Issue 097
August 2021

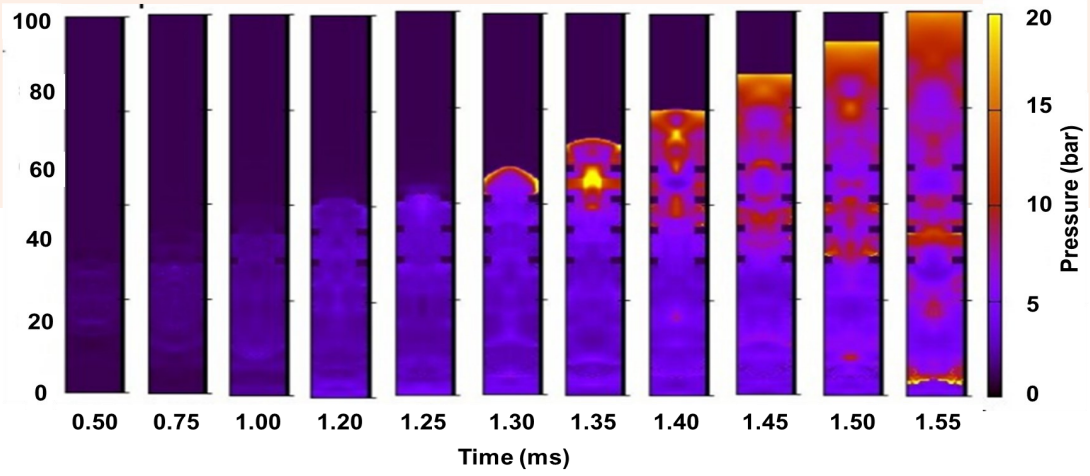
The Fourth State

Newsletter of the Institute For Plasma Research, Gandhinagar, Gujarat (India)

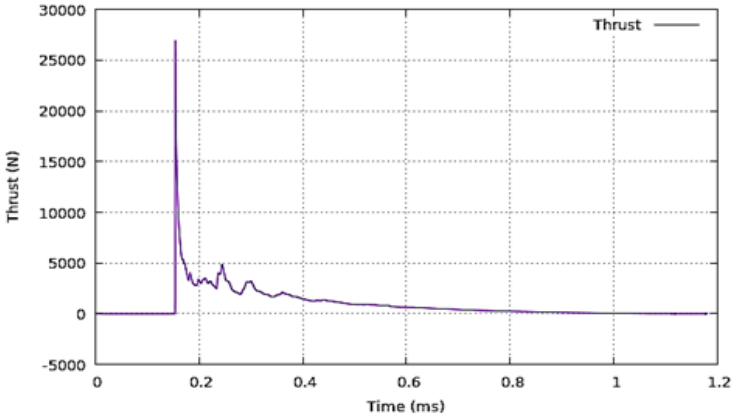
HPC Corner : Rocket Propulsion with Detonations: A Numerical Simulation Study

The rising interest in space travel has resulted in an intensifying effort from the international community to develop robust rocket propulsion systems. Combustion flames, generally seen in daily life, progress via heat conduction and mass diffusion, and are called deflagration. A shock-driven mode (Detonations) of combustion is also possible, in which high-pressure shock compresses gases and dissociates the molecules of gases leading to the ignition of a combustible mixture that rapidly releases energy in the form of the shock waves. Detonation wave moves with supersonic speed, hence there is very little time for any motion making the process nearly isochoric. This is advantageous as isochoric processes are thermodynamically efficient. Pulse Detonation Engines (PDE) is a futuristic propulsion system, aimed to tap the higher thermodynamical efficiency of the detonations. In PDE, detonations are formed in a pulsed manner by injecting a fuel-air mixture and igniting it repeatedly. Ignition is provided as a spark and detonation is formed by a process called Deflagration to Detonation Transition (DDT). With each pulse of detonation exhausting from the engine chamber, an impulse is imparted to the chamber and a push is provided to the rocket. With a high enough frequency of operation, a substantial thrust can be generated.

