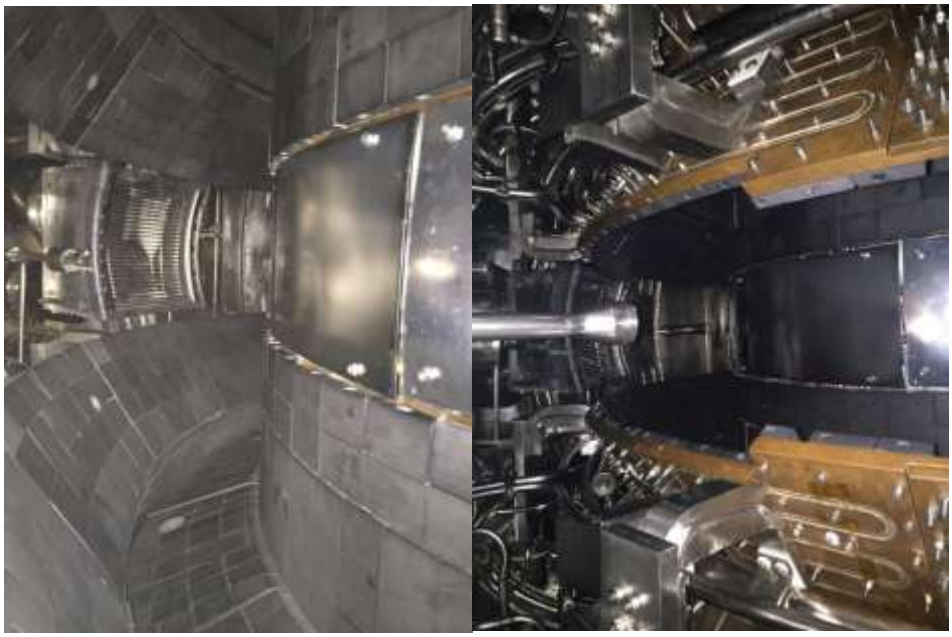
MP3-Nuclear Power Programme – Stage-3

3.07 Fusion Reactor

3.07-0100 Tokamak Research and Fundamental Plasma Studies

Steady-state Superconducting Tokamak -1 (SST-1): This machine has completed the 1st phase of up-gradation with successful installation and integration of all its First Wall components (also known as plasma facing components). The First Wall of SST-1 comprises of ~ 4500 high heat flux compatible graphite tiles being assembled and installed on 136 Copper Chromium Zirconium (CuCrZr) heat sink back plates engraved with ~ 4 km of leak tight baking and cooling channels in five major sub groups equipped with ~ 400 sensors and weighing ~ 6000 kg in total in thirteen isolated galvanic and six isolated hydraulic circuits. The phase-1 up-gradation spectrum also includes addition of Supersonic Molecular Beam Injection (SMBI) both on the in-board and out-board side, installation of fast reciprocating probes, adding some edge plasma probe diagnostics in the SOL region, installation and integration of segmented and up-down symmetric radial coils aiding/controlling plasma rotations, introduction of plasma position feedback and density controls etc. After the phase-I up-gradation, initial plasma experiments in up-graded SST-1 have begun, after a brief engineering validation period of six weeks. The first experiments in SST-1 have revealed interesting aspects on the `eddy currents in the First Wall support structures' influencing the `magnetic Null evolution dynamics' and the subsequent plasma start-up characteristics after the ECH pre-ionization, the influence of the first walls on the `field errors' and the resulting locked modes observed, the magnetic index influencing the evolution of the equilibrium of the plasma column, low density supra-thermal electron induced discharges and normal ohmic discharges etc. Presently; repeatable ohmic discharges regimes in SST-1 having plasma currents in excess of 65 KA (q_a ~3.8, B_T =1.5 T) with a current ramp rates ~ 1.2 MA/s over a duration of ~ 300 ms with line averaged densities ~ 0.8 X 10^{19} m^{-3} and temperatures ~ 400 eV with copious MHD signatures have been experimentally established. A vessel opening of SST-1 for an audit of the installed First Wall Components, improvements of some of the installed diagnostics and addition of some of the new diagnostics had been done. Elongation of the plasma duration up to one second or more with position and density feedback as well as coupling of Lower Hybrid waves are be persuaded in SST-1 experiments. The core plasma parameters is expected to be improved with further optimizations and with wall conditioning.



