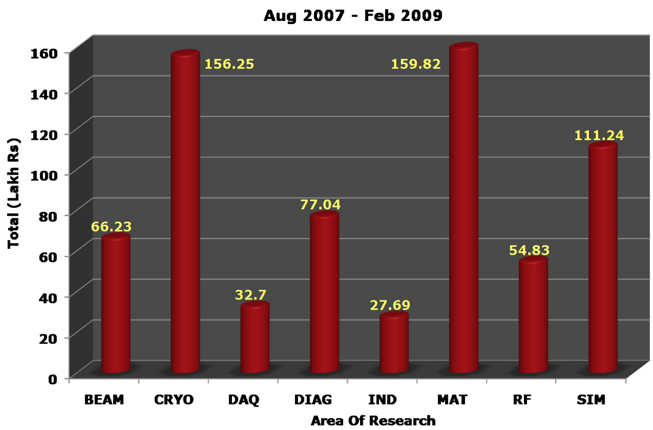


Figure B.2.2. Areas of research that have been funded under NFP.

B.2 ITER-India

ITER-India (http://www.iter-india.org) is the Indian Domestic Agency in ITER (http://www.iter.org), which is a multinational project involving the European Union, China, India, Japan, South Korea, Russia and the United States. ITER, meaning the way stands for the International Thermonuclear Experimental Reactor, which is a nuclear reactor based on thermonuclear fusion reactions aimed at solving long term energy problems of mankind. ITER is being built at Cadarache in the South of France, near the port of Marseille. India is the last member to join ITER in 2005 and is responsible for delivery of about 9% of the ITER machine components like the other parties, except for the EU, which being the host, supplies about 45%. The components to be delivered by India are to be primarily manufactured by Indian Industries or in collaboration with Indian industries. The remaining only about 10% of ITER cost is jointly funded by the Parties through cash contributions.

In 2008-2009, ITER as well as ITER-India has made significant progress in towards resolving many of the outstanding design issues and launching of the procurements. Presently the focus of the activities is completion of the remaining part of the ITER design and ITER-India is also involved in various design and analysis activities related to that before the construction can be started. The International Organisation (IO) has signed several procurement arrangements in 2008-2009 with the Parties; the first procurement Arrangement with India is due to be signed in April 2009.

ITER-India as also IPR personnel participated actively in numerous ITER meetings to resolve many of the outstanding issues in the project, the most prominent being the STAC (Science and Technology Advisory Committee), MAC (Management Advisory Committee) and Council meetings, which are held twice a year, as also the IO-DA coordination meetings which are held almost every month, alternately through Video Conferencing and in-person meetings. The IO-DA coordination is the highest decision making body within the IO and the DAs and act as the decision making project board. Apart from these top level meetings, the ITER-India personnel were also involved in several working groups, Integrated Project Teams (IPTs), Review groups etc which also have regular interactions either through regular Video Conference or in-person meetings. Several ITER-India personnel have also visited ITER, Cadarache as also other Domestic Agencies to work actively towards finalizing of the ITER designs.

Following is a brief account of the activities in the different Procurement Package areas of ITER-India:

WBS 1.5 In-Wall Shielding (IWS)

(i) CAD and Analysis of ITER Vacuum Vessel In-Wall Shielding

Development of conceptual design, Finite Element analysis (structural, thermal, electro-magnetic and coupled) and final engineering design of ITER Vacuum Vessel In-Wall Shields (VV-IWS) for vessel sector # 1 and 7 has been carried out with support from M/s Altair Engineering India Limited, Bangalore. Design of about 120 numbers of IWS blocks for vessel sector -1 and 7 has been completed. A numbering scheme has been developed to uniquely identify every block and every component of block. Figures B.3.1. shows the 3D model of one of the IWS blocks (Row_22_A) for which detailed structural analysis has been carried out. Figure B.3.2. shows the FE model used for the analysis. Figure B.3.3. shows the stress distribution on different components if IWS block due to the combination of self weight, electro-magnetic load and pre-tension of the bolts. Block is considered immersed in water at 110^{o}C. Maximum stress concentration of about 480 MPa is observed on support rib joint with flexible housing. The stress concentration is on very limited and localized region which can be neglected. Over all stress concentration is within acceptable design limits. More detailed analysis is in progress.

(ii)Corrosion study of IWS materials: Corrosion study of VV-IWS materials (SS 304B4, SS 304B7, SS 430, SS316L(N)(IG) and XM-19) under normal and off-nor-

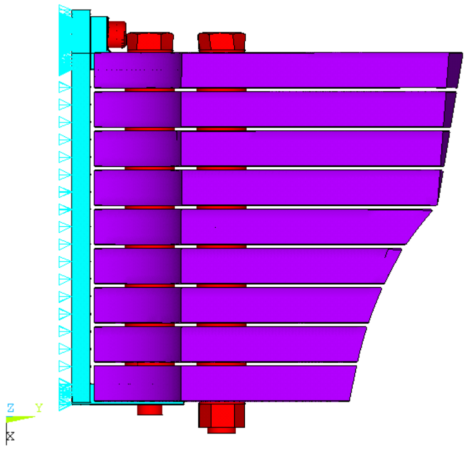


Figure B.2.1.: 3D Model of IWS block Row_22_A

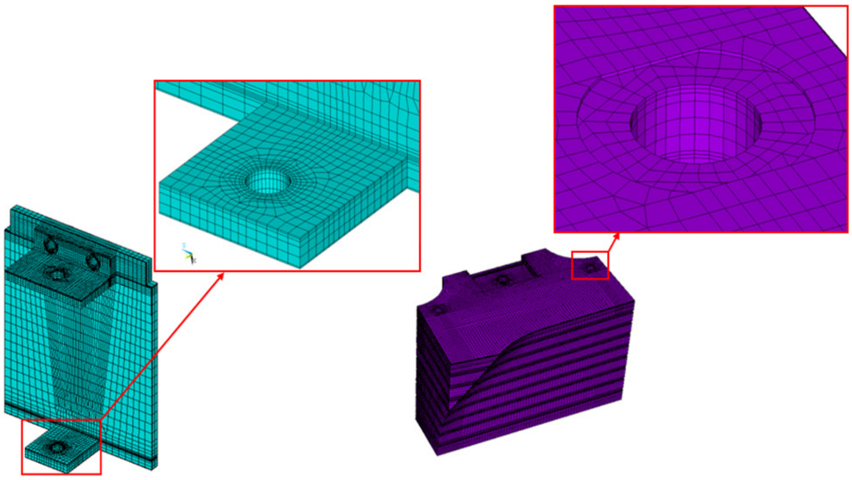


Figure B.2.2.Finte Element model of IWS block Row_22_A

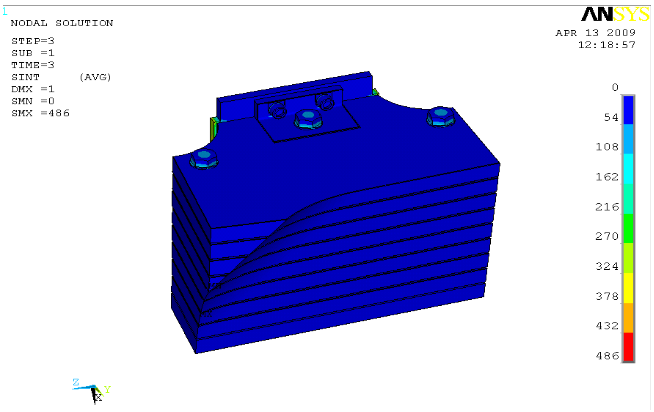
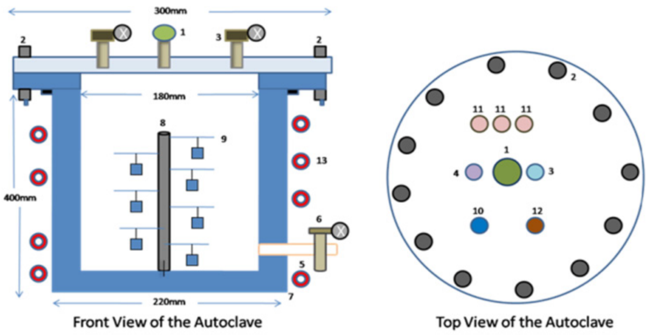


Figure B.2.3 Stress distribution on IWS block Row_22_A



Legend corresponding to above outlined image:
1 –Pressure Gauge
2 – Flange Bolt
3 – Water Inlet
4 –Top Outlet
5 – Bottom Outlet
6 – High pressure Valve
7 – Autoclave Body
8 – Custom Designed Sample Stand
9 – Sample Holding Hanger
10 – Thermocouple
11 – For Electro-chemical electrodes (plug holes when doing immersion test)
12 – Hot Nitrogen Inlet
13 – Electric Coils

mal operating conditions of vessel cooling is very important for the design of IWS blocks. As a large number of bolts are used in IWS block assembly, many crevices are formed. During the operating cycle of ITER vacuum vessel, these crevices can accelerate corrosion of the materials. Hence, crevice corrosion of the IWS materials under operating conditions is essential. This study is being carried out with support from M/S. TCR Engineering Services, New Mumbai. This study includes, (a) immersion test and (b) electro-chemical polarization test with different water chemistry, water temperature and drying (with hot nitrogen) operation. Three material samples (SS 304B4, SS 304B7 and SS430) were exposed to five operating cycles (100 ^{o}C, 200 ^{o}C and drying) during three months in three different autoclaves. Water used for this study have 1000

Figure B.2.4. Autoclave design for immersion tests ppb chlorides impurities plus 2 ppm hydrogen peroxide. Results show 0.1696 % and 0.0840 % increase in weight for SS 304 B4 and SS 304 B7 respectively. This increase is primarily due to oxide layer formed on the surface as indicated by surface analysis study. The result also shows 0.00471 % loss of weight for SS 430. This is due to the corrosion of the material. This loss of weight corresponds to maximum 0.03 mm per year corrosion rate for SS 430 in given operating conditions.

WBS 2.4 Cryostat & VVPSS

ITER-India Cryostat & VVPSS group had taken various tasks under signed task agreement (TA) between ITER Organization (IO) and ITER-India during this period. WBS dictionary and detailed planning & scheduling up 4th level for Cryostat and VVPSS procurement package (PP) had been prepared during this period. Technical discussions had been done with IO for getting inputs and clarification for given tasks. First draft copy of System Requirement document (SRD) for Cryostat had been prepared under a design work order (DWO) from IO.

Cryostat & VVPSS group is doing following design and analysis tasks under TA :

Task- 1: Overall design of cryostat

(1)Perform overall design of cryostat to meet all the functional requirements to cryostat.
(2)Review and optimize the segmentation of cryostat vessel for transportation taken into account of the transportation constraints both in India and France.
(3)Develop installation scheme for cryostat.
(4)Develop overall schedule for cryostat fabrication and installation. This schedule should be consistent with the Integrated Project Schedule of ITER.

Task-2: Cryostat structural and electromagnetic analysis

(1)Perform detailed structural analysis, under the given design conditions, to optimise the main structures such as adopting domed top lid, optimisation of the cryostat wall thickness and simplification of ribs (including

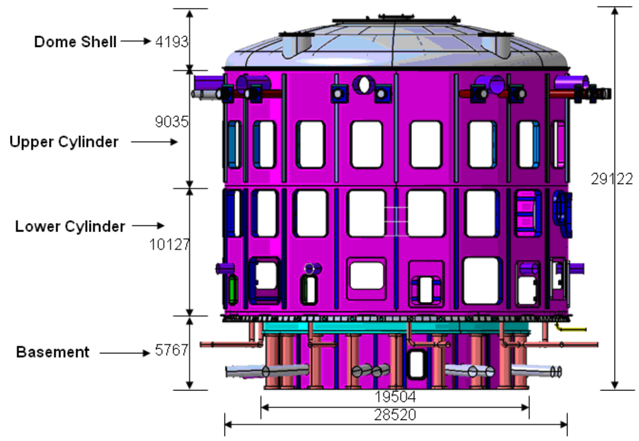


Figure B.2.5. Typical cryostat structure

eliminate ribs inside the small cylinder) and supports layout, considering the upper bio-shield supported from the building.
(2)Perform detailed structure analysis for penetrations under the operation and accident conditions.

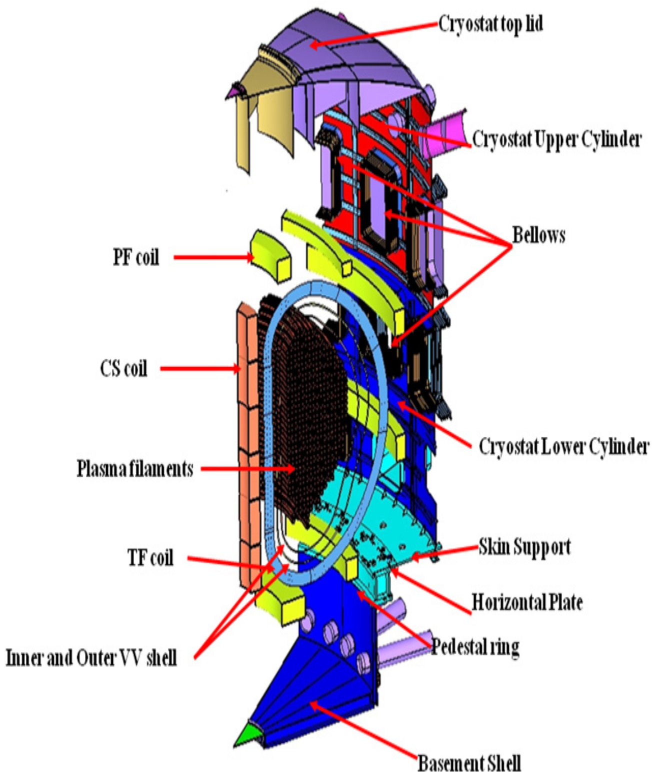


Figure B.2.6. 40 degree sector for Electro-M agnetic and structural analysis

Task- 3: Cryostat thermal analysis

(1)Perform analysis for overall thermal performance in operation and accidental conditions (such as coolant leakage in cryostat), heat exchange with the thermal shields should be considered.