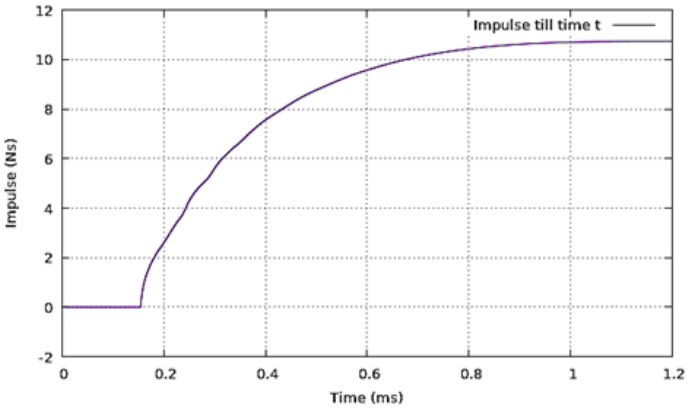
Simulations are performed to study this process using an in-house modified CFD code based on Conchas-Spray. Deflagration is started by a spark ignition, which transfers into detonation after the DDT process. Turbulences in the flow accelerate the DDT process. To enhance the level of turbulence, some blockages are also used in the chamber, which are called DDT enhancement devices. As seen in the pressure plots, initially flame propagates slowly and then the pressure at the flame front rises. The curved shock at the flame front is formed and quickly accelerates to form a fully developed detonation. Detonation wave and burnt mixture behind it exits the chamber which produces the thrust.



The deflagration flames accelerate as it move forward in the chamber, as the rate of chemical reactions increases with temperature. Further, the turbulences develop in the flow and they accelerate the flame propagation.



Magnitude of time dependent thrust during the exhaust process. Thrust remains zero till the detonation wave is away from the open end and then a sharp peak appears when shock front crosses the open end. Sharp peak also signifies that the shock front is spatially very thin.

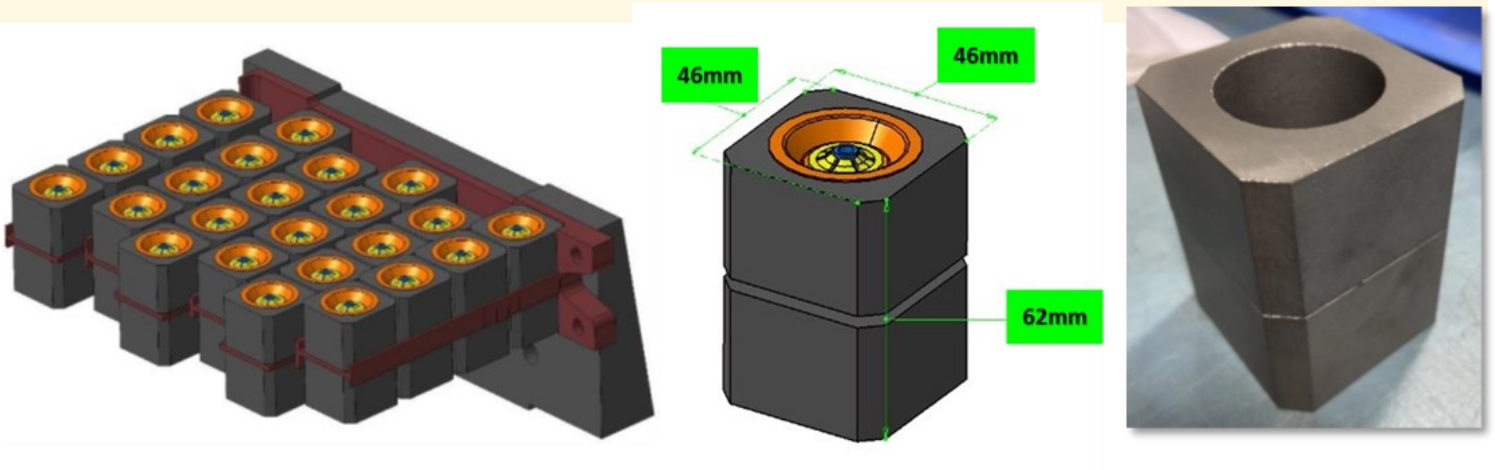


Impulse imparted to the rocket till time ‘t’. Impulse remains zero before the exhaust starts. It becomes constant when all the burnt products exit the chamber and chamber returns to initial ambient conditions of temperature and pressure.

Development and Qualification of the Radiation Shielding Ceramics by ITER-India

Shielding against the Neutrons produced by nuclear reaction is the major concern for ITER during D-T operations. Common neutron moderators are graphite, ordinary water and heavy water which can't be used in large quantities due to French regulations. The other options iron, concrete or graphite are also become out of the list due to its heavy weight as the total weight of each ITER port should not exceed 48 tons in fully equipped condition. Hence Boron Carbide (B4C) material has extensive potential to be used as Neutron shielding to protect system/equipment/human from the high energy neutrons.