(Fig 1: SST-1 Vacuum Vessel with installed First Wall Components)

Aditya Upgrade

Dis-assembly of existing Aditya machine As a part of upgradation, the existing Aditya machine is completely dismantled up to the bottom I-beams holding the TF coils. All the coils and structural elements, except few TF coils are found to be in good condition even after 25 years of Aditya operation. After elaborate ECDS measurements and marking of each and every component, more than 28 different components of the tokamak are removed during the course of the disassembly.

Re-assembly, installation and testing of upgraded Aditya Machine: The new buckling cylinder and new vacuum vessel has been delivered. The new vacuum vessel has been baked and vacuum of ~ 10^{-10} Torr has been achieved. After refurbishment of the TF coils, the reassembly has been started and substantial progress has been made. The buckling cylinder has been placed along with TR 1 coil in the center. After that the inner Cs of TF coils have been placed. This has been followed by winding of the divertor coils using CTC cables. After completion of in-situ winding of 6 numbers of Divertor and FFB coils, the vacuum vessel has been placed on the machine and positioned precisely with its major axis aligned to central axis of TR1 coil. After completing the vacuum vessel placement, the outer Cs of TF are being connected to the inner Cs to make the TF coil complete.

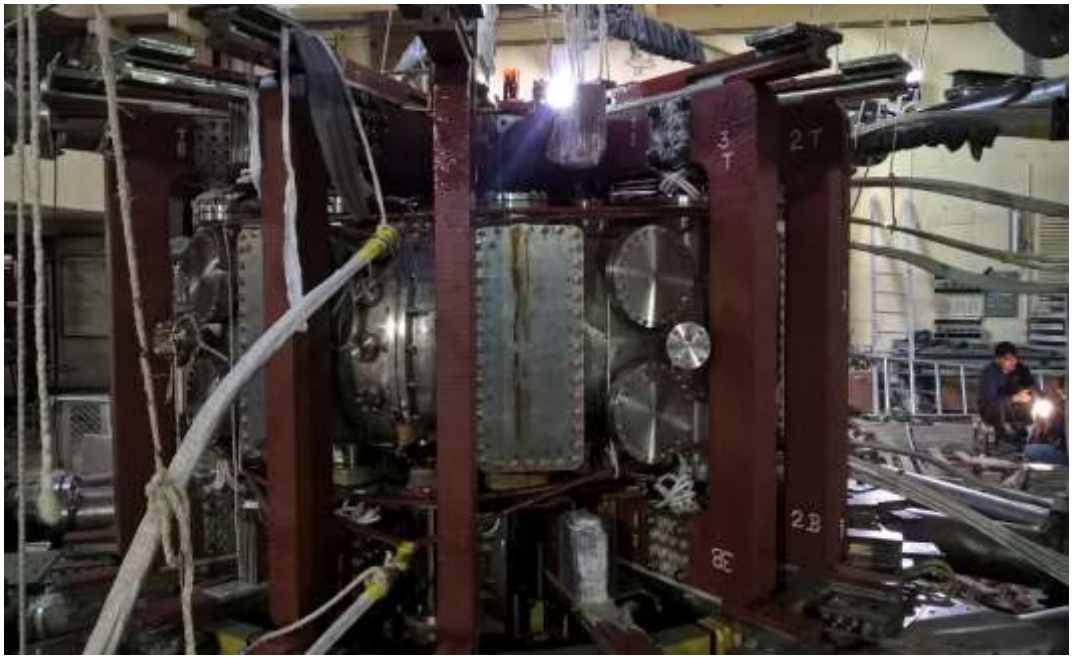


Figure Installation of TF coils with new vacuum vessel is in progress.

Heating and Current Drive Systems

Lower Hybrid Current Drive (LHCD) System: For launching LHCD in SST-1, a new grill antenna made of SS has been fabricated and installed by replacing the already present copper antenna. This UHV compatible antenna has been tested to withstand the high temperature baking inside the vacuum. The modification work to resolve the interface issues of hard x-ray diagnostics with other sub-systems of SST1 machine is completed successfully. The parallel operation of multi klystrons system using single regulated high voltage power supply (RHVPS) is successfully carried out using bleeder resistance with all the modules (65 in numbers) connected in the circuit. From campaign-XIII onwards, the LHCD power has been successfully launched in to the SST1 machine and encouraging experimental results have been obtained. The upgradation work in the Aditya tokamak provides an opportunity to upgrade lower hybrid current drive (LHCD) system on ADITYA machine to drive plasma current non-inductively and enhance the coupling of RF power to the plasma by using a new type of antenna which is often referred as passive active multi-junction (PAM) antenna.