(2)Perform thermal analysis at the pedestal ring area to evaluate the temperature decrease due to heat conduction through the magnet gravity supports and the temperature rise due to heat conduction through the VV supports.

Task -4: Detailed design of cryostat components

(1)Perform detailed design of sub components of cryostat vessel.

(2)Design the transport frame for sub components of cryostat.

(3)Perform detailed design for the supports of cryostat, including anchor bolts embedded in the concrete of the Tokamak building.

(4)Perform detailed design for cryostat overpressure protection system and cryostat drainage system.

(5)Develop CATIA models and drawings for cryostat components.

WBS 2.6: Cooling Water system

1.The System Requirement Documents (SRD) of Component Cooling Water System (CCWS), Chilled Water System (CHWS) and Heat Rejection System (HRS) have been prepared

2.The Process Flow Diagrams (PFD) of CCWS, CHWS and HRS have been prepared

3.Space reservations of major equipments have been done in Site service building

4.The SRDs of various clients have been reviewed

5.The feasibility study of water treatment facility for ITER-CWS has been carried out

6.Effects of Design Change Requests (DCR) 154 and 159 have been studied and the comments were sent to ITER-IO.

7.The monthly updates of Planning & Scheduling activities were being submitted to ITER-IO

8. IN-CWS and IO-CWS teams visited the manufacturing facilities of M/s Kirloskar Brothers Limited, Kirloskarwadi, M/s Alfa Laval Limited, Pune and M/s Paharpur cooling towers limited, Kolkata and initiated the preliminary discussions about the capabilities in delivering the equipments in India's package.

WBS 3.4 Cryo-distribution and Cryo-line

The ITER cryodistribution system and the system of cryogenic lines as well as manifolds are part of the in-kind supply for India. The design, engineering and analysis of the torus and cryostat (T & C) cryoline have been done to satisfy the functional requirements. Six process pipes, namely 4.5 K Supercritical Helium (SHe) supply, 4.5 K SHe return, fast cool down, cold He exhaust, 80 K Gaseous Helium (GHe) supply and 100 K GHe return, are assembled inside a thermal shield and outer vacuum jacket. The process pipes have different diameters and thermally insulated with 10 layers of Multi Layer Insulation (MLI). The process pipes are mechanically supported along their length using fixed and sliding supports at predefined locations to maintain the pipe configuration as well as to support the fluid weight. ANSYS© Simulation 10.0, CATIA® Version 5.16, HYDRA Metal Bellow Manual, HYDRA Metal Hose Manual, Flexperte - calculation program for flexible elements, CAESAR II© 5.1 and ASME B 31.3 have been used as the design guideline and analysis tools. The guideline of Expansion Joint Manufacturer's Association (EJMA) has been also used as the further support to the design.

Figure B.2.7 shows the final concept of cross-section generated for main line and branch line. Based on the results of pipe stress analysis, internal fixed and sliding support has been designed. Pipe stress analysis of each process pipe as well as outer vacuum jacket along with external bellow has been carried out. CATIA models generated for the straight, elbow, C and T sections are shown in figures B.2.8 (a), (b), (c) and (d). The optimized fixed support has been designed modeled and analyzed for its integrity for the functional requirements.

Stress analysis of the internal process pipe for each typical section of cryoline has been carried out using pipe

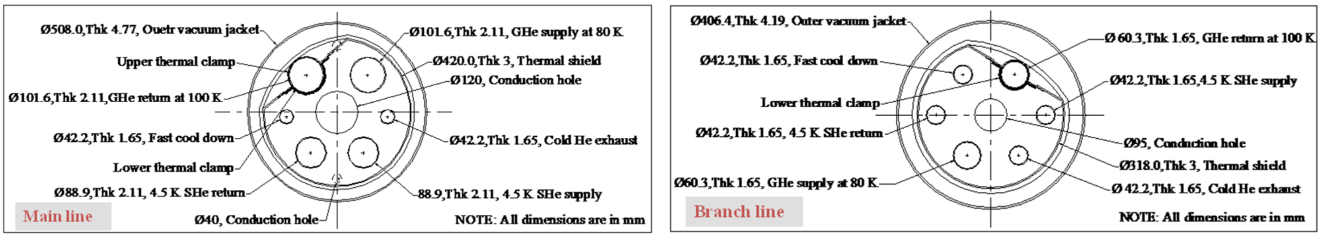


Figure B.2.7 Cross-section of Main and Branch line

stress analysis software CAESAR© II. Results of the analysis have been compared with the limit specified in process piping code ASME B 31.3. The stress analysis has been done under following load conditions, (i)Sustained load case: Includes static weight and pressure (W+P) ;(ii)Expansion load case: Due to thermal expansion of the piping system (T); (iii)Operating load case: Algebraic sum of the above two load (W+P+T). A prototype test concept for the ITER-cryoline has been generated. A concept for prototype thermal shield test also has been made. The prototype thermal shield is presently under fabrication.

WBS 4.2 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 Laboratory, before delivery to ITER, to test corresponding systems to full operational parameters.

During the year the conceptual designs for the DNB power supply was completed and the report went through an international review. The document was approved by ITER and adopted as the basis for the Procurement Arrangement. Another report on specifications of a High Voltage Power Supply for the RFX, Italy was also completed. The design report for the IC Power Supplies, which was completed earlier, was further converted into a procurement arrangement.

A Memorandum of Understanding was signed between ITER-India and the Electronics Corporation of India, Hyderabad to further collaborations between the two organizations. The collaborations are in the field of electronic equipments to be supplied to ITER as a part of various packages. Another Memorandum of Understanding was signed between ITER-India and the Nuclear Power Corporation of India, Mumbai for collaborations in technical, management, procurements and other areas of mutual interest.

WBS 5.1 ION CYCLOTRON HEATING & CURRENT DRIVE

Detail design, analysis & preparation of engineering drawing for various sub-system/components up to pre-driver stage related to R & D unit completed. Procure-

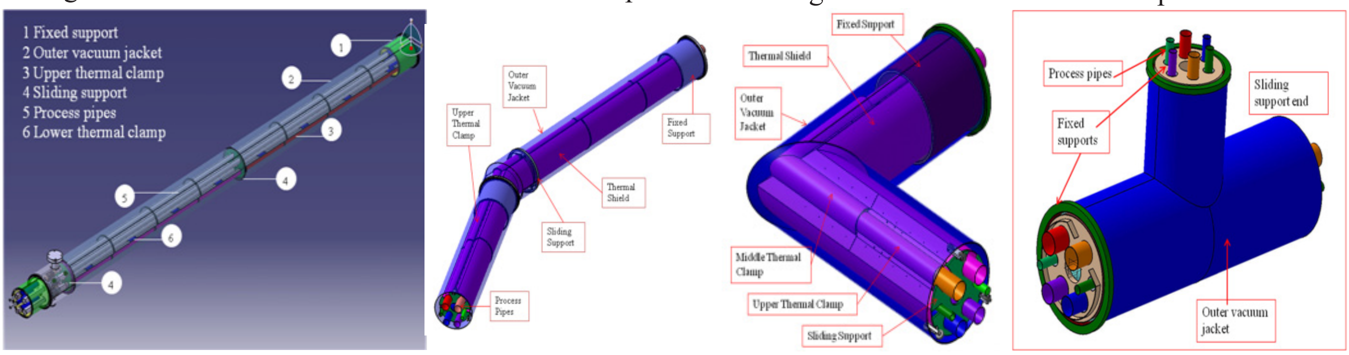


Figure B.2.8 (a) Straight section (b) Elbow section (c) C – section (d) T - Section ment activities for low power RF section initiated. P.O. placed for Tetrode for pre-driver stage. Vendor development process for high power RF components/systems is ongoing. Design & developmental work for local control unit (LCU) is being carried out with ECIL through MoU. Planning of qualification test for end stage tube in terms of high power, high frequency and long pulse operation through international collaboration has been initiated. Lab setup initiated for R & D activity. Reliability, Availability, Maintainability & Inspectability (RAMI) analysis for the entire ITER ICRF system is completed through credited ITER Task agreement (C70TD01FI).

Preparation of documents related to Procurement Arrangement (PA) for ITER ICRF Source package, which includes technical, contractual, detail schedule indicating major milestones, various interface documents, plant breakdown structure etc. have been initiated. Finalization of collaboration document between ITER-India & IPP on up-gradation task of one of the IPP's RF Source completed. Tri-party discussion between GA, USA, IPP, Germany & ITER-India held at GA, USA on up-gradation scheme. Collaboration agreement signed between ITER-India & IPP.

WBS 5.2 ECH Start-Up Package

A noteworthy achievement for the ITER-India ECH group , during this period was to successfully host the 5th IAEA Technical Meeting on "ECRH Physics & Technology for Large Fusion Devices"18-20, Feb-2009 at ITER-India site, Gandhinagar. In view of our participation especially in the ITER-ECH system, it was felt that the event could provide a good platform with international experts in the fields such as ECH systems, Gyrotron development etc., available for direct interactions and discussions. About 50 delegates participated in the three day conference out of which 20 were international delegates. Also the event has provided a good opportunity to introduce the National Gyrotron Development program to the ITER-ECH community and accordingly few National representatives were invited and succeeded in this effort. The event was well planned and executed flawlessly by the Local Organizing Committee with the cooperation from all the involved colleagues and senior management.

However, during this period, the ECH Start-Up package has undergone a significant Design Change Request (DCR) owing to some of the basic changes in the ITER Start-up Scenario. The Design Change has been actively perceived by investigating the physics basis to ascertain ITER Change Request and its effectiveness. Consequent to the technical resolution of the DCR, Management level negotiations with ITER have yielded favorable results in redefining this procurement package. Revised scope & specs have been agreed up on but would need further formalization into the ITER baseline documentation. The package is under conceptual design stage and working towards the formal procurement arrangement which is expected to be signed some time during 2010.

Also the group has taken up an ITER-Task on RAMI (Reliability & Availability Analysis) for the ITER-EC H&CD System. This, being a relatively new subject area, should help us acquire new domain knowledge.

WBS 5.3 Diagnostic Neutral Beam (DNB)

For the DNB which is to be used in ITER for measuring the He ash density in the D-T plasma through charge exchange resonance spectroscopy (CXRS), consolidation R&D program and completion of DNB engineering formed the two major activity areas for the year 2008-2009. Activities under DNB R&D and DNB engineering are summarised below.

Following table lists the system parameters.

Ion species	H^-
Energy	100 keV
Beam current	60 A
Duty cycle and modulation	3s ON/ 20s OFF, 5 Hz
Accelerated current density	300 A/m^2
Beamlet divergence (core)	<7 mrad

DNB R&D

The most significant aspect of DNB development is the R&D on large area RF ion sources where: 1) production of uniform plasma, 2) extraction of high current density –ve ion beams in a reduced ratio of electron : ion extraction, 3) low loss transport of beams over large path lengths, 4) successful operation of an electrostatic ion separation system, etc. forms the primary focus. Hence, an aggressive, two pronged R&D program has been undertaken for DNB. The first relates to the construction of a test facility for DNB under the domestic program, and the second, to the Indian participation in the international facility coming up for R&D in Europe. The domestic program has been reviewed and approved by the IO.

In parallel, a fast track experimental program (reported separately, under an IPR programme) has been initiated for the operation of 1/8 size (of ITER & similar to the source operating in IPP Garching) based on RF plasma source. Activities for the Indian test facility have been initiated and the laboratory for housing the facility is under construction. Procurement of components, which replicates the ITER DNB design, is expected to start after final approval of manufacturing design by the IO.

DNB Engineering

The ITER DNB system is placed in the NB cell of ITER building, sharing the injection port with the H&CD NB. Following the completion of the conceptual design for DNB, the major activity area during the 2008-2009 period has been the engineering design of the DNB components. During this phase, the detailed design of DNB with required physical parameters and applicable codes and standards has been carried out, including electrostatic, thermal and mechanical analysis of the components. A brief description of the present status of the design of DNB system is presented in the following sections and subsections.

Transmission and Power loads

Beam transmission has been studied using PDP/BTR codes (developed by Russian Federation and provided by IO) considering core divergence values of 3, 5, 7, 10 mrad. A 15% halo was considered with the divergence of 15 mrad. For the worst case scenario, divergence considered is 10 mrad for neutralizer and 3 mrad for calorimeter. Table-2 presents the summary of heat loads and transmission for different combinations of divergence and deflections due to stray magnetic fields and mechanical misalignments. The BLCs are designed for the worst load conditions available from this table, keeping in view the modulation in DNB.