Boron Carbide has been proposed for the use in the Diagnostic Shield Module (DSM) for the Diagnostic ports of ITER tokamak. The design, manufacturing, supply and commissioning of all components contained within the Upper Port # 9 (UP#09) is in the scope of India. Hence procurement of DSM material as per ITER requirement is part of this Procurement Arrangement (PA).



(Left and Middle) DSM design for UP#09 (Right) Final product B4C unit cell for UP#09 DSM

Boron Carbide is readily available in powder form in the Indian market however in case of ITER, due to the vacuum rules B4C powder can't be used for shielding hence it needs to be converted into plates/blocks/pellets for design of shielding. ITER -India started prototype activities for the development of hot pressed boron carbide blocks/pellets, instead of importing this ceramic from outside. ITER-India with the support of an Indian Industry, has demonstrated the manufacturing capability for large scale, vacuum-hot pressed blocks/pellets with machining feasibility for the final product. Development activities have been carried out as per ASTM C750 (Nuclear Grade Boron Carbide Powder), ASTM C751 (Boron Carbide blocks/pellets) and other stringent requirements of ITER. The B4C blocks/pellets have been fabricated in vacuum at high temperature range of 2050-2100 °C and high pressure ~30MPa.

(Left and Middle) : Samples of Boron Carbide blocks and pellets (Right) Final product B4C unit cell for UP#09 DSM

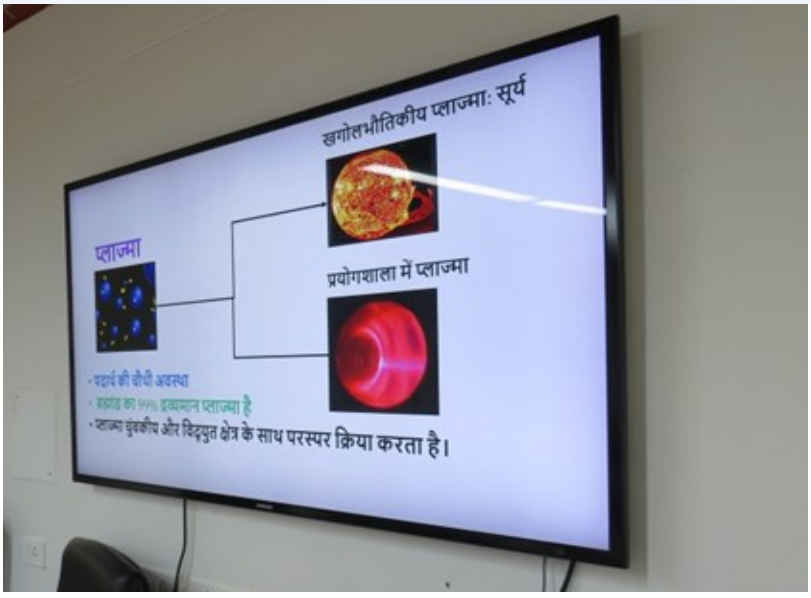
To qualify this material as per ITER requirements, its chemical composition, mechanical, thermal, physical properties are studied and validated. Scanning Electron Microscopy (SEM) studies conducted to calculate the grain size in microstructure.

One of the key challenge in qualification of this material is the out-gassing rate as it is to be used in ultra-high vacuum environment in ITER Ports and having very large surface area. In addition to B4C sample blocks and pellets, the out-gassing rate of B4C final product is also determined in IPR Vacuum Calibration Lab's out-gassing test facility. Special cleaning, pre-baking at 1000 ℃ in vacuum as per ITER Vacuum Handbook requirements has been implemented before installation of the samples in the out-gassing testing facility. The achieved outgassing rate ≤ 1 x 10^{-8} Pa $m^3s^{-1}m^{-2}$ at 100 ℃, fulfils the requirements derived for the ITER ports as well as vacuum hand book. The process of hot-pressing used in development of this ceramic doesn't include any sintering aids and additives hence it is the unique hot pressing method which is one of the reason to achieve the stringent outgassing requirements for ITER.

This successful development and qualification of the radiation shielding ceramics was carried out by the ITER-India Diagnostic Group.