Electron Cyclotron Resonance Heating (ECRH) System: The 42GHz/500kW Electron Cyclotron Resonance Heating (ECRH) system has been emerged as a main system for SST-1

tokamak and extensively used to start-up the tokamak. After the refurbishment of SST-1 with in-vessel components, the 42GHz system is used as routine system. The 82.6GHz/200kW has been planned to connect with SST-1. The ECRH launcher has been modified successfully to accommodate the 42GHz and 82.6GHz systems along with hard X-ray diagnostics. The system is successfully commissioned on tokamak and high power test are carried out up to 325kW power.

Fundamental Plasma Sciences

Large Volume Plasma Device (LVPD): Experimental and developmental activity in was widely focused to different physical phenomenons. Investigations were carried out primarily on, 1) understanding plasma turbulence excited by trapped energetic electrons in source plasma and investigating the loss pathways of energetic electrons, 2) on augmentation of 40 channel Data Acquisition System(DAS) to LVPD machine and lastly, 3) on pursuing investigation on fluctuation induced total flux(particle and energy) in the background of ETG, initiated efforts in developing a new diagnostic for real time measurement of electron temperature and its fluctuations.

Interaction of Low Energy Ion and Neutral Beams with Surfaces: The addition of new electromagnet to the system has helped to increase the ion (hence neutral) flux by a factor of twenty while decreasing the electrical power consumption. The maximum density calculated was 2.2×10^{13} cm^{-3} which is twenty times 1.1×10^{12} cm^{-3} measured when the old electromagnet was used. With the increase in ion flux by a factor of twenty we now expect the neutral flux has also increased by the same factor. This has paved way to develop and setup the neutral beam diagnostics sub-system to be added to the existing system.

SYstem for Microwave PLasma Experiments (SYMPLE): The investigations planned on High Power Microwave (HPM) plasma interaction in SYMPLE (System for Microwave Plasma Experiments) is now taken up in two phases, Phase-1 addressing interaction of plasma with moderate power HPM and Phase 2 involving extremely intense HPM. The experimental set-up for the two phases is being carried out in two separate labs. As for the Phase-1, the work carried out includes i) Procurement of an S Magnetron, ii) Design and indigenous development of a pulsed modulator in order to drive the magnetron, iii) Designing a coupling system for HPM – plasma coupling and iv) Development of a plasma system with a steep axial electron density gradient at the interaction regime, followed by a uniform axial and v) Design and development of an HPM Mode Converter. For the Phase-2 system, development of a

Backward Wave Oscillator (BWO) based HPM source is under way at BARC, as a collaborative effort with BARC. For this system, design and development of a coupling system that is high power compatible, incorporating an appropriate directional coupler and facilities for power measurements is presently under way.

Plasma Torch Experiment: Experiments to study force balance dynamics of plasma column in the plasma torch were continued. Magnetic probes were used to gather information about the arc root transients and detailed spectral analysis was performed to understand the processes. Robust enthalpy probe was fabricated and used to find the local plasma enthalpy and temperature of the thermal plasma of torch. Computer simulation of plasma torch was extended to include time-varying dynamics. A high-fidelity simulation code developed by University of Texas at Austin was used through collaboration. A simple model of torch was developed and the gas and plasma dynamics were simulated.

Plasma Wake-Field Accelerator (PWFA) Experiment: A prototype Lithium (Li) heat pipe oven based plasma source with a uniform temperature for PWFA experiment has been developed. For accurate determination of Li vapor density, Spectral interferometry (Hook Method) has been implemented in the present experimental setup. Extensive and critical alignment were carried out optimize the Hook experimental setup for fringe contrast and quality. The recharge of the prototype heat pipe oven with fresh Li has been initiated to carry out the next set of experiments. The site clearance of IPR LINAC building has been obtained from AERB. The preparation of second stage documents for LINAC building to be submitted to AERB are in progress as suggested by IPR LINAC committee. Designing of bending magnet for IPR LINAC low energy beam line in collaboration with RRCAT, Indore has been initiated.

Theory and Simulation

Dusty plasma / Complex plasma studies

Analytic structure of confined dust vortex flow in plasma: Small size heavily charged dust particles in plasma are of interest in many applications: the hot plasma edge of a tokamak, swimming of microorganisms, bacterial turbulence, viscoelastic fluids and many life-saving biotechnology applications. A fresh application of elements of 2D fluid model to dusty plasma models has been done. The results from the study allow quantification of the notion of dusty plasma medium as a paradigm for a wide range of natural flow processes having scales inaccessible to ordinary laboratory experiments.

*Studies on Strongly coupled Viscoelestic medium***:** A Poynting like theorem has been constructed for the generalized Hydrodynamic fluid model. The theorem was verified numerically in detail. A new

class of sub/ super-luminar dipole structures moving at speeds less /more than the phase velocity of the transverse shear wave have been identified numerically.