Beam source

Beam source consists of ion source and accelerator system. The ion source model is provided by IO as an input to the design. The task of accelerator design and integration of the ion source formed the major activities. These are described below.

(i) Ion source

With the preliminary model of Ion source available, necessary modifications are being carried out to adapt the design for DNB (Figure B.2.9), which includes provision for handling a power load of 0.01 MW from the back streaming positive ions, with a maximum power density of 1.2 kW/cm2. The integration of Beam source with HV bushing is the other major activity (presently ongoing & addresses to the interfaces of hydraulic, Gas Feed, Electrical feed through). Availability of the DNB source model shall lead to final design.

(ii) Extractor and accelerator system

The extractor and accelerator system for the diagnostic neutral beam is a three grid system consisting of a plasma grid (PG), the extractor grid (EG) and the grounded grid (GG). Each grid consists of 1280 apertures and is distributed in 4 segments, each segment having 320 apertures. The aperture shapes of the PG and EG, the entrance and exit aperture diameters of the EG, the inter grid distances and the extractor voltage have been optimized to get a beamlet divergence of 2 mrad using the SLAC code.

(iii) High Voltage Bushing

A new design of HV bushing which shall have a horizontal mounting (contrary to vertical mounting in DDD) has been developed taking the design in DDD 5.3 as the

BLC	Tr	NEUT - LEAD		NEUTRALIZER		Tr	RID - LEAD		RID WALL		Tr	CALORIMETER	
Code used	BTR	BTR	BTR	PDP	PDP	BTR	BTR	BTR	BTR	BTR	PDP/ BTR	BTR	BTR
Case	After GG (MW)	Neut Lead-edge PPD (MW/ m^2)	SINGLE Neut Leading edge Load (MW)	Neut PPD (MW/ m^2)	Neut Load On SINGLE wall (MW)	After Neut. (MW)	RID Lead-edge PPD (MW/ m^2)	RID Lead-edge Load (MW)	RID PPD (MW/ m^2)	SINGLE RID Load (MW)	After RID (MW)	PPD (MW/m^2)	Max. Heat load on SINGLE Calorimeter arm (MW)
10mrad+ 2mrad misalignment	5.97	0.78	0.007	0.075	0.218	4.73	5.94	0.025	0.77	0.29	2.40	5.03	1.2
		Total intercepted power by Neutralizer = 1.24 MW					Total intercepted power by RID = 2.33 MW					Intercepted power by Calorimeter (closed) = 2.40 MW	
10mrad+ 7mrad deflection	5.95	3.02	0.032	0.14	0.43	4.11	9.82	0.06	0.96	0.30	1.89	4.0	0.933
		Total intercepted power by Neutralizer = 1.84 MW					Total intercepted power by RID = 2.22 MW					Intercepted power by Calorimeter (closed) = 1.89 MW	
3mrad+ 2mrad misalignment	5.97	0.09	0.000	0.046	0.09	5.61	0.765	0.004	1.23	0.33	3.15	8.2	1.58
		Total intercepted power by Neutralizer =0.36 MW					Total intercepted power by RID = 2.46 MW					Intercepted power by Calorimeter (closed) = 3.15 MW	
3mrad+ 7mrad deflection	5.95	0.43	0.004	0.275	0.39	4.41	8.22	0.03	1.21	0.33	2.08	6.7	1.04
		Total intercepted power by Neutralizer = 1.54 MW					Total intercepted power by RID = 2.33 MW					Intercepted power by Calorimeter (closed) = 2.08 MW	
IDEAL case 3mrad	5.99	0.00	0.00	0.02	0.04	5.77	0.39	0.002	1.13	0.33	3.26	8.0	1.63
		Total intercepted power by Neutralizer = 0.22 MW					Total intercepted power by RID = 2.51 MW					Intercepted power by Calorimeter (closed) = 3.26 MW	

Table –2 Worst heat loads (yellow mark) for different beamline components for different beam scenarios.

baseline. Each component of the assembly is designed to satisfy electrostatic, structural, thermal, safety, seismic and vacuum requirement of overall system. The overall diameter of HVB was obtained 1.6 m and the height is 1.9 m. Electrostatic and Structural analysis of the structure has been carried out for validation of the design. The exploded view of HV bushing is shown in figure B.2.10.

Beam line components (BLC)

The Neutraliser, RID and Calorimeter constitute the Beam line components. All these components have undergone a complete assessment from the thermal structural aspects and the design validated for conformity w.r.t the ITER codes and standards. Manufacturing technologies have been established and discussions have been initiated with the industry for its realization. The components are described below:

(i) Neutralizer

The neutraliser has four vertical channels of rectangular cross-section, each 3 m long and 1.7 m high. Leading edge elements are incorporated on panel wall. The H2 gas supply manifold is placed in the lower part of the

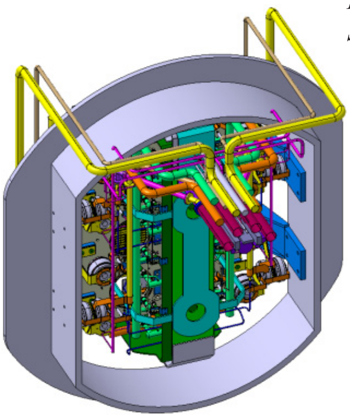


Figure B.2.9 Layout of Ion Source

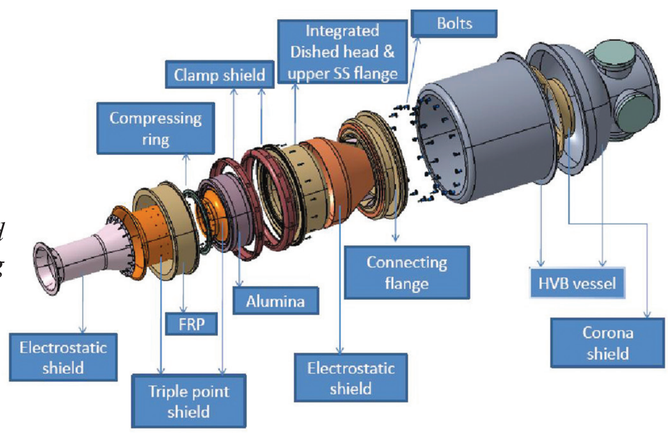


Figure B.2.10 Exploded view of HV bushing neutralizer.

(ii) Residual Ion Dump (RID)

The RID structure consists of five vertical dump panels, a support frame, manifolds and headers for the water coolant supply. The five panels produce four channels, 1,500 mm in height and 1,000 mm in axial length. Each channel is 104 mm wide at the entrance and 96 mm at the exit.

(iii)Calorimeter

A moveable beam dump, the calorimeter, can be introduced in to the beam path downstream of the RID, allowing the injectors to be commissioned/conditioned and tested independently of the ITER plasma operation. The calorimeter for DNB consists of two panels. Each panel is a stack of 18 Heat transfer elements made of CuCrZr. Each H.T.E. is 368 mm in length, 67 mm in width and 17 mm thick. In stacked condition each panel has a height of 1.21 m. Two options (liner and rotary) for the movement mechanism have been considered.

(iv)Exit Scrapper

In order to protect the bellow and the fast shutter from excess heat loads and to reduce the heat loads on the cross over point of the HNB and DNB an exit scraper has been provided. The 0.75 m long scraper is placed between the exit wall of the DNB vessel and the fast shutter. The optimized exit opening for the scraper is 0.53 x 0.96 m^2.

DNB Vessel

As per the outer boundaries obtained from ITER – IO, the DNB vessel has dimensions of 8430 mm in length, 3730 mm in width and 3545 mm in height. The vessel shall house the ion source, the neutraliser, the RID and the calorimeter. The high voltage bushing shall be mounted on the vessel from the back flange. Initial structural analysis of the vessel has been carried out. Final dimensions of the vessel will be decided, once the integration phase is over.

Front end components

Fast shutter :It provides part of the primary vacuum confinement of the NB system and also guarantees the confinement of radioactive materials in case of accidental over pressurization. A fast shutter (opening and closing time ~ 1 s) is located downstream of the calorimeter, at the exit of the vessel (Figure B.2.12). It is envisaged that the fast shutter shall be under a common specification and is likely to adhere to a common procurement program.

Absolute valve: The valve for DNB and H&CD beam lines shall have identical designs and shall be procured under a common procurement program. The purpose of valve is to prevent any back flow of tritium from the machine into the beam line and to provide complete sealing to the machine in case the DNB has to be vented for maintenance operations.

Bellow: The DDD design of the drift duct bellow (with two bellows reinforced with equalizing rings, an intermediate pipe and extremity flanges) is being studied.

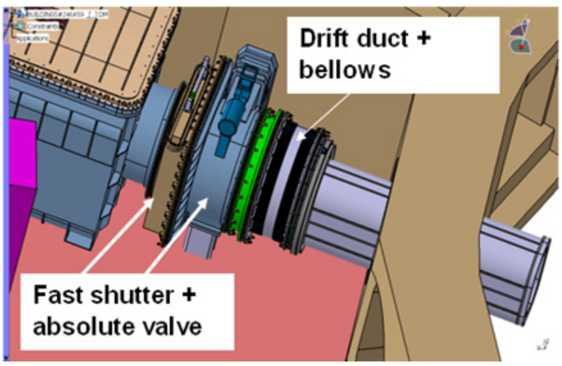


Figure B.2.11 Front-end Components

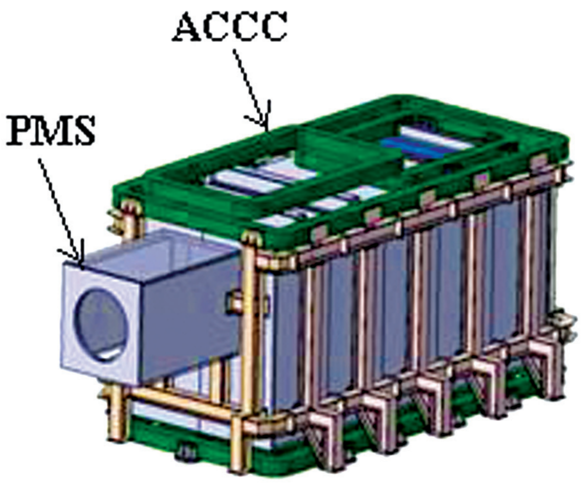


Figure B.2.12 Magnetic field reduction system

Sample numerical calculations are being done as per EJMA standard for verifying the design.

WBS 5.5 ITER-India Diagnostics

The Diagnostic items to be delivered to the ITER project by ITER-India were finalized to consist of the following subsystems:

(i)Electron Cyclotron Emission (ECE) Diagnostics: Ex-cryostat transmission and receiver equipment and a set of Radiometers and a Michelson Interferometer.

(ii)Beam emission Spectroscopy (BES): a set of ex-port-plug optical assemblies, spectrometers and 2-D array detectors
(iii)X-Ray Spectroscopy (XCS): A Survey Spectrometer to be housed in an Equatorial Port and one High Resolution Spectrometer, viewing the edge plasma, in an Upper Port-plug along with array detectors.

(iv)Upper port-plug (UPP 09): The Port-plug that would house the XCS (edge) spectrometer and other ITER specified equipment. Since the Upper Port-plug is scheduled for an earlier delivery, activities related to the design of the UPP were commenced. Vibration and Thermal Hydraulic analysis were undertaken on a preliminary design of the port-plug structure. On the basis of this, a Design Work Order was accepted for a similar analysis on the existing generic design from ITER organization. Work on this is in progress. An Engineer was deputed to work at IO site at Cadarache to develop the generic design. Initial calculations to assess the signal levels to be measured by the three diagnostics were begun and descriptions of the diagnostic systems were arrived at in collaboration with other ITER partners sharing the diagnostics with us. These results were presented at the 15th meeting of the Task Group on ITPA (Diagnostics). Scientists were deputed to Cadarache to develop an understanding of the machine design and the diagnostic design constraints and requirements.

ITER-India and IPR jointly hosted the above international (15th TG meeting of ITPA - Diag) meeting in Ahmedabad, during Nov. 21-25, 2008. About 25 foreign delegates and an equal number from India participated in the meeting.

Activities of the Fusion Physics and Information Technology group

Following the 2007 design review of ITER, the parties decided to carry out activities to resolve various outstanding Physics issues on a voluntary basis. Under these activities, IN took up the responsibility of validating the previous results on electromagnetic loads on the machine during abnormal events like plasma disruptions and vertical displacement events (VDEs). These load estimates were carried out originally on the basis of the DINA code simulations. We repeated these simulations using the Tokamak Simulation Code (TSC), obtained from PPPL, Princeton University, US under a collaboration agreement. The results on VDE and disruption carried out using TSC matches reasonably well with DINA though there are some differences in the current quench rates. These results were presented in different ITPA meetings in 2008 as well as in the IAEA FEC, 2008 Conference Figure B.2.14 shows an example of DN and UP-VDEs, where only the initial plasma vertical position is slightly different. The vertical position evolution, also shown in the figure, as computed by the TSC and DINA codes matches reasonably well except for the final current quench phase.