तकनीकी के साथ, विज्ञान की बात

''तकनीकी के साथ, विज्ञान की बात'' कार्यक्रम का पहला व्याख्यान दिनांक 30.06.2021 को वर्चुअली आयोजित किया गया, जिसमें एलवीपीडी अनुभाग के डॉ. रितेश सुगंधी, वैज्ञानिक अधिकारी-जी ने ***विशाल आयतन प्लाज़्मा डिवाइस का कंप्यूटरीकृत संचालन एवं नियंत्रण (Computerized Operation and Control of Large Volume Plasma Device)*** पर बहुत की विस्तार से चर्चा की। डॉ. रितेश सुगंधी ने इस महत्वूर्ण और जटील विषय पर बहुत सरल और आसान हिंदी में चित्र सहित पवर पॉइंट प्रस्तुतिकरण दिया। उन्होंने वर्ष 1997 से प्रांरभ इस प्रणाली की सृजन यात्रा को व्यापक रूप से समझाया और वर्तमान में कंप्यूटर से संचालन एवं नियंत्रण की प्रक्रिया पर भी चर्चा की। उन्होंने विश्व भर में मूलभूत प्लाज़्मा अनुसंधान के बारे में जानकारी देने के साथ आईपीआर में एलवीपीडी पर किये जा रहे प्रयोगों का विस्तार से उल्लेख किया एवं प्लाज़्मा ऊर्जा, कण परिवहन की जांच, तरंग प्लाज़्मा अध्ययन और खगोलीय भौतीकीय घट्नाओँ पर भी चर्चा की। कार्यक्रम के अंत में श्रोताओं की शंकाओं का समाधान किया।



विश्व पर्यावरण दिवस - 2021

विश्व पर्यावरण दिवस - 2021 के अवसर पर गुजरात पर्यावरण प्रबंधन संस्थान (GEMI) द्वारा काव्य-लेखन प्रतियोगिता का आयोजन किया गया था। यह प्रतियोगिता सभी के लिये खुली थी एवं इसे हिंदी, गुजराती एवं अंग्रेजी तीनों भाषाओं में अलग-अलग आयोजित किया गया था। इस प्रतियोगिता में प्लाज़्मा अनुसंधान संस्थान के श्री रजनीकांत भटासणा, वैज्ञानिक सहायक - सी ने हिंदी काव्य लेखन में भाग लिया। काव्य-लेखन प्रतियोगिता का परिणाम 25 जून को घोषित किया गया, जिसमें श्री रजनीकांत ने दूसरा स्थान प्राप्त किया है। पुरस्कार के रूप में इन्हें 3000 रुपये नकद एवं प्रमाण पत्र प्राप्त हुआ है। इस उपलब्धि के लिये इन्हें हार्दिक बधाई।


Forests & Environment Department
Government of Gujarat

REIMAGINE RECREATE RESTORE

GEMI
Gujarat Environment Management Institute (GEMI)
(An Autonomous Institute of Government of Gujarat)

Poetry Competition

WORLD ENVIRONMENT DAY
5th June, 2021

Certificate

This is to Certify that
Mr. Rajnikant Bhatasana
has secured Second position in Poetry Competition in Hindi language organized by the Gujarat Environment Management Institute (GEMI), Gandhinagar.
The Institute wishes him/her a best of future.