Laser Plasma interaction studies

Ion acceleration from laser-bacteria interaction (with TIFR): Ion-acceleration has been studied by varying polarization state of light experimentally at TIFR. EMPIC simulations were carried out by varying the polarization which corroborate those experimental results. Electron yield is also calculated as number of ellipsoids (which mimic bacteria) on the slab increases and corresponding structure of anharmonic potentials are extracted from simulations.

Understanding of generation of x-rays from laser irradiated bio-plasmas (with TIFR): It was demonstrated by the TIFR experimental group that laser irradiated biological target consisting of a few micron-layer of E. Coli bacteria doped with silver chloride (AgCl) nano-particles can lead to enhanced x-ray emission by 100 times compared to the case with only E.coli. Those experimental results were reproduced by electromagnetic particle-in-cell (EMPIC) simulations. Detailed analysis with a simple nonlinear oscillator model and EMPIC data show that anharmonic resonance absorption is the most dominant mechanism behind such enhanced absorption.

Collisional absorption of laser light in under-dense plasma: A study by PIC simulation: Absorption of a normally incident s-polarized laser light in a homogeneous, under-dense plasma-slab due to electron-ion collision is studied by using particle-in-cell simulations. Our particular interest is to investigate variation of anomalous collisional absorption with laser intensity. Preliminary results shows that 20-30% of laser light can be absorbed by collisional processes. Further investigation is in progress.

Molecular dynamics study of laser driven atomic cluster: A two and three dimensional Molecular Dynamics (MD) simulation code has been developed for studying intense laser interaction with atomic nano-clusters. For a given cluster size and a plasma density, both energy conservation and correct plasma oscillation are obtained only for certain values of the soft-core parameter lower than the half of the inter-ionic distance. Further MD simulations are carried out including the driving laser field. Results are now being analyzed to identify anharmonic resonance absorption by electrons. Further effect of magnetic field on the dynamics of cluster electrons and resulting absorption of energy will also be studied.

Investigation of shock-shock interaction and Mach reflection in laterally colliding laser-blow-off plasmas: Interactions of two Li plasma plumes and shock waves are investigated at various pressures in the argon gas ambient. Fast imaging and optical emission spectroscopy are used to study the plume dynamics and characteristic emission of plasmas. The expansion of plasma plumes in the ambient gas leads to the formation of an interaction zone. It is found that the shock-shock interaction depends on the angle of incidence between two shock waves at the initial time of interaction.

Non-linear Plasma Theory

Nonlinear kinetic model of plasma waves and turbulence: The structure of motion and waves observed in fluids has much complex structure at the microscopic granular level. The dispersive plasma medium has strong capacity to amplify this microscopic contrast and bring it to more visible, macroscpoic scales. Properties of these nonlinear plasma structures are examined in recent simulations observing them propagate stably, preserve their identity across strong interactions and display close correspondence with observable processes in nature.

Particle-in-cell simulation of large amplitude ion-acoustic solitons: Propagation of large amplitude ion-acoustic solitons has been studied in the lab frame (x, t) using a 1-D particle-in-cell code. It is observed that for very low Mach numbers the numerical solution closely matches the KdV soliton solution obtained in the wave frame and propagates without distortion

Parametric Study of Capacitive Coupled Plasma using Fluid Modeling: In this present work, a parametric study using fluid modelling by varying the applied radio frequency (RF) in a broad pressure regime (20 mTorr to 0.7 Torr) has been made and characteristic features of the discharge and its sensitivity to various plasma parameters have been explored. The outcomes of simulation have been verified with well-established fluid based analytical models and are found to be in decent agreement.

Collisionless sheath heating in CCP discharges via higher order sinusoidal signals: Collisionless heating of the electrons in the vicinity of sheath region corresponding to higher order sinusoidal signal in a current driven radio frequency capacitively coupled plasma (RF-CCP) discharge has been investigated analytically and further verified by particle-in-cell (PIC) simulation. The simulation results for collisionless sheath heating are found to be in good agreement with analytical predictions

Fusion related studies

3D transport simulations of plasma limiting region of tokamak Aditya: Strong 3D character of a localized ring like plasma limiter element in Aditya allows studying 3D variations in plasma boundaries of large reactor grade tokamaks. A detailed investigation of first results from the 3D plasma transport simulations shows 3D flow patterns and existence of resulting parallel and radial flow shear in the device SOL. In the present work the origin of these complex flow patterns is studied and estimates of resulting large scale plasma fluctuations in the plasma equilibrium are made.