In the IT group, we have established a high speed dedicated leased line link to ITER. For this a 45Mbps leased line connection from ITER-India to TIFR, Mumbai was established which is then connected to the TIFR-CERN 1 Gbps connection. To establish the leased line connection between ITER-India and ITER-Cadarache, coordination between a number of involved parties, namely Bharti Airtel (ISP for ITER-India), TIFR, Geant and Renator in Europe (ISPs for the TIFR-CERN link) as well as with ITER IT personnel was required and India was the first among all the ITER DAs to successfully establish the ITER Collaborative Network (ITER-CN) on this leased line link. Under this link, we have commissioned the Sky-X accelerator required to transmit data at a faster rate than permitted by TCP-IP protocol

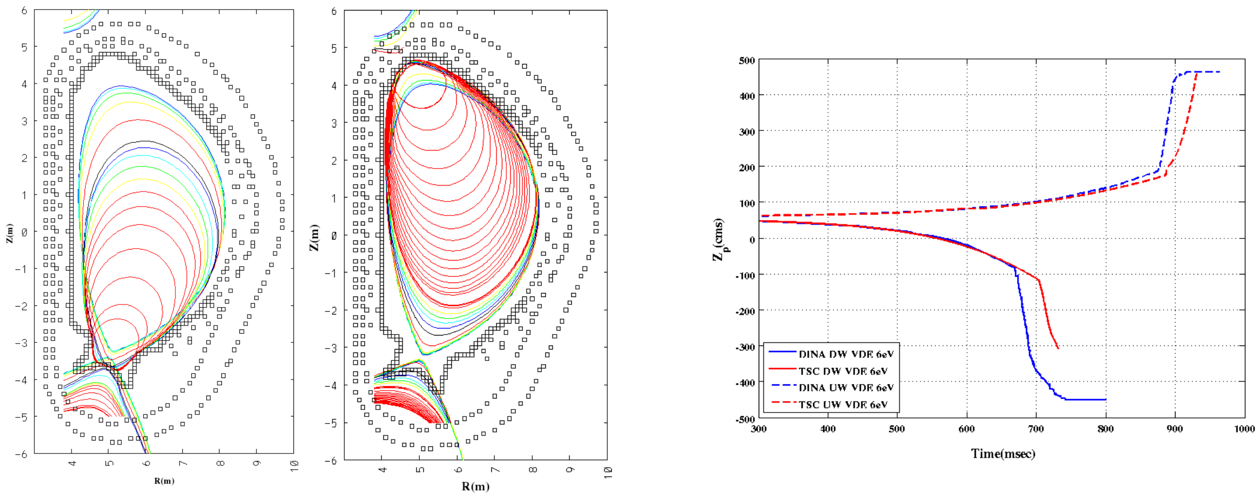


Figure B.2.13 Evolution of the plasma separatrix in the DP and UN-VDE cases, the evolution of vertical postion by TSC and DINA codes are compared on right.

over distances separated by large latency and successfully transmitted data at sustained speeds of 34 Mbps over the 45 Mbps link. The CATIA servers have also been commissioned on this network which has made the CAD data locally accessible on the local servers. Figure B3.32 shows the CATIA IBM servers for CATIA installed at ITER-India. We also commissioned three more High Definition Video Conference systems, two at ITER-India and one at IPR in the office of the Chief Scientist of ITER-India (IPR Director). These Video Conference systems are heavily used for numerous meetings among the ITER partners.

CODAC Activities

Although CODAC is not a procurement package of ITER-India, IPR has decided to proactively work for ITER CODAC (Command Data Access and Communication) software package and hence a CODAC division has been set up. ITER CODAC is the integrated control, data access and communication system for the ITER machine. CODAC is responsible for coordinating all ITER Plant Systems, orchestrating the operation and gathering all data produced by ITER. All the ITER plant systems are supplied in kind by the various DAs as part of their procurement packages. This poses a great challenge for CODAC group for integration of all the subsystems. To ease out the integration process CODAC group decided to establish a standardization process so as to ensure a uniform technology and Hardware software framework across all the plant systems supplied by the DAs. CODAC group also decided to provide an entity, the Plant System Host (PSH), in every Plant System to facilitate a standard interface enabling smooth integrations.

As part of standardization process they identified various R & D task and Contracts for the DAs and their industries. These tasks were offered to DAs under competitive bidding. Under this process, CODAC Division submitted and successfully won the bid for the R & D Task titled "Implementations of Plant System Host and Prototype of Mini CODAC", involving task worth 1.8 Million Euros (Rs.12. Crores.). The scope of this task is to design and implement the Plant System Host and its interfaces to Technical Subsystems and CODAC Systems as well as to design and implement a prototype of Mini CODAC. Mini CODAC provides a subset of the CODAC Systems functionality required to perform Factory Acceptance Test (FAT) of Plant Systems.

The task will be executed over a period of three years by a team of engineers from CODAC Division and Indian IT industries along with ITER CODAC group. For this all formalities of selecting Indian IT industries through ITER-India approved tendering process has been completed and finally Tata Consultancy Services (TCS) has been selected as the vendor to execute the task. The task execution will start around middle of July 09.

C. ACADEMIC PROGRAMMES

C.1 DOCTORATE PROGRAMME

In the Ph.D. programme conducted by the institute twenty-three (23) research scholars have been enrolled at present. Out of them, fifteen (15) are working in theoretical and simulation projects while six (6) are engaged in experimental projects. Two (2) new students have joined this programme during the year and are going through the course work. After successful completion of this course work, they will be enrolled for their Ph.D. works.

Ph.D. THESIS SUBMITTED

Computational Studies of Radar Cross Section of Plasma Shielded Objects
Bhaskar Chaudhury
Devi Ahilya Vishwa Vidyalaya, Indore, 2008

Studies of Edge and SOL Turbulence in Tokamaks
Nirmal K. Bisai
Gujarat University, Ahmedabad, 2008

Effect of Process Parameters on Plasma Nitriding
Suraj Kumar Sinha
Devi Ahilya Vishwa Vidyalaya, Indore, 2008

Study of Equilibrium and Fluctuations in a Currentless Toroidal Plasma Device
Rajwinder Kaur
Gujarat University, Ahmedabad, 2009

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.

C.3 Basic Physics Laboratory for students

Activities of students' lab to exposure of 1st year students to different experimental techniques, such as: vacuum system, electronics, data acquisition, and planning an experiment: This lab also supplements some basic plasma physics understanding through experiment. Presently, there are three experiments to cater the above-mentioned objectives. These are: glow discharge experiment in glass chamber, metal chamber and controlled experiment on electromagnetic noise.

Glow discharge glass chamber set-up is a 120 cm long, 15 cm dia glass tube with RP and DP. A base pressure of $8X10^{-5}$ mbar and working pressure of $5X10^{-2}$ mbar is maintained. Argon and air were used. Phenomena observed are, anode glow, cathode glow, striations, anode spots. Discharge current and voltage were monitored. A beam probe and a CCD camera were used to study the oscillation and anode spots. Another glow discharge metal chamber set up was used to study above-mentioned phenomena. In addition, in metal chamber set-up anode was rotated to study anode spots further. DC discharge is produced with a power supply 1 kV, 1 A.

Initially, gas breakdown was studied by varying electrode distance and pressure. Breakdown followed well-known Paschen curve. Various structures of glow discharge were also observed. In the course of investigating the general characteristics of glow discharges, like other previous observations an unexpected phenomenon appeared. In a limited pressure range and over a certain current density the anode surface instead of being filled with uniform glow (called anode glow) becomes overlaid with a number of brilliant spots, called anode spots. Parametric study of anode spot were also performed (1) by varying pressure and follow the anode spot evolution, (2) by varying discharge voltage and follow the anode spot evolution and also (3) by changing anode material. Onset current for formation anode spot was also noticed. Finally using rotating anode, the anode spots were monitored.

In most experiments noise coexist with signals. Understanding noise is essential to remove it efficiently. The goal of the experiment on noise study is to produce the noise in a controlled way and try to find and compare different ways to remove it. For this purpose, an inductive loop was used to measure the time-varying magnetic fields While performing this experiment students came across undesired signals. Goal was to understand and remove those undesired signal. A capacitor was discharged through a wire and a resistance to generate the time-varying magnetic field. Two inductive loops were placed near to the current carrying wire. Different types of unwanted oscillation were observed. Later on the oscillations were removed from the signal. The integrated probe signal matches quite well with the current variation (magnetic field variation) through the wire.

D. TECHNICAL SERVICES

D.1 Engineering Services

D.1.1 Air conditioning and Water Cooling

The Water-cooling and Air conditioning group supplied chilled water with required conductivity, temperature, pressure & flow rate to Cryogenics plant and the various other experimental systems. The frequent regeneration of water treatment plants has been carried out to maintain the required conductivity. The Variable frequency drives have been installed for RF systems process cooling pumps. Installation, testing & commissioning of the new LHCD water-cooling system was successfully implemented. The new LHCD cooling water system consist of two main Headers, 50 NB Header – A with nitrile foam insulation and un-insulated 150 NB Header - B.

Designing of P & ID layout of 12 kA Cryogenics Power Supply cooling water system and Negative Ion NBI cooling water system were completed. The piping work to supply chilled water to 12 kA Cryogenics Power Supply and Negative Ion NBI will start soon. The painting of cooling water MS piping, structure, valve etc has been carried out. Repairing of 610 TR x 3 nos. cooling tower basin with FRP lining has been carried out. 31 nos. split air conditioners have been installed in various labs/ Cabins in IPR and FCIPT.

The maintenance of central AC plants, various package units, water coolers, split air conditioners and window air conditioners has been carried out in IPR, ITER-India, FCIPT and Hostel & Guesthouse with the help of contractors.

D.1.2 Drafting Services

- Drawing section caters to different scientific groups of the institute in generating the Engineering / fabrication drawings, Plotting drawings/poster. Conceptual sketches are converted to drawings and then into details engineering drawings.
- During this year they have helped users in getting number of systems fabricated from within Institute's workshop as well as from outside manufacturers by preparing those drawings.
- Drawing section is currently using MDT software for generating 2D drawings and 3D models. But now intend to migrate to CATIA software which will facilitate in improving our section output and as well as to take up more complex job which can be generated in CATIA with ease.
- Other area where Drafting section is involved is in checking the fabrication drawings supplied by the fabrication vendor, before they start their fabrication activity, cost estimation before the work is contracted to outside vendors.
- Drafting section work in co-ordination with workshop for the internal manufacturing and fabrication activities to deliver the machined / fabricated items to users in short duration as well as minimum wastage of material.

D.1.3 Mechanical Workshop

* In recent past, workshop has established a procedure to enable user to get their items, diagnostics systems manufactured and fabricated in minimum possible time. By identifying the skill sets, work distribution is arranged accordingly which has enabled us to complete the task in hand in shorter duration.
* Different groups also get additional support from members of workshop to solve their technical problems in their laboratory related to mechanical assemblies etc.
* We have already started using latest tools and related fixtures to improve upon the quality of machined components and minimize the time spent in machining.
* We have recently undertaken manufacturing of JIG and fixtures for the items that are repeatedly made by the user.
* Workshop is also helping other groups to undertake development work in their field of expertise from other R & D institutions wherein support for workshop related activities are necessary .

D.1.4 Computer Services

The computer center actively supported the IT infrastructure of the institute by catering to the personal and organization computing requirements of the institute members and the institute

The work done, can be categorized as following :

◊ Enhancements to the in-house softwares developed for administration, cafeteria, accounts and security and maintenance of the same

◊ Hardware and software installations and troubleshooting

◊ Monitoring Internet security setup and conducting audits, maintaining Internet servers and services, maintaining CAD/CAM servers and computational machines like Cray, cluster etc

◊ Extending the infrastructure by networking hostel, guest house, utility building, thereby connecting them with the main building and providing computational resources at those places

◊ Procurement, installation and configuration of fault tolerant services and shifting Internet services to the same.

◊ Commissioning a 512 Kbps internet connection exclusively for the FCIPT campus and configuring all systems there to use the same, as well as the existing link at the main campus

◊ Upgrading the 64 kbps leased like connection between the main campus and the the FCIPT campus to a 2 Mbps link

◊ Setting up connectivity between the ITER-India office and the main campus and providing remote access to the computer center servers from the remote campus

D.1.5 Electronics Services

Electronics Group is involved in Design, Development and Maintenance of Signal Conditioning Unit, and front end electronics of different Plasma Diagnostics in Aditya, SST-1, Beta and Basic Experiments. The front-end electronics is generally comprised of analog components like pre-amplifiers, amplifiers, filters, opto-isolators, attenuators, multiplexers, drivers etc. Detectors used are magnetic-coils, magnetic-loops, photo-diodes, Photo-multiplier tubes, Surface barrier diodes and various types of diode arrays etc. Front end electronics parameter such as gain, attenuation and bandwidth are frequently required to change depending on signal strength and frequency spectrum. This is done manually in Aditya by changing passive components. In SST-1, we have implemented CAN bus Instrumentation, which allows diagnostics users to set all the front-end electronics parameters from a remote computer connected on the network. For this, a USB based CAN interfacing is used and software is developed in LabView. The very user friendly GUI in LabView supports features of detecting nodes connected through CAN, presence of modules in each node, Monitoring, Setting gain, filter cut off frequency etc and writing same parameters in excel file.