(A.K. Jha, IFS)
PCCF & Director

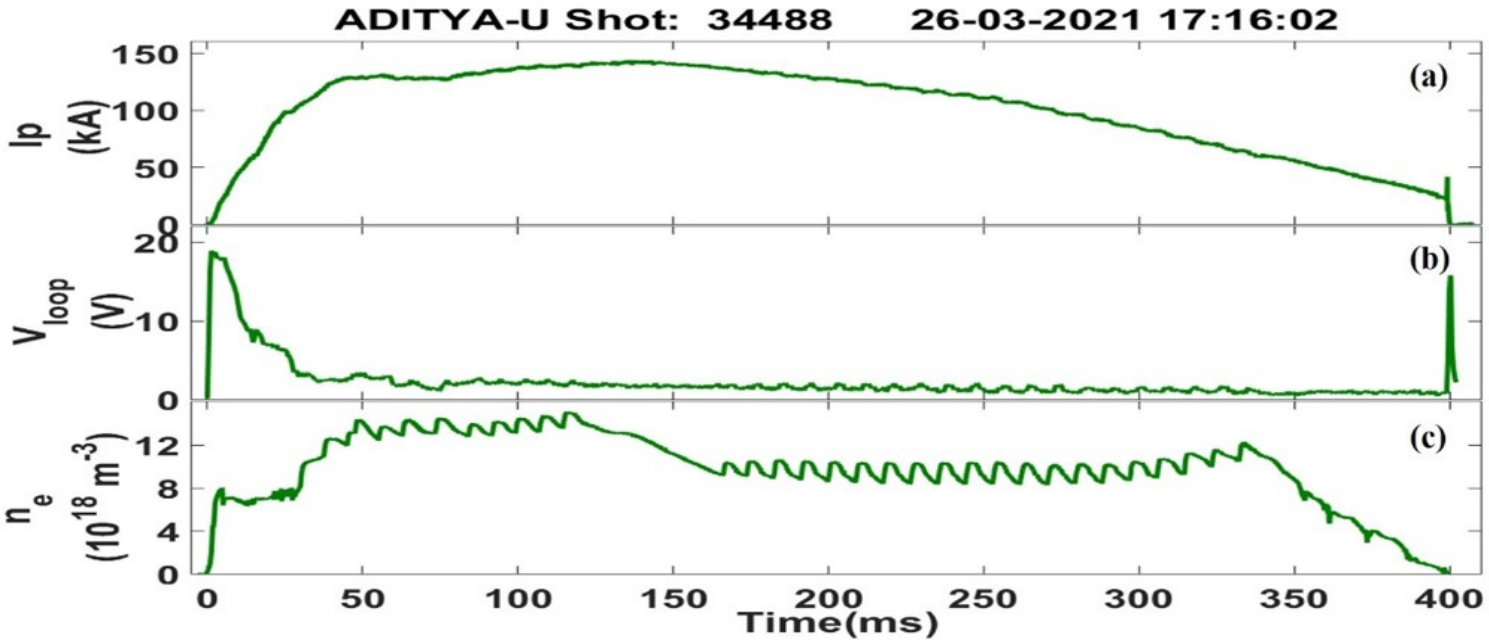
We Provide Environmental Solutions

Date of issue: 6th July, 2021
Certificate no.: GEMI/e-Contest/06/1/05

Note: This is the digital Certificate issued by Gujarat Environment Management Institute based on details submitted by participant.