Reactor design study: The SST2 reactor radial buildup is obtained by a given aspect ratio and a blanket thickness at the inboard side using SPECTRE code. The other geometrical parameters of reactor is obtained self-consistently.. The optimization of number of PF coils, its sizes and locations are essential. The optimization is carried out to maximize the flux linkage with plasma, minimize the coil currents for obtaining the required shape of the plasma and so on. For this study, MVMOMS code is used and a typical set of PF coil system is obtained. The 2D model of reactor components along with plasma has

been constructed. The structural analysis of coil system and neutronic performance analysis of SST2 is in progress.

Equilibrium reconstruction: The equilibrium reconstruction using IPREQ code is automated and used to simulate couple of experimental shots. The magnetic probe signals are compared. The gain factor for plasma current and external coils are found to be different and is estimated for each probe. With same gain factors, various experimental shots are reconstructed to compare the experimentally observed signals. It is planned to use other experimental observations such diamagnetic loop signal to improve the reconstruction methodology. This code will be integrated with ADITYA data system so that shots can be analysed with ease.

Facilitation Center for Industrial Plasma Technology (FCIPT-IPR)

A. Sponsored Projects and Ongoing Activities

- A new project has been sanctioned by Amrita University, Coimbatore, Tamilnadu; for developing a system to deposit TiN coatings for aerospace applications.
- A new project has been sanctioned by DST, for design and development of environmental friendly plasma system for "In-line treatment of textile" at moderate speed (20-40 m/min.). This system will be commissioned at MANTRA, Surat, and Gujarat.
- A new project has been sanctioned by DST, for development of Oxygen diffusion barrier coatings on poly-ethylene substrates using plasma technologies.
- DST has sanctioned a new project, in May 2015, for developing a radical plasma nitriding process to improve the life of cutting blades, mostly used as agricultural implements by the farmers of Nagaland. Conceptual design of the cathodic cage using hollow pipes has been finalized. Feasibility experiments have been carried out and the results have been analysed. Modifications in the system design are being worked out.
- DST has funded a project for the enhancement in reliability of biomedical implants by using a combination of Plasma Nitriding & TiN; in collaboration with CGCRI, Kolkata. Plasma Nitriding, followed up with TiN coating of Ti based alloys and SS 316L have been completed. Experiments to optimize the process parameters for obtaining best corrosion resistance are in progress.
- In a project meant for developing a 5 kW microwave source in-order to gasify low grade Indian coal; the system components have been installed. Power coupling to main reactor and testing of gas-gen set has been completed. Now, the experiments will be conducted for syn gas generation though coal gasification which will be further utilized for electrical power (3 phase, 15 kW) generation through gas gen set.

- In a DST sanctioned CZTS solar cell project, H_2S gas line with the necessary detectors and safety controls has been installed, and the associated experiments have been initiated. Experiments to optimize the CZTS layer deposition are in progress. Got a project extension till May 2016.
- In the project sanctioned by LPSC, ISRO, all the four activities viz. thruster material erosion, magnetic permeability, magnetic field, and the surface flashover studies have been successfully completed, using a Hall effect thruster materials. All the diagnostics and setup were developed at FCIPT, IPR and a large amount of useful data was generated.
- Vertical nano-dots on GaSb substrate have been successfully produced by magnetron based system and the role of ion flux on the pattern formation has been identified. The project work, sanctioned through DST Fast track Young Scientist program, has also been completed.
- The project on plasmonic coupling studies of self-assembly nano-particles, s*anctioned by DST-Nano Mission is being done.* The sticking probability of silver atoms on a patterned substrate has been successfully measured. MD simulation of the same was also carried out. The final project report is being prepared as the project has been successfully completed.
- **Plasma Torch activity:** A 100 kW capacity Plasma torch was designed, fabricated, installed. The torch was tested & demonstrated at 60 kW capacity. Enthalpy probe diagnostics system has been developed for technology transfer to industry.

B. Material Characterization Activity

- Installation of a Field Emission Scanning Electron Microscope (FESEM) from Carl-Zeiss is completed at FCIPT, IPR.
- LAICPMS (Laser Ablation Inductively Coupled Plasma Mass Spectroscopy) system of ThermoFisher has been installed at FCIPT, IPR.
- Transmission Electron Microscope (TEM) has been installed and commissioned at FCIPT, IPR.