We have in house developed Infrared Camera that will be used for thermal imaging of plasma facing components. We have been able to capture image on PC screen. Development process include testing with sensor, design and development of electronics and data acquisition, integration with PCI frame grabber board and image processing. The Electronics module include ultra low noise bias , power supply, analog signal conditioning, stepper motor controller for lens assembly, FPGA based digital electronics for generation of synchronization signals for detector as well as PCI frame grabber, control and trigger signal for ADC, motor, master clock generation, micro controller based supervisory and control, CMOS to RS 422 converter design for transmission of video data over long cable.

SST-1 Electronics for Soft-X-Ray, Microwave Interferometer diagnostics is tested in integrity with simulated signal, Data Acquisition and control. Electronics for Bolometer and Spectroscopy diagnostic with new features design is in progress.

A standalone 12 bit Data Acquisition system for 5 channels with on board SBC(single board computer) is designed. The system supports simultaneous acquisition at sampling rate of 1MS/sec, with on board memory for individual channel. The DAQ software is developed in NI LabWindows/CVI. The design is conceptualized and prototype is tested for single channel. The PCB has been designed and fabricated.

For PCI based Data Acquisition System Development, PLX9054 based PCI card with 8 bit ADC and on board memory is developed. Graphical user interface is designed in CVI and the project is converted in Visual C++ application with needed all modification for compatibility between Visual C++ and LabWindows/CVI

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D.2. Library Services

Library for Knowledge and Knowledge for Progress, this is the belief of IPR Library. Library is constantly striving to ameliorate with innovative ideas in information dissemination and adding intelligence to information to accomplish the desired organizational outcome. Library envisions the future and always endeavors to keep up with the rapid technological advancements to meet the complex information needs of its agile users in these changing times. Transformations to Library 2.0 with users participation will not only give a sense of belongingness to the users but also respect and recognition to the library and its conscious staff.

Library continued to collaborate with other libraries to provide efficient services not only to Plasma and Fusion scientists working at IPR and FCIPT but also to scientists and engineers working in the international projects such as ITER-India and other Institutes like CAD BARC and Universities across India.

Collection and Services

Library added 496 Regular Books, 60 Technical Reports, 24 Pamphlets, 186 Reprints, 40 IPR Publications and Downloaded 66 Reprints and 2 Books.

Library Issued 6323 Books; 39 Journals; 2 Standards; and 330 Reports/Bound Volumes/Software and provided 132112 photocopies.

Satisfied 74.87% Inter Library Loan requests by borrowing documents from other libraries and satisfied 75.86% requests received from other libraries.

Library added a new online database viz., SCOPUS and continued to provide access to other e-resources, like e-journals including ScienceDirect, PROLA, IOP Historical Archive. Continued to update library's web site to include new information and resources, added IPR LiBlog (a Blog for Plasma Physicists) and a CAS for Plasma Physicists using Web 2.0 tools.

Library arranged a demonstration of NAS Product for managing CD/DVD collection, and an Information Literacy Program for SCOPUS database February 19 and March 3, 2009 respectively.

Infrastructure:

-Purchased a New Server Class Machine (HP Xeon ML350) for Library Database (LibSys) Management

-Added a New Bar Code Scanner

E. PUBLICATIONS AND PRESENTATIONS

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

Loss Less Real-time Data Compression based on LZO for Steady-State Tokamak
H.D. PUJARA and MANIKA SHARMA
Fusion Engineering and Design, 83, 363-365, 2008

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GAUTAM C. SETHIA, ABHIJIT SEN and FATIHCAN M. ATAY
Physical Review Letters, 100, 144102, 2008

Influence of the Radio Frequency Ponderomotive Force on Anomalous Impurity Transport in Tokamaks
H. NORDMAN, R. SINGH, T. FULOP, L.-G. ERIKSSON, R. DUMONT, J. ANDERSON, P. KAW, P. STRAND, M. TOKAR and J. WEILAND
Physics of Plasmas, 15, 042316, 2008

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S SUNIL, AJAI KUMAR, R K SINGH and K P SUBRAMANIAN
Journal of Physics D: Applied Physics, 41, 085211, 2008

Space- and Time-resolved Visible-emission Spectroscopy of Aditya-tokamak Discharges using Multi-track Spectrometer
SANTANU BANERJEE, VINAY KUMAR, M B CHOWDHURI, J GHOSH, R MANCHANDA, KETAN M PATEL and P VASU
Measurement Science and Technology, 19, 045603, 2008

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K. KISHOR KUMAR and S. MUKHERJEE
Thin Solid Films, 516, 4535-4540, 2008

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S. KAR and S. MUKHERJEE
Physics of Plasmas, 15, 063504, 2008

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P.K. SHARMA, S.L. RAO, K.K. RAMELLA, D. BORA and LHCD GROUP
Fusion Engineering and Design, 83, 601-605, 2008

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M.R. JANA and S.K. MATTOO
Fusion Engineering and Design, 83, 649-654, 2008

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SWAPNA S. NAIR, JINTO THOMAS, C. S. SUCHAND SANDEEP, M. R. ANANTHARAMAN and REJI PHILIP
Applied Physics Letters, 92, 171908, 2008

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R. K. SINGH, AJAI KUMAR, V. PRAHLAD and H. C. JOSHI
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A. BASU, J. DUTTA MAJUMDAR, J. ALPHONSA, S. MUKHERJEE and I. MANNA
Materials Letters, 62, 3117-3120, 2008

Hot Electron Generation by Highly Efficient Absorption of High Intensity Femtosecond Laser
Light in Plasma Generated on Sub-lambda Gratings
S KAHALY, G R KUMAR, S YADAV, S SENGUPTA, A DAS and P K KAW
Journal of Physics: Conference Series, 112, 022102, 2008

Stability of One-dimensional Relativistic Laser Plasma Envelope Solitons
V SAXENA, A DAS, S SENGUPTA, P KAW and A SEN
Journal of Physics: Conference Series, 112, 022110, 2008

Estimation of Partial Pressure during Graphite Conditioning by Matrix Method
P CHAUDHURI, A PRAKASH and D C REDDY
Journal of Physics: Conference Series, 114, 012023, 2008

Vacuum System Requirement for a 5 Km Baseline of Gravitational-Wave Detector
S SUNIL and D G BLAIR
Journal of Physics: Conference Series, 114, 012025, 2008

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A PRAKASH A, P CHAUDHURI, S KHIRWADKAR, N CHAUHAN, P M RAOLE, D CHENNA REDDY and Y C SAXENA
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Journal of Physics: Conference Series, 114, 012067, 2008

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GAJENDRA PRASAD SINGH, ALPHONSA JOSEPH, PRAKASH MANOHAR RAOLE, PREMA KANTA BARHAI and SUBROTO MUKHERJEE
Science Technology Advanced Materials, 9, 025007, 2008

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A. K. CHATTOPADHYAY
Plasma Devices and Operations, 16,115–126, 2008

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SHARAD KUMAR YADAV, AMITA DAS and PREDHIMAN KAW
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GURSHARN SINGH and S. CHATURVEDI
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MANASH KUMAR PAUL and DHIRAJ BORA
Pramana, 71, 117, 2008

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M. Z. TOKAR, T. E. EVANS, R. SINGH and B. UNTERBERG
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The Potential of Pulsed Underwater Streamer Discharges as a Disinfection Technique
SURYAKANT B. GUPTA
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ARUNA THAKAR, AJAI KUMAR, JINTO THOMAS and CHHAYA CHAVDA
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A.K. SRIVASTAVA and G. PRASAD
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M.R. JANA, S.K. MATTOO, A.K. CHAKRABORTY, U.K. BARUAH, G.B. PATEL and P.K. JAYAKUMAR
Fusion Engineering and Design, 83, 729-735,2008

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VIPIN K YADAV and D BORA
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A 1-MV Magnetically Insulated Tesla Transformer
MARKO ISTENIC, BUCUR M. NOVAC, JING LUO, RAJESH KUMAR and IVOR R. SMITH
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Compact Sub-Kilojoule Range Fast Miniature Plasma Focus as Portable Neutron Source
RISHI VERMA, M V ROSHAN, F MALIK, P LEE, S LEE, S V SPRINGHAM, T L TAN, M KRISHNAN and R S RAWAT
Plasma Sources Science and Technology, 17, 045020, 2008

MHD-Neutronics Modeling for Magnetized Target Fusion
S. CHATURVEDI
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P.V. SUBHASH, S. MADHAVAN and S. CHATURVEDI
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C.P.C. WONG, J.-F. SALAVY, Y. KIM, I. KIRILLOV, E. RAJENDRA KUMAR, N.B. MORLEY, S. TANAKA and Y.C. WU
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R. SRINIVASAN, S.P. DESHPANDE and THE INDIAN DEMO TEAM
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E. RAJENDRA KUMAR, C. DANANI, I. SANDEEP, CH. CHAKRAPANI, N. RAVI PRAGASH, V. CHAUDHARI, C. ROTTI, P.M. RAOLE, J. ALPHONSA and S.P. DESHPANDE
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S. NEGI, M. WARRIER, S. CHATURVEDI and K. NORDLUND
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Current Drive by Helicon Waves
MANASH KUMAR Paul and DHIRAJ BORA
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R. KAUR and S. K. MATTOO
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HASI RAY
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SEJAL SHAH and M. BANDYOPADHYAY
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E 2. TECHNICAL REPORTS

Microcontroller based Amplitude and Phase Control Prototype Loop of High Power RF Source for ICRH System for Fusion Grade Tokomaks
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IPR/TR-143/2008 (AUGUST, 2008)

An Experimental Setup for the Systematic Study of the Expansion Dynamics of Laser-Blow-Off Plasma Plume in Variable Transverse Magnetic Field
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NIRAV Y. JOSHI and P.K. ATREY
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Development of High Power Coaxial Vacuum Window for ICRF
DHARMENDRA RATHI, KISHORE MISHRA, SIJU GOERGE, ATUL VARIA, RAJ SINGH, S V KULKARNI, and ICRH-RF GROUP
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RAJIV SHARMA, B. SARKAR, HITEN VAGHELA, SATISH R.B, GIRISH GUPTA and Y C SAXENA
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RAJIV SHARMA, B. SARKAR, Y.C. SAXENA and CRYOGENIC GROUP
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IPR/TR-150/2008 (DECEMBER, 2008)

Installation and Testing of 1kA Power Supply for Superconducting Loads
A. N. SHARMA, U. PRASAD, P. VARMORA, K. DOSHI, S. PRADHAN and MAGNET DIVISION
IPR/TR-151/2009 (MARCH, 2009)

E 3. CONFERENCE PRESENTATION

Workshop on Superhydrophobic Coatings, NAL, Bangalore, India, 9-10 April, 2008

Plasma Assisted Superhydrophobic Coatings and Potential Applications
N. I. Jamnapara, A. Satyaprasad, S. K. Nema, S. Mukherjee

Workshop on Steel and Fabrication Technologies for Fusion Programme (WS & FT-2008), Institute for Plasma Research, Ahmedabad, 21-22 July 2008

ITER-Cryostat and In-wall shields
Bharat Doshi

Test Blanket Module: Steels and Fabrication Technologies
E. Rajendra Kumar and Indian TBM Team

Stainless Steels for Vacuum Vessel of Fusion Grade Machine
Ranjana Gangradey

Prototype Divertor System: Steels and Fabrication Technologies
Sameer Khirwadkar

Prototype Superconducting Magnet: Steels and Fabrication Technologies
S. Pradhan

Hot-DIP Aluminising process for TBM Applications - An Overview
Nirav Jamnapara, S. Mukherjee, P.M. Raole, E. Rajendra Kumar

2nd ITER International Summer School 2008, Kyushu University, Fukuoka, Japan, 22-25 July, 2008

Investigation of observed H-alpha intensity fluctuations in the edge region of Aditya Tokamak
R.Manchanda, Joydeep Ghosh, M.B. Chowdhuri, Santanu Banerjee, Vinay kumar, P. Vasu, Ketan. M. Patel, D. Raju, R. Jha, P.K. Atrey, C.V.S. Rao, P.K. Chattopadhyay, S. Joisa, S.B. Bhatt, N. Ramasubramanian, R.L. Tanna, Y.C. Saxena and Aditya Team

Ahmedabad Library Network (ADINET) Seminar at AMA, Ahmedabad, 9th August 2008

Scholarly Search Engines
Saroj Das

25th Symposium on Fusion Technology, Rostock, Germany, September 15-19, 2008

ITER Vacuum Vessel: Design review and start of procurement procedure,
K. Ioki, C. Bachmann, P. Chappuis, J.-J. Cordier, B. Giraud, Y. Gribov, L. Jones, C. Jun, B.C. Kim, E. Kuzmin, H. Pathak, P. Readman, M. Sugihara, Yu. Utin, X.