C. Projects with International Collaboration

- **Investigation of local structure and magnetism properties of Cobalt nano-structures (*Indo-Italian program*):** Most of the experimental part has been completed. Characterization, including synchrotron based analysis, is in progress. As part of the project, an Indo-Italian work-shop (NEEM 2015) was held in Rome during October12-14, 2015.
- **Plasmonics based CZTS Solar Cells (*Indo-UK DST program*):** In this project we have successfully demonstrated that silver nanoparticle arrays are suitable as back reflectors and performed the MD simulation for the nanoparticle self-assembly. Optimisation of CZTS solar film is going on.

D. Proposals under consideration

- In the back drop of successful completion of the SPIX-II project, a new project proposal named SPIX-III has been submitted to ISAC, ISRO. The main objective is to upgrade the existing SPIX-II facility at FCIPT, IPR.
- A proposal was submitted to M/s Loxim industries ltd., Ahmedabad, in July 2015; for feasibility study on plasma surface activation of Poly-Ethylene for proper adhesion of water based inks.
- A proposal was submitted to M/s Alfa Corpscles pvt. Ltd., Delhi, in November 2015; for plasma surface activation of hernia mesh as bio implants.

E. MOUs signed

- An MoU was signed between IPR and M/s B L Engineering, Ahmedabad, for transferring Plasma Pyrolysis technology for solid waste. The MoU is for five years and on non-exclusive basis.
- A technical consultancy agreement was signed between IPR and GIFT city (Gandhinagar, Gujarat), for setting up of a 15 Kg/hr capacity plasma pyrolysis system – for solid waste disposal – at GIFT city premises. The demonstration of this unit will pave the way for establishment of plasma pyrolysis as a candidate technology for smart cities.
- An MoU was signed between IPR and CLRI - a CSIR lab in Chennai , for developing a plasma pyrolysis system for disposing tennary waste.
- An MoU was signed between IPR and WRA – at Thane in Maharastra – for improvement in surface properties of woollen fibres and fabric.

3.07-0200 Development of Auxiliary Technologies for Fusion

Magnets: Fusion relevant magnet technology witnessed a boost in the activities during the reporting period. The 1:1 prototype Edge Localized Coils for the Joint European Torus (JET) at United Kingdom was successfully realized at IPR. Two 1:1 prototype coils for the JET Tokamak were successfully tested in representative operative conditions soon thereafter and qualified the specified technical criteria. These activities were carried out under a India-European Union joint agreement. With the successful completion of the JET ELM coils, several of the state-of-the-art technologies have now been realized between IPR and its associated Indian industries. State-of-the-art copper sheathed MgB_2 strands have now been in-house manufactured in several meters of single length having very competitive current densities of

10^4-10^5 A cm^{-2} in a temperature range of 20-30 K in self-field. Both monofilament and multifilament strands have been successfully fabricated in long lengths and have been characterized in an in-house pulse tube refrigerator facility. For the first time in the country, superconducting cavity magnets for Gyrotron applications have been indigenously developed and demonstrated. These magnets are supporting an ambitious multi-institutional program on developing a 42 GHz CW gyrotron within the country. Magnet Technology Development Division has also made significant progress in the initial research trials on developing small lengths of high field high current carrying strain resistant Nb_3Al superconductors for fusion relevant magnet applications. An indigenous facility of first-of-its kind towards mechanically characterizing superconducting and insulating materials at low temperatures is also in advanced stage of realization during this period. In parallel, facilities at conduiting fusion relevant Nb_3Sn based state-of-art superconductors into cable-in-conduit-conductors (CICC) have also been realized as IPR-Indian Industry initiative. These superconducting CICC would be used for the central solenoid applications of the Steady State Superconducting Tokamak apart from being used towards developing fusion grade high field prototype magnets.

3.07-0300 Technologies for Fusion Reactor Materials, Blankets, Shields, Divertor and Fuel Cycle

Indian Test Blanket Module (TBM) Program: The TBM Division is developing Lead-Lithium Ceramic Breeder (LLCB) blanket module for testing in ITER. This program is in progress through collaboration with BARC, Mumbai, and IGCAR, Kalpakkam. Lead-Lithium R&D activities are focused towards the development of precise diagnostics for measurement of Pb-Li pressure, flow rate, and Pb-Li level in various tanks etc. for prolonged operation. In this connection, a sensitive flowmeter using water cooled Hallbach magnet has been developed, calibrated and successfully tested in Pb-Li environment. Remotely controlled pneumatic actuator valves (Fig-1), with operation range up to ~400 ^oC have also been tested in a dynamic Pb-Li flow loop for ~1000 hr duration. Pb-Li production system (Fig-2) has also been developed and trails run have been started for indigenous development of Pb-Li eutectic alloy. An experimental set up is indigenously built to estimate the effective thermal conductivity of uncompressed lithium ceramic pebble bed in stagnant helium gas environment to simulate the thermal behaviour inside the fusion blanket. It is based on the principles of the steady state and axial heat flow method.