Wang and S. Wu
Progress in design and integration of the ITER Electron Cyclotron H&CD system
Caroline Darbos, Mark Henderson, Ferran Albajar, Timothy Bigelow, Tullio Bonicelli, Rene Chavan, Gregory Denisov, Damien Fasel, Roland Heidinger, Jean-Philippe Hogge, Noriyuki Kobayashi, Bernhard Piosczyk, Shambhu Laxmikanth Rao, David Rasmussen, Gabriella Saibene, Keishi Sakamoto, and Koji Takahashi

The TEXTOR Seminar at Forshungszentrum Julich, Germany, 26 September 2008

Diffuse Reflection modeling and noise stability analysis for Tomographic Reconstruction of Tangential Images
Santanu Banerjee and P. Vasu

22nd IAEA Fusion Energy Conference (FEC 2008) Geneva, Switzerland, 13-18 October 2008

Simulations of ITER Disruption and VDE scenarios with TSC and comparison with DINA results (IT/P6-17)
I. Bandyopadhyay, Y. Nakamura, M. Sugihara, H. Fujieda, A. Sen, S.C. Jardin

Measurement Requirements and the Diagnostic System on ITER: Modifications Following the Design Review (IT/P6-21)
A E Costley, S Allen, P Andrew, L Bertalot, R Barnsley, X R Duan, A Encheva, C Ingesson, D Johnson, H G Lee, Y Kawano, A Krasilnikov, V Kumar, Y Kusama, E Marmar, S Pak, C S Pitcher, C V S Rao, G Saibene, D Thomas, P R Thomas, P Vasu, G Vayakis, C Walker, Q W Yang, V Zaveriaev and J Zhao

Turbulent transport and flow effects on NTM evolution and trigger mechanisms (TH/4-2)
A Sen, R. Singh, D. Chandra, P. Kaw, D. Raju

Nonlinear Excitation of Zonal Flow and Geodesic Acoustic Modes in the Edge of Tokamak Plasma (TH/P8-14)
R. Singh, R. Goswami, R. Ganesh, P. K. Kaw, and J. Weiland

Progress in ITER Heating and Current Drive System (IT/P2-1)
K. Sakamoto, F. Albajar, T. Bigelow, B. Beaumont, A. Becoulet, T. Bonicelli, D.Bora, D. Campbell, J. Caughman, A. Chakraborty, C. Darbos, H.Decamps, G. Denisov, R. Goulding, J. Graceffa, T. Gassmann, R. Hemsworth, M. Henderson, G.T Hoang, T. Inoue, J. Jacquinot, A.Kasugai, N. Kobayashi, Ph. Lamalle, A. Mukherjee, M. Nightingale, D. Rasmussen, S. L. Rao, G. Saibene, R. Sartori, B.Schunke, P. Sonato, D. Swain, K. Takahashi, M.Tanaka, A. Tanga, K. Watanabe

A Lower Hybrid Current Drive System for ITER (IT/P7-1)
G.T. Hoang, A. Becoulet, JF Artaud, B. Beaumont, J.H. Belo, G. Berger-By, J.P.S.Bizarro, P. Bonoli, J. Decker, L. Delpech, A. Ekedahl, J. Garcia, G. Giruzzi, M.Goniche, C. Gormezano, D. Guilhem, J. Hillairet, F. Imbeaux, F. Kazarian, C. Kessel, S.H. Kim, J.G. Kwak, J. Lister, X. Litaudon, R. Magne, S. Milora, F. Mirizzi, J.M.Noterdaeme, R. Parker, Y. Peysson, D. Rasmussen, P.K. Sharma, M. Schneider, E.Synakowski, A. Tanga, A. Tuccillo, Y. X. Wan.

National Workshop on Recent Trends in Polymer Science, Institute of Advanced Study in Science & Technology, Guwahati, Assam, 21-22 October 2008

Plasma Polymerization and its Applications
S.K. Nema

Safe Disposal of Plastic/Polymer Waste and Energy Recovery using Plasma Pyrolysis Technology
S.K. Nema

The 2008 Annual Meeting American Institute of Chemical Engineers (AIChE), Philadelphia, 15-21 November 2008

The Heat Rejection System of the ITER Reactor
G. Dell'Orco, W. Curd, D. Gupta, L. Fan, K.P. Chang, I. Kuehn and A. Kumar

15th Meeting of the ITPA Topical Group on Diagnos-

tics, Gandhinagar, India, 17-20 November 2008

Modeling of Wall reflections in Optical Measurements in Tokamaks
Santanu Banerjee and P. Vasu

International Conference on Recent Advances in Microwave Theory and Applications (MICROWAVE 2008), Jaipur, 21-24 November 2008

Design analysis of test bed with variable VSWR and variable phase angle for frequency range of 35 to 65 MHz
R.G. Trivedi, R. Singh, K. Rajnish, M. Kushwah, A. Bhardwaj, H. Machchhar, A. Mukhrjee

Indo-Russian Workshop on High Energy Density Physics for Innovative Technologies and Industry Applications, International Institute of Information Technology (IIIT), & Defence Institute of Advanced Technology (DIAT), Pune, India, November 19-21, 2008

Plasma Pyrolysis Technology for Safe Disposal of Biomedical Waste
Vishal Jain

National Seminar on Non Destructive Evolution (NDE-2008), Lonavala, ISNT Mumbai Chapter, December 1-3, 2008.

Non-destructive Test of Brazed Cooling Tubes of a Prototype Bolometer Housing Using Active IR-thermography Technique
Kumudni Tahiliani, Santosh P. Pandya, Shwetang Pandya, R. Jha and J. Govindarajan

22nd National Symposium on Cryogenics, at IISc, Bangalore during December 4-6, 2008

Evolution of Thermal Shield for ITER Torus and Cryostat Cryoline
S. Badgujar, H. Vaghela, N. Shah, R. Bhattacharya and B. Sarkar

Temperature Sensor Bonding and Thermalization for Measurement of Temperature during Proto-Type Cryoline Test of ITER
R. Bhattacharya, D. Sonara, H. Vaghela, N. Shah, S. Badgujar and B. Sarkar

Comparative Study of Two Concepts for 80 K Helium Generation System
N. Shah, R. Bhattacharya, H. Vaghela, S. Badgujar and B. Sarkar

Integrated Stress Analysis for Section of ITER Torus & Cryostat Cryoline
H. Vaghela, S. Badgujar, N. Shah, R. Bhattacharya and B. Sarkar(Best Paper Award)

Radiation Effects on Insulation System for Superconductiong Fusion Magnets
Rajiv sharma, V.L. Tanna, Anurag Shayam, Basant Das and B. V. Dave

18th International Toki Conference (ITC18), Toki, Japan, 9-12 December 2008

Development of Reconfigurable Analog and Digital Circuits for Plasma Diagnostics Measurement Systems
Amit Kumar Srivastava, Atish Sharma, Tushar Raval

23rd National Symposium on Plasma Science & Technology (PLASMA 2008), Bhabha Atomic Research Centre, Trombay, Mumbai, India, December 10-13 2008

Spectroscopic Characterization of Penning Plasma Discharge Source
Jalaj Jain, Ram Prakash, Bishu Agarwal, P. Vasu, Vinay Kumar, R. Manchanda and S. Banerjee (Buti Award)

Microcontroller Based 8 Channel Delayed Pulse Generator Interfaced with CAMAC System
Narendra Patel, Chhaya Chavda, P. K. Chattopadhyay and Aditya data acquisition Section

Chemical Erosion and Re-Deposition of Carbon First Wall Structures
P. N. Maya, Udo von Toussaint and S. P. Deshpande

Design and Fabrication of a High Tc BSCCO based Square Helmholtz Coil
Pramoda K. Nayak, U. Prasad, A. Amardas, A. N. Shar-

ma, D. Patel & S. Pradhan
On-Line Remote Data Monitoring for Steady-State Tokamak Data Acquisition System
Manika Sharma, Amit Kumar Srivastava and D Chenna Reddy

CAMAC Based Test Signal Generator Using Re-Configurable Device
Atish Sharma, Tushar Raval, Amit K Srivastava and D Chenna Reddy

Role of Energetic Electrons in Hot Filament Produced Currentless Toroidal Plasma
T. Shekar Goud, R. Ganesh, K. Sathyanarayana, D. Raju, Mohandas K.K, C. Chavda, Aruna Thakar M, N.C. Patel

Experimental Investigation of 10 Ka-Class HTS Conductors towards the Development of Large-Current Capacity HTS Conductor for Fusion Magnets
Gourab Bansal, Nagato Yanagi

Development of UHV Compatible Wilson Feed Through for Probe Drive
K. M. Patel, S. B. Bhatt, P. K. Chattopadhyay, B. G. Arambhadiya

Designing of Electrode for High Energy Charged Particle Acceleration
Basanta Kumar Das and Anurag Shyam

SiC Coated Graphite Limiter for Aditya Tokamak
S. B. Bhatt, P. Santra, K. A. Jadeja, P. A. Rayjada, N. l. Chauhan, D. Chenna Reddy, P. M. Raole, Y. C. Saxena

Performance Test Result of Beam Transport of SST-1 Neutral Beam Injector
M. R. Jana, S. K. Mattoo, R. Uhlemann

Operational Experience of SST-1 NBI Control System With Prototype Ion Source
V. B. Patel, P. J. Patel, N. P. Singh, G. B. Patel, Raja Onali, V Tripathi D Thakkar, L. N. Gupta, V Prahlad, S. K. Sharma, M. Bandyopadyay, A K Chakraborty, U. K. Baruah, S. K. Mattoo and NBI Team

Simulation of Casing Effects on SST-1 Superconducting Magnet's Electrical Behavior
Ramesh Babu G. and Dr. Chenna Reddy D.

Mesh Sensitivity Study and Optimization of Fixed Support for Iter Torus & Cryostat Cryoline
Badgujar S., Vaghela H., Shah N., Bhattacharya R. and Sarkar B.

Philosophy of Stress-Strain Measurement for Proto-Type Cryo-Line of ITER
Bhattacharya R., Vaghela H., Shah N., Badgujar S. and Sarkar B.

Time Synchronization System for SST-1 LAN
Manisha Bhandarkar, Kirti Mahajan, Harish Masand, Kirit Patel, Aveg Kumar, H Chudasama and Chenna Reddy

Web Based SMS Alert System for SST-1
Harish Masand, Manisha Bhandarkar, Aveg Chauhan, Hitesh Chudasama, Kirti Mahajan & Chenna Reddy, SST-1 Operation and Control Group

Conceptual Design of Cs Delivery System for ISTF
G. Bansal, M. Bandyopadhyay, A. Chakraborty, M. J. Singh, A. Gahlaut

Observation of Current Drive By Helicon Waves in A Small Aspect Ratio Torus
Manash Kumar Paul and Dhiraj Bora

Fabrication and Installation of New 2-Turns Correction Coils for Error Field Compensation in ADITYA Tokamak
R. L. Tanna, C. N. Gupta, Gattu Ramesh, M. B. Kalal, D. S. Varia, P. S. Bawankar, S. B. Bhatt, D. Chenna Reddy, J. Ghosh, P. K. Chattopadhyay, Y. C. Saxena and the ADITYA Team

Experimental Studies on New Error Field Compensation for Ohmic Coils in Capacitor Bank Discharges of ADITYA Tokamak
R. L. Tanna, J. Ghosh, P. K. Chattopadhyay, C. N. Gupta, S. B. Bhatt, Y. C. Saxena and the ADITYA Team

Design of Telescopic Stub Tuner of 3-1/8” Transmission line for 100 KW RF-ICRH Input System

Atul Varia, Raj Singh, S. V. Kulkarni and RF Group
Development and Testing of Regulated DC Filament Power Supply (14V, 450A) for 200KW, 91.2Mhz ICRH System for SST-1
Azadsinh Makwana, Y. S. S. Srinivas, S. V. Kulkarni and RF-ICRH Group

Design Aspects of 13.56 MHz, 1 KW, CW-RF Oscillator for Plasma Production
Sunil Kumar, Bhavesh Kadia, Raj Singh, Atul Varia, Y. S. S. Srinivas, S. V. Kulkarni and RF-ICRH Group

Design of High RF Power Multi-Limb Phase Shifter for Antenna-Plasma Matching for SST-1
Sunil Dani, Raj Singh, S. V. Kulkarni and ICRH-RF Group

Development of 1KW Solid State RF Power Amplifier for 91.2 MHz, 1.5 MW, ICRH System for SST-1
Gayatri Ashok, Bhavesh Kadia, Pragya, S. V. Kulkarni and ICRH-RF Group.

Multiple Analog Pulse With Different Duty cycle in Master of Digital Pulse for ICRH Aditya System
Ramesh Joshi, Manoj Singh, H. M. Jadav, Kishore Misra, S. V. Kulkarni & ICRH-RF Group

Automatic Impedance Matching Network for ICRH-RF Experiments on SST-1
R Joshi, M Singh, H. M. Jadav, D. Purohit, Siju George, K Rajnish, Raj Singh, S. V. Kulkarni & ICRH-RF Group

60kv, 10Amp DC Power supply Multiple Input Control and Monitoring System for the Operation of Various High Power RF Generation System.
Kirit M Parmar, Y. S. S. Srinivas, S. V. Kulkarni and ICRH-RF Group.

Conditioning Technique for High Power RF Vacuum Transmission Line Components Using Multi-Pactor Plasma
Kishore Mishra, D. Rathi, Siju George, Atul Varia, M. Parihar, H. M. Jadav, Y. S. S. Srinivas, Raj Singh, Sunil Kumar and S. V. Kulkarni

Liquid Phase Shifter for Antenna-Plasma Matching for ICRH Heating Experiments on SST-1
Raj Singh, Sunil Dani, S. V. Kulkarni and ICRH-RF Group

FPGA Based Interlock and Control System for Lower Hybrid Current Drive System.
Harsha Machchhar, P. K. Sharma, S. V. Kulkarni and LHCD Group.

Automation of ICRH Vacuum System on Aditya Tokamak
Dharmendra Rathi, Kishore Mishra, Ramesh Joshi, H. M. Jadav, S. V. Kulkarni & ICRH RF Group

Development of 70kv, 22A DC Power Supply System for High Power RF and Microwave Tubes
Y. S. S. Srinivas, Rajan Babu, Azad Makwana, Kirit Parmar, S. V. Kulkarni and RF Group.

Development of Pre-Driver Amplifier Stage for Generator of SST-1 ICRH System
Sunil Kumar, Azad Sinh Makwana, Y. S. S. Srinivas, S. V. Kulkarni and ICRH-RF Group

A Concept on Control of Electron Temperature Gradient in Large Volume Plasma Device
L. M. Awasthi, S. K. Mattoo, R. Jha, R. Singh, and P. K. Kaw

Observation of Equatorial Electrojet like Irregularities in High Beta Plasma of Large Volume Laboratory Device
L. M. Awasthi, R. Singh, R. Jha, S. K. Mattoo, Y. C. Saxena and P. Kaw

Improved Confinement of Electron Plasma in SMARTEX-C
L. T. Lachhvani, S. Pahari, C. Ramdas, Y. C. Saxena

Plasma Rotation and Confinement Studies in BETA Device
R. Kaur and S. K. Mattoo

Up Gradation of LHCD System for RF Power Level Up to 2MW for SST1
P. K. Sharma, K. K. Ambulkar, P. R. Parmar, C. G. Virani, A. Thakur, S. V. Kulkarni & LHCD Group

Ramp Generation Circuit for Probe Diagnostics Using Micro-Controller for LHCD System

Chetan Virani, P. K. Sharma and LHCD Group
Measurement of LHCD Antenna Position in ADITYA Tokamak
K. K. Ambulkar, P. K. Sharma, P. R. Parmar, C. Virani, A. Thakur, S. V. Kulkarni and LHCD Group

Development of Multi-Channel Rectangular RF Window Employing High Temperature Vacuum Brazing Technique
P. K. Sharma, K. K. Ambulkar, P. R. Parmar, C. G. Virani, A. Thakur, L. M. Joshi, S. C. Nangru & LHCD Group

Quasi- Optical Mode Converter for High Power Gyrotrons
B K Shukla and M V Kartikeyan

Design and Development of Micro-Controller Based Calorimetric Power Measurement for High Power Microwave Tubes
Dharmesh Purohit, Pragnesh Dhorajiya, Rajan Babu, K. Sathyanarayana, Jatin Patel, Harshida Patel, B K Shukla and S V Kulkarni

Development of Cast Resin Multisecondary 1600kVA Transformer for Regulated High Voltage Power Supply –A Prototype
V. Tripathi, N. P. Singh, L. N. Gupta, Kapil Oza, Paresh Patel and U. K. Baruah

CAMAC Based 4 – Channel 12 –Bit Digitizer
Amit K Srivastava, Atish Sharma, Tushar Raval and D Chenna Reddy

Conceptual Design of Fast Reciprocating Probe Drive for SST-1 Tokamak
M. V. Gopalkrishna, V. M. Bedkihale, V. R. Prajapati and R. Jha

Second Harmonic Pre-ionization / Start-up Experiments in Tokamak Aditya
K. Sathyanarayana, R. L. Tanna, S. B. Bhatt, Ramasubramanian, N, Manoj Kumar, R. Manchanda, Santanu Banerjee, P. K. Atrey, D. Raju, B. K. Shukla, P. S. Bawankar, K. M. Patel, J. M. Sonara, Ketan. M. Patel, Vishnu Chaudhary, Pragnesh. D, Dharmesh P, Sanjay Kulkarni, Y. C. Saxena and Aditya Team
Study of Large Amplitude Plasma Oscillation / Waves in Cold Plasma
Prabal Singh Verma, S. Sengupta, P. K. Kaw

Plasma Generation and Expansion At the Anode Surface in a Virtual Cathode Oscillator
Gursharn Singh and Shashank Chaturvedi

Effect of A Transverse Magnetic Field on Diffused Plasma Parameters
M. Chakraborty, M. Bandyopadhyay, B. Das, M. K. Mishra

Effect of Filament Position on Plasma Parameters in A Double Plasma Device
M. Chakraborty, B. Das, M. K. Mishra, M. Bandyopadhyay

Computational Study of Mach Stem Formation in Water
S. Madhavan, P. Pahari and S. Chaturvedi

Finite Element Analysis of CICC Joints in SST-1
Amardas and S. Pradhan

Influence of Surface Produced Negative Ions on Sheath Structure
Sejal Shah and M. Bandyopadhyay

Multi- CPU Simulation of Tearing Modes and M=1 Internal Kink Mode
S. Chatterjee, M. P. Bora, A. Sen

System Integration of RF Based Negative Ion Experimental Facility at IPR
G. Bansal, M. Bandyopadhyay, M. J. Singh, A. Gahlaut, J. Soni, K. Pandya, K. G. Parmar, J. Sonara and A. Chakraborty

Study of Plasma Dynamic Across a Transverse Magnetic Field by Fluid Modeling
Kavita Rani Rajkhowa, M. Bandyopadhyay and M. Chakraborty

Transverse Drift Velocity of a Pulsed – Plasma in a Curved Magnetic Field
R. Paikaray, D. C. Patra, N. Sasini, B. Mohanty, G. Sa-

hoo, J.Ghosh, A. K. Sanyasi
Studies of Plasma Turbulence in Large Volume Plasma Device in Presence of a Conducting Aperture
L. M. Awasthi, S. K. Mattoo, and R. Jha (Best Poster Award)

Anode Spots and their Transition to Striation in a DC Glow Discharge
K. K. Barada, S. K. Tiwari, P.S. Ghosh, P. Bawankar, A. Bandyopadhyay, J.Ghosh and P. K. Chattopadhyay

Experimental Investigation of Low Frequency Electrostatic Fluctuations in BETA Device
R. Kaur, R. Singh, A. K. Singh, and S. K. Mattoo

Locked States Observed in the Rotation of a Carbon Nanotube Based Motor
S. Negi, M. Warrier, S. Chaturvedi and K. Nordlund

Equation of State of Aluminium in Warm Dense Matter Regime
Vinayak Mishra and S. Chaturvedi

Kinetic Trapped Particle Instability and Stock Formation in Large Amplitude Ion-Acoustic Waves
D. Sharma, A. Sen and P. K. Kaw

Electron Acoustic Dromions: A Numerical Analysis
S. S. Ghosh, Y Omura, A. Sen and G. S. Lakhina

Development of Circuit Model for Arcing on Solar Arrays
Bhoomi K. Mehta, S. P. Deshpande, S. Mukherjee, S. B. Gupta, M. Ranjan, R. Rane, N. Vaghela, V. Acharya, M. Sudhakar, M. Sankaran, E. P. Suresh

The Kelvin Helmholtz like Instability for Sheared Electron Flow in the Presence of in-Plane Equilibrium Magnetic Field
Sita Sundar, Gurudatt Gaur, Amita Das, Predhiman Kaw and Sarveshwar Sharma

Nonlinear Simulations of a 2-D Sheared Electron Flow in the Presence of In-Plane Equilibrium Magnetic Field
Gurudatt Gaur, Sita Sundar, Amita Das, Predhiman Kaw and Sharad Kr. Yadav

Propagation of Electron Magnetohydrodynamic Structures in a Two-Dimensional Inhomogeneous Plasma
Sharad Kumar Yadav, Amita Das and Predhiman Kaw

Sluggish Response of Untrapped Electrons and Global Electrostatic Micro-Instabilities in a Tokamak
J. Chowdhury, R. Ganesh, P. Angelino, J. Vaclavik, L. Villard and S. Brunner

Excitation of Ion Acoustic Wave Through a Metal Plate
Satyananda Kar and Subroto Mukherjee

Experimental Studies of Visco-Elastic Properties of a Strongly Coupled Dusty Plasma in Presence of Magnetic Field
P. Bandyopadhyay, U. Konopka, G. Morfill, A. Sen and P. K. Kaw

Coupled Nonlinear Stationary Waves in Cold Relativistic Electron Plasma
Vikrant, Abhijit Sen and Predhiman Kaw

Surface Free Energy Analysis for Bipolar Pulsed Argon Plasma Treated Polymers
S. Pelagade, Sejal Shah, R. S. Rane, N. L. Singh, S. Mukherjee

Surface Modification of Polycarbonate by Nitrogen Plasma Treatment
Anjum Qureshi, S. Pelagade, N. L. Singh, S. Mukherjee, U. Despande, T. Shripathi

Effect of Substrate Biasing and Post Deposition Annealing on Titanium Nitride Hard Coating
R. Rane, Kishor Kumar, N. Vaghela, N. Chauhan, P. Raijada and S. Mukherjee

Study of Secondary Particle Growth in Copper Oxide Nanopowder Produced by Exploding Wire Method
Rashmita Das and Anurag Shyam

Strategy for Control and Data Acquisition of Negative Ion Source at IPR
Jignesh Soni, Vishnukumar B. Patel, Agrajit Gahlaut, M. Bandyopadhyay, Mahendrajit Singh, Gourab Bansal, Jaswhant Sonara, K. G. Parmar, Kushal Pan-

dya and Arun Chakraborty
Power Supply System for the Negative Ion Source at IPR
Agrajit Gahlaut, Jashwant Sonara, K. G. Parmar, Jignesh Soni, M. Bandyopadhyay, Mahendrajit Singh, Gourab Bansal, Kushal Pandya and Arun Chakraborty

Challenges in the Deposition of Plasma Polymer Films in Large Area Capacitively Coupled Radio Frequency Plasma
Purvi Kikani, Arun P., R. Rane, N. Chauhan, Adam Sanghariyat, S. Mukherjee and S. K. Nema

Plasma Nitriding and Microstructure Study of Ball Bearing Steel
Ravindra Kumar, J. Alphonsa, Ram Prakash, A. K. Agarwal, K. S. Boob, J. Ghanshyam, Pratipal Rayjada, P. M. Raole and S. Mukherjee

Development of FPGA Based Multi Channel Interlock with PC Interface for High Power RF and Microwave Tubes
Harshida Patel, Jatin Patel, Dharmesh Purohit, Rajan Babu, K.Sathyanarayana, B. K. Shukla and S. V. Kulkarni

Pulsed Laser Deposition of Thin Film of Molybdenum
A. T. T. Mostako, C. V. S. Rao and Alika Khare

Design Scheme of a 1 MW Solid State Pulsed Power Supply for Plasma Sputtering Applications
Suryakant B. Gupta, Naresh Vaghela, Keena Kalaria, Subroto Mukherjee

Generation of Chemically Reactive Species by Corona Discharges in Water
Suryakant B. Gupta, Hansjoachim Bluhm

Characterization of Glow Discharge Plasma in a Toroidal Device
Manash Kumar Paul and P. K. Sharma

Development of CCD Controller for Scientific Application
M. S. Khan, M. F. Pathan, U. V. Shah, B. G. Anandrao

Characterization of the Neon Ion Beam Emitted from a Low Energy Plasma Focus Device
M. Bhuyan, N. K. Neog, S. R. Mohanty, C. V. S. Rao, P. M. Raole

Up Gradation and Calibration of Aditya Charge Exchange Neutral Particle Analyzer for Better S/N Ratio
Santosh P. Pandya, Kumar Ajay and J. Govindarajan

Lens Design for Uncooled Thermal Imaging Camera
Shwetang Pandya, J. Govindarajan, Ikbal Singh

Studies of X-Ray Emission from a low Energy PF Device Using Vacuum Photodiode
N. Talukdar, T. K. Borthakur, N. K. Neog, C. V. S. Rao, A. Shyam

Application of Laser Induced Fluorescence Spectroscopy to Probe Flowing Plasma Parameters
Kshitish K. Barada, Amitava Bandyopadhyay, Prabal K. Chattopadhyay

Study of Plasma Interaction in a Multi Magnetron System
Kishor Kumar K, S. Mukherjee

Optical Emission Spectroscopic Study of Planar Magnetron Plasma
Kishor Kumar K, Jashashree Ray, P. I. John, Jaydeep Ghosh, R. Manchanda, Ketankumar Patel, S. Mukherjee

Compact Curved Plate Electrostatic Charge Exchange Neutral Energy Analyzer for Tokamak Core Ion Temperature Estimation
Santosh P. Pandya, Kumar Ajay & Govindarajan

Measurement of Neutral and Gas Temperature in a Large Volume Multi Cusp Ion Source Using a Spectroscopic Technique
Bharathi Punyapu and Prahlad Vattipalle

SST-1 Thomson Scattering Diagnostic Data Acquisition System
Chhaya Chavda, Kiran Patel, Ajaikumar and Laser Diagnostic group

Multi Channels Phase Shift Measurement Electronics for SST-1 Far Infrared Interferometer Diagnostic
Vipal Rathod, L. K. Bansal, C. J. Hansalia, Rachana Rajpal, Prabal Chattopadhyay

Prototype Design of AVR Micro Controller Controlled DDS (Direct Digital Synthesis) Waveform Generator
Jignesh Patel, Pramila, Rachana Rajpal and Electronics Group

Density & Temperature Measurements of Pulsed Plasma Produced inside a Curved Vacuum Chamber
N. Sasini, R. Paikaray, L. Dinda, G. Sahoo, J. Ghosh, A. K. Sanyasi

Soft X-Ray Pulse Height Analyzer Diagnostics for SST-1 Tokamak.
Y Shankara Joisa

Synthetic Spectrum of Neutral Helium Line Emission in Purely Ionizing and Recombining Plasmas
Bishu Agarwal, Jalaj Jain, Ram Prakash, Ravindra Kumar, Vinay Kumar and P. Vasu

Studies on Plasma Profiles and its Effects on Dust Charging in Hydrogen Plasma
B. Kakati, S. S. Kausik, B. K. Saikia and M. Bandyopadhyay

Hydrogen Molecules for Electron Temperature Diagnostic of Plasmas
R. Manchanda, S. Banerjee, K. M. Patel, J. Ghosh, Vinay Kumar, P. Vasu and Aditya and SST-1 team

Design and Development of Laser Heated Emissive Probes
Payal Mehta, Arun Sarma, Rajwinder Kaur, J. Ghosh, Ketan M.Patel and Shwetang Pandya

Abel Inversion of Asymmetric Plasma Density Profile at Aditya Tokamak
N. Y. Joshi, P. K. Atrey, S. K. Pathak.