Figure Lead-Lithium loop for diagnostics testing.

(Inset: Photograph of Hallbach magnet arrangement)

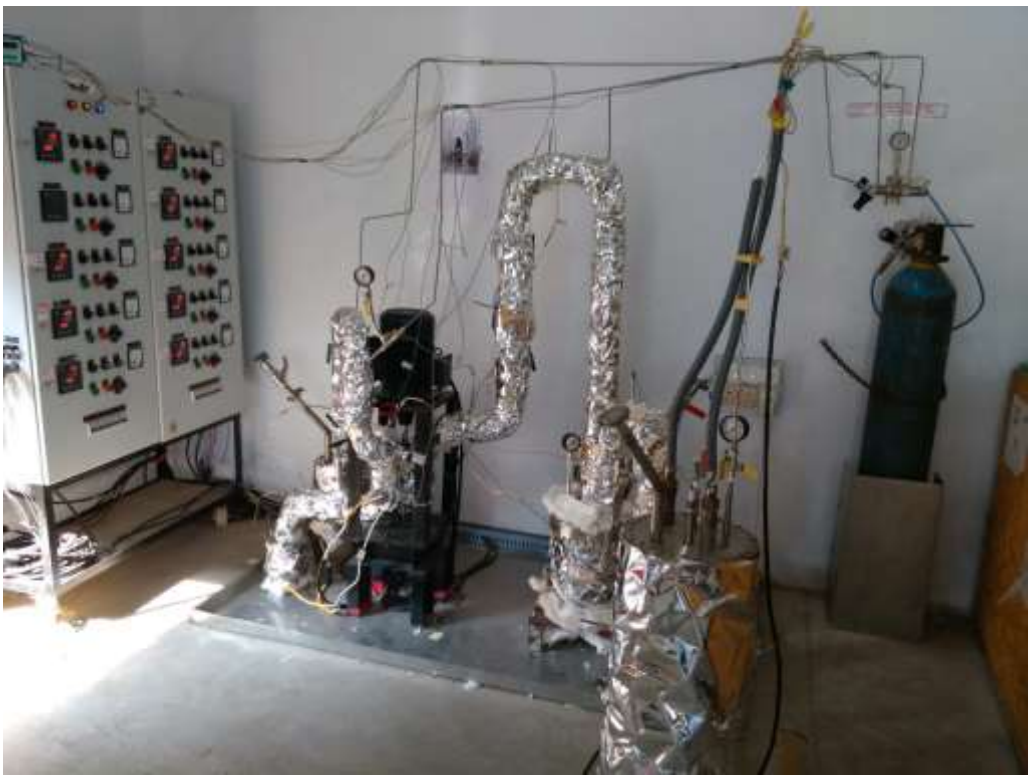


Fig-2. A small scale Pb-Li production system developed and tested

Divertors: To simulate the first wall materials getting exposed to very high heat flux, a facility (High Heat Flux, HHF) had been operationalized with the complete data acquisition and control system. Through the first phase of MOU signed between the institute and ARCI (Hyderabad), 500 micron thick pure tungsten coatings have been developed on CuCrZr and SS316L substrates. Those coatings have found to withstand more than 1000 thermal cycles at 500^{o}C surface temperature. High Pressure High Temperature Water Loop System for HHF test facility is at advanced stage of completion. Experimental and simulation studies on tungsten irradiation damage using low and high energy ion beams is in progress. Electromagnetic Analysis of ITER-like Divertor have been performed for various Major Disruption scenarios. Obtained results are being checked by comparing with data in available literature as well as through interactions with international experts. Material Coating Facility (Magnetron Sputter Coating System) has been installed. Heater Assembly used for substrate heating is being upgraded by the supplier for improved functionality at high temperature up to 1000^{o}C. Fabrication of curved tungsten macro-brush for Dome application is also in progress.

Fusion Reactor Materials Development and Characterization: Work on processing of nano Oxide Dispersion Strengthened 9Cr-RAFM steel by HIPing route for enhancing operational temperature window of future Fusion Reactors (~ up to 650°C) and high resistance to irradiation embrittlement and swelling is in progress as a multi-Institutional effort. Er2O3 coating is being developed for its application as Tritium Barrier coating in Test Blanket Modules. Systematic improvisation of Er2O3 coating surface morphology with variation in process of Metal oxide decomposition using dip-coating technique is achieved. Functional materials activities such as MgAl2O4 ceramic development activity for IR and RF windows is in progress with the trials of synthesis using solid state route and Sol-Gel technique. The defect size calibration and detection technique using known size weld defects with DAC (Distance amplitude curve fitting) generation in weld samples has been established as a part of NDT activity. Tungsten being the main Plasma Facing Material in Fusion Reactors, needs to study for radiation damage and fuel retention. This study was done under an IAEA agreement with collaboration of scientists at other organizations such as IUAC, IGCAR, BARC and ARCI in India.

Continuing Schemes (Expected to continue beyond 2 years in XII-Plan)

ITER-India: From the beginning of the project in 2007, a total 14 out (of 15) Procurement Arrangements (PA) have been signed. Eleven major contracts for the manufacturing of ITER components have been signed till date. Good progress is made at manufacturing site and some components are delivered to ITER and also to other DA sites. Pre-procurement activities for remaining PAs are going on. The summary of activities completed during the reporting period is given below:

In-kind Credit Received

- So far the earned value in terms of credit received from ITER Organization (IO) is 21526 IUA (ITER Units of Account).
- Task Agreement (TA) credit received from IO till date is 2833.669 IUA.

Manufacturing

- Cryostat Base section Tier-1 manufacturing is completed and delivered at ITER site at France, and manufacturing of Lower Cylinder is in progress.
- For In-wall shielding (IWS), Platforms for PS-2 of VS-4 and VS-5 are manufactured and delivered to EU-DA. Fabrication of Support ribs and lower brackets for PS-1 of VS-6 has been completed and delivered to KO-DA. Factory Acceptance of manufactured IWS components is ongoing.
- Manufacturing of first Lot of Cooling Water piping is completed and *delivered* at ITER site, France.
- Manufacturing of Acceleration Grid Power Supplies (AGPS) for SPIDER facility has been completed and will be shipped soon to Padova, Italy.
- Manufacturing of Prototype Grid for DNB Accelerator and for Prototype Post Insulators has been completed.

R&D and ITER-India Lab activities

- Prototype Cryoline installation at ITER-India lab is completed and qualification test is in progress.
- Cold Circulators installed in the Test Auxiliary Cold Box (TACB) and tested successfully in Japan.
- Commissioning of Driver stage amplifier (HPA-2) in the frequency range 35-65 MHz is completed successfully. Diacrode based final stage amplifier (HPA-3) integrated with driver stage (HPA-2) amplifier and commissioning of HPA-3 is started at ITER-India lab.
- Vacuum vessel for Diagnostic Neutral Beam (DNB) is successfully installed and commissioned with all the interface needs for Operating components at ITER-India lab.
- Prototype Grid for DNB Accelerator and Prototype Post Insulators have been tested electrically upto 140kV and mechanically beyond 10kN.
- Development of Scaled & Full scaled Residual Ion Dump Panel completed.
- Design and procurement activities for Gyrotron Test Facility at ITER-India lab is in progress.

Design and Analysis

- Preliminary Design of Cryostat Instrumentation is nearing completion.
- Final design review completed for Lot Y2 Cryolines and Preliminary Design Review completed for Lot Y1 Cryolines.
- Preliminary Design review activities of Cryoplant Termination Cold Box (CTCB) of Cryodistribution System are in progress.
- Design and optimization of radiometer and power cum frequency splitter unit for the same completed.
- Design activities for Upper Port 9 viz. Thermo-hydraulic analysis, interface detailing and EM load analysis performed.

Award of contract

- Contract for Diagnostic Neutral Beam Neutralizer and Residual Ion Dump is awarded to PVA Tepla, Germany.
- Contract for X+Z group of Cryolines is awarded to M/s Air Liquide, France.

Project Management, Quality & Safety and Infrastructure

- Detailing of ITER-India schedules was done for the ITER detailed schedule monitoring and review of integrated ITER project schedule with IO and DAs.
- Impact-coordination of the Project Change Requests (PCRs) from ITER-IO was carried out with ITER-India package members.
- Participation in Annual ITER intellectual property meeting was done to discuss IP related matters and developing IP awareness to staff within the organization & project.
- Risk Management activities were carried out viz. Identification of new risks & mitigation plans and updating of ITER-India risk register.
- Quality audits of manufacturers were carried out by ITER-India and ITER-IO teams.

Figure Diagnostic Neutral Beam (one of the in-kind deliverable to ITER Project from India) Vessel with detachable top lid configuration, successfully installed and commissioned at ITER-India lab

Figure Prototype Cryoline Installed at ITER-India Laboratory, Completion of Thermal Cycling test from 300 K to 4.5 K, three times.