Development of Calibration Set-Up for ECE Radiometer Systems at Institute for Plasma Research
N. Y. Joshi, Varsha Siju, H. B. Pandya, P. K. Atrey, S. K. Pathak

Uncooled Microbolometer IR Camera Design
Hitesh Mandaliya, Praveenlal E. V., Rachana Rajpal, J. Govindrajan, Shwetang Pandya

Second Harmonic Pre-ionization / Start-up Experiments in Tokamak Aditya
K. Sathyanarayana, R. L. Tanna, S. B. Bhatt, Ramasubramanian. N, Manoj Kumar, R. Manchanda, Santanu Banerjee, P. K. Atrey, D. Raju, B. K. Shukla, P. S. Bawankar, K. M. Patel, J. M. Sonara, Ketan M. Patel, Vishnu Chaudhary, Pragnesh D., Dharmesh P., Sanjay Kulkarni, Y. C. Saxena and Aditya team

Understanding and Comparison of Plasma Flows Measurements Using Magnetized and Un-Magnetized Mach Probe
Deepak Sangwan, M. V. Gopalkrishna and R.Jha

15th International Conference on Positron Annihilation (ICPA--15), Saha Institute of Nuclear Physics, Bidhannagar, Kolkata, 17 - 23 January 2009

Paul Trap for Pure Positron Plasma – A Prelude to Electron-Positron Plasma in a Laboratory
M. Bajpai, L. T. Lachhvani and Y. C. Saxena

18th International Photovoltaic Science and Engineering Conference (PVSEC 18), Kolkata, India, January 19-23, 2009

Langmuir Probe Diagnostics of a Multi-Hole Cathode Very-High-Frequency (55 Mhz) Plasma for Deposition of Si:H Thin Films
C. Jariwala, P. Vasu, A. Chainani, V. Dalal and P.I. John

5th IAEA Technical Meeting on ECRH Physics & Technology for Large Fusions Devices, Gandhinagar, India, February 18-20, 2009

Design Change, its Implications & Alternate Options for the EC Source System for ITER Plasma Start-Up
S.L.Rao, U.K. Baruah, M. Kushwah, Rajnish K., I Bandyopadhyay, Satyanarayana K., V. Rathod and S. P. Deshpande

National Conference on Recent Advances in Surface Engineering (RASE-2009), National Aerospace Laboratories (NAL), Bangalore, 26-27 February 2009
Deposition of Teflon like Coatings using EPA and PECVD
A. Satyaprasad, S. Mukherjee, S.K. Nema

Plasma Assisted Superhydrophobic Coatings and Potential Applications
N.I. Jamnapara, A. Satyaprasad, S.K. Nema, S. Mukherjee

Development of Titanium Nitride hard Coating using Magnetron Sputtering
R. Rane, Kishor Kumar, K.N. Vaghela, N. Chauhan, P. Rayjada , S. Mukherjee

Workshop on Active Beam Spectroscopy for the control of fusion plasmas, Lorentz Center, Leiden, The Netherlands, 24-27 March, 2009

Effect of wall reflection on CXRS diagnostics in Textor and ITER
Santanu Banerjee, P. Vasu, Manfred Von Hellermann, Roger Jaspers and Ephrem Delabie

E 4. INVITED TALK DELIVERED BY IPR STAFF

AMITA DAS

Gave an invited talk entitled "Coherent Structures and Intermittency in Plasma Turbulence" at 2008 ICTP International Workshop on the Frontiers of Modern Plasma Physics, Trieste, Italy, 14-25 July 2008.

P. K. SHARMA

Gave an invited talk entitled "Role of high power RF and microwave systems in fusion plasmas" at the Workshop on Electronic Tube Technology – 2008 (ETT-08), CEERI, Pilani, Rajasthan on 25th August 2008.

Gave an invited talk entitled "RF based Plasma Sources" at Dept. of Science & Technology and Plasma Science Society of India (DST-PSSI) Meet, Ahmedabad, on 10th April 2008.

P. M. Raole

Gave an invited talk at the National Workshop on Characterization techniques for Carbon Materials, S.P.University Vallabh Vidyanagar, Gujarat, 23-24, December 2008

Gave an invited talk at the Workshop on Scanning Electron Microscopy, S.P.University, Vallabh Vidyanagar, Gujarat, 19 – 24, January 2009.

S. K. NEMA

Gave an invited lecture on "Plasma Based Technologies & Their Applications", Dept. of Chemical Engineering, Nirma University, December 2008

U.K. BARUAH

Gave an invited lecture on 'High Voltage, High Current DC Power Supplies' at Theme Meeting on "Low Energy RF Linacs and Associated Technologies" at BARC, Mumbai, India, 29-30 December 2008

B. SARKAR

Gave an invited talk on " Challenges of Cryogenic System for Thermonuclear Fusion" at the Workshop on Hundred Years of Helium Liquefaction and Research: Thereafter in India at National Physical Laboratory, New Delhi, India, September 23-24, 2008

Gave an Invited talk on " Cryogenic System Overview and Indian Contribution to ITER Project" at DAE-BRNS Theme meeting on cryostat, cryolines and their applications in large accelerator systems" at Variable Energy Cyclotron Centre, Kolkata, India, December 8-9, 2008

Gave an Invited talk on "Cryogenics for ITER Magnets and Cryo-pump System" at VECC – KEK Joint School on Superconducting Technology, at Variable Energy Cyclotron Centre, Kolkata, India, March 16 – 20, 2009

Suryakant B. Gupta

Gave an invited talk on "Potential of plasma science for surface treatment industries" at the Central Institute of Tool Design, CITD, Hyderabad, India, 20 March 2009

P. J. PATHAK

Attended MANLIBNET Round Table discussions at EDI Ahmedabad on 17 May 2008

Gave lecture on "Standardization in Libraries" at UGC Sponsored Refreshers Course at DLIS Gujarat University, Ahmedabad on September 9, 2008

Gave lecture on “Changing Role of School Librarians” at DIET Library Ahmedabad on September 11, 2008

Gave lecture on “Knowledge Management in Libraries” at UGC Sponsored Refreshers Course at DLIS Gujarat University, Ahmedabad on September 16, 2008

Gave lecture on “Bibliographic Standards” for BLIS and MLIS Students of DLIS Gujarat University on January 29, 2009

Plenary & Invited talks given at 23rd National Symposium on Plasma Science & Technology (PLASMA 2008), Bhabha Atomic Research Center, Trombay, Mumbai, December 10th – 13th 2008

Shishir Deshpande on “The ITER Collaboration” (a Plenary talk)

C.V. Srinivasa Rao on “Diagnostics for Burning Plasmas: Challenges & Possible Solutions” (a Plenary talk)

R. Singh gave an invited talk entitled on “Density Limits in Toroidal Plasmas”

V. Prahlad and NBI Team gave an invited talk entitled on “1st Ion Beam on SST-1 NB Test Stand”

S. K. Nema, P.I. John, and V. Jain gave an invited talk entitled on “Evolution of Plasma Pyrolysis Technology at FCIPT for Safe Disposal of Medical and Organic Waste”

R. Ganesh, W.W. Lee, S. Ethier, J. Manickam, and R. Kolesnikov gave an invited talk entitled on “Understanding Ion Transport in Fusion Plasmas Using Multiscale Massively Parallel Gyrokinetic Plasma Simulations”

Sambaran Pahari gave an invited talk entitled on “The Exotic World of “Non-Neutral Plasmas”

Invited talks given at DST-SERC School on “Science and Technology of Processing Plasmas”, BITS, Ranchi, 20th Dec.2008

P. M. Raole on “Plasma processing and Applications”

P. M. Raole on “Surface characterization of Low Pressure Plasma Modification of Materials”
P. M. Raole on “Fusion Reactor Materials – Challenges and Opportunities”

S. K. NEMA on “Understanding Low & Atmospheric Pressure Plasmas and Their Applications”

S. K. NEMA on “Designing Considerations in a Low Pressure Plasma Reactor”

E 5. TALKS DELIVERED BY DISTINGUISHED VISITORS AT IPR

Dr Chirag Kalelkar, Institute for Research in Electronics and Applied Physics, University of Maryland, USA gave a talk on “Drag Reduction by Polymer additives in decayingfluid turbulence”.

Dr. Ikbal Singh, Instruments Research and Development Establishment, DRDO, Dehradun gave a talk on “Optical design of Thermal Imaging Systems”.

Prof. A Ganguli, IIT Delhi gave a seminar on “Recent Investigations on Helicon Plasmas in Conducting Waveguides”.

Dr. Manish Dev Shrimali, LNM IIT Jaipur, India gave a lecture on “Inducing Order in Coupled Chaotic Maps”.

Dr. Ghananand Sharma Jadli, Retired Prof. Shahjanand College, Ahmedabad gave a literary talk in hindi on “Manas men Vishwashanti”.

Dr. Saswati Datta, Head, Beauty Technology Division, Procter & Gamble, Miami Valley Innovation Center, Cincinnati gave a seminar on “Plasma Surface Modification From Computers to Diapers”.
Mr. Dinesh Nath, gave a lecture on “Direct Numerical Simulation in a Nonhelical Dynamo Transitions”.

Mr.Hemen Kakati, gave a lecture on “Discharge and Deposition Characteristics of RF Magnetron Plasma”.

D. Buchenau, G. Gerbeth gave a lecture on "Liquid Metal Activities at Research Centre Dresden-Rossendorf", Department Magnetohydrodynamics, Institute of Safety Research (FZD), Germany

E 6. COLLOQUIA PRESENTED AT IPR

Dr Didier van Houtte, ITER Organization, France gave a talk on "A RAMI Approach for a Reliable ITER Machine" (Colloquium #203)

Prof. K A Tanaka, ILE, Osaka, Japan gave a talk on "Study of proton and hot electrons characteristics for fast Ignition" (Colloquium #204)

Dr. Monojoy Goswami, Computational Chemical Sciences, Oak Ridge National Laboratory gave a talk on "Morphology and Dynamics of Polymer Nanocomposites" (Colloquium #205)

Dr. Ulrich Schramm, Forschungszentrum Rossendorf (FZD), Germany gave a talk on "Surfing the plasma wake - particle acceleration with laser light" (Colloquium #206)

Prof. S. K. Mattoo, Institute for Plasma Research gave a talk on "Accelerators for development of nuclear fusion technology in India" (Colloquium #207)

E 7. SCIENTIFIC MEETINGS HOSTED BY IPR

Report on the Nuclear Activation Workshop ACT-2008

The workshop was held from 5th to 9th of May 2008. There were totally 45 participants who attended the workshop. There were 6 experts in the field of nuclear activation Dr. Robin Forrest, Fusion Scientist, Culham Laboratory, UKAEA along with 4 other experts from BARC and IGCAR.

Dr. Robin Forrest conducted a training programme on European Activation System (EASY) code to IPR members involved in neutronics analysis of ITER packages. There were 10 students from various universities and institutes who also took part in the training programme. The programme comprised of 8 lecture presentations from Dr. Robin Forrest and 4 lectures from experts from BARC and IGCAR.

A daylong 'hand-on' experience on getting acquainted and solving problems using EASY-2007 code. The workshop focused on nuclear activation aspects of fusion reactor design and nuclear safety issues related to activation.

Workshop on "Steels and Fabrication Technologies for fusion programme" (WS&FT-08), at IPR during 21-22 July 2008.

15th ***Meeting*** of the ITPA Topical Group on Diagnostics, held in Ahmedabad, India, Nov.17-20, 2008, hosted by ITER-India and IPR
(28 foreign delegates have participated in the conference in addition to equal number of Indian participants)

National ***Workshop*** on "Characterization techniques for Carbon Materials" was organized by IPR at S.P.University Vallabh Vidyanagar, Gujrat, during December 23-24, 2008

Workshop for the ITER Cryogenic System, IPR on February 10-11, 2009.

5th IAEA ***Technical Meeting*** on ECRH Physics and Technology for Large Fusion Devices, Gandhinagar, India, February 18-20, 2009

International ***Symposium*** on High Performance Nanostructured Materials (ISHPNM09), IPR, 19-20 February 2009, which was co-sponsored by Board of Research in Fusion Science and Technology (BRFST). A special session on SiCf /SiC composites for fusion applications had been organized in this symposium.