Aditya-U Update : Plasma Pulse Length Enhancement ~ 400 ms

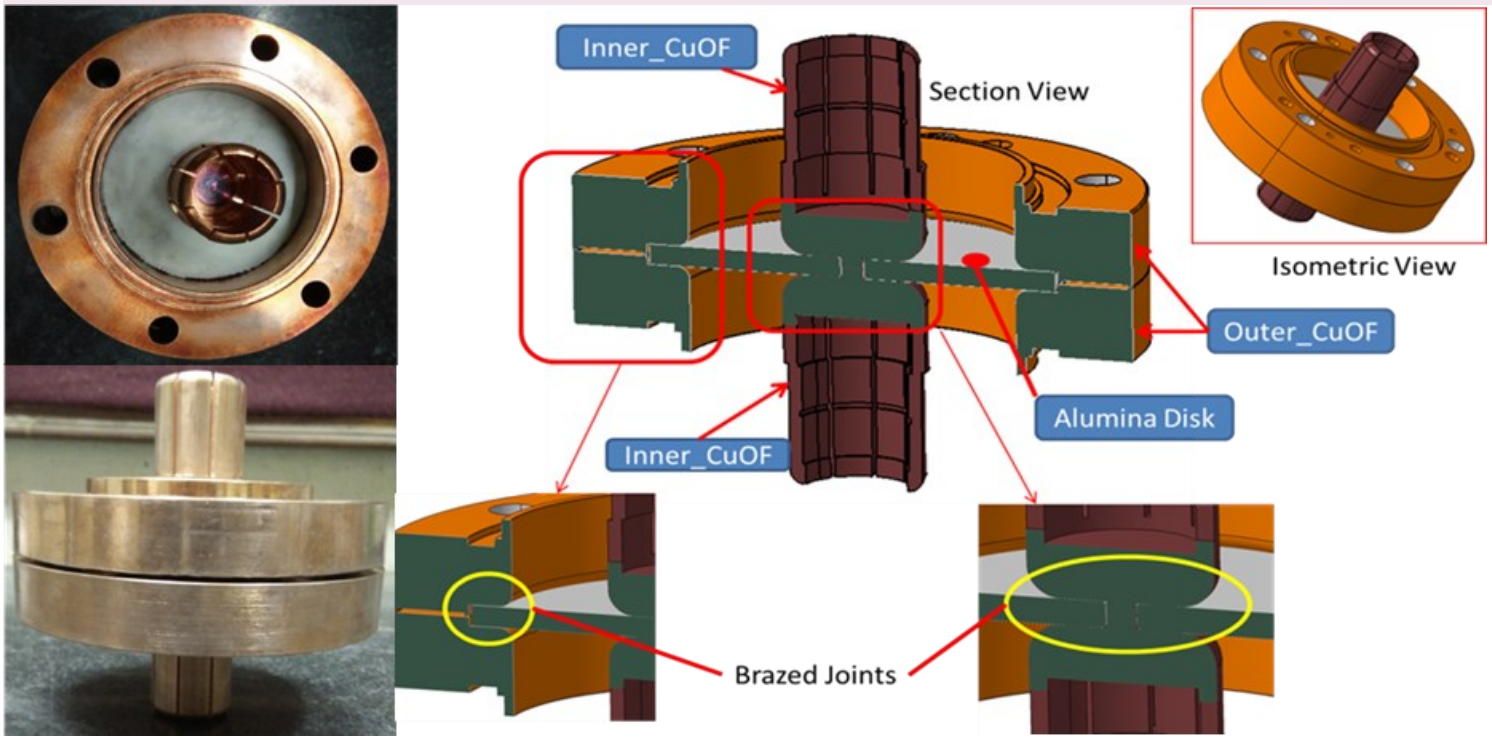
The plasma current pulse length enhancement of the order of ~ 400 ms has been achieved for the first time ever in ADITYA-U using negative convertor power supply operation. The time traces of a typical ADITYA-U discharge (#34488) parameters as shown in Fig. 1 represents plasma pulse length enhancement. Note that the plasma density remained flat up to ~ 340 ms. Substantial reduction in wall recycling and impurity influx along with robust control of real-time horizontal plasma position control leading to utilization of maximum available *vs* and produced longest discharge ever in ADITYA-U.



Time traces of ADITYA-U shot (#34488) parameters (a) Plasma Current (kA), (b) loop voltage (V) and (c) Chord averaged electron density (ne) (m-3).

RF Technology: Indigenous Development of Vacuum Barrier

A vacuum barrier is used in fusion machines and accelerators to deliver RF power from generators to systems operated in high vacuum. It also provides high voltage isolation between the inner & outer conductors of RF coaxial conductors. Such barriers, used in a brazed configuration with Alumina as an isolator, are not commercially manufactured in India as they must be made to specific design & functional needs. This necessitates import of costly barriers (Rs.10-12 Lakhs/piece). Such a barrier, developed indigenously in association with NFTDC, comes at half the price of the imported product. Additionally, this development provides confidence in achieving the similar brazed ceramic-to-metal assemblies in other applications like accelerators.



Configuration of Indigenously developed Vacuum Barrier

Adieu to Retiring Employees

Three employees of IPR superannuated from service on 30-June, 2021. **Shri R. T. Pandya** (Office Assistant-C, Date of Joining : 20-Dec-1989), **Shri B.K.B.S. Rao** (Purchase Officer-II, Date of Joining : 27-Nov-1996) and **Shri Mangesh Vartak** (Dy. Officer (Admin), Date of Joining : 13-Oct-1988). While Shri Pandya and Shri Vartak were with the IPR Administration, Shri Rao was with the IPR Purchase section.

On behalf of all the staff members of IPR, FCIPT, ITER-India and CPP, we thank them for their dedicated services to IPR and wish them a happy, healthy and fruitful retired life.

(L-R) Shri R T Pandya, Shri B K B S Rao Shri Mangesh Vartak who retired on 30-June-2021

Tree Plantation Drive @ ITER-India

A Tree Plantation drive was held by staff members of ITER-India around the open space available adjacent to Sangath Skyz building on 24th June, 2021 with the aim to keep the surrounding area clean and green. The objective of the program was to create awareness among the staff members regarding the importance of ecology and the natural environment.

Tree Plantation Drive @ ITER-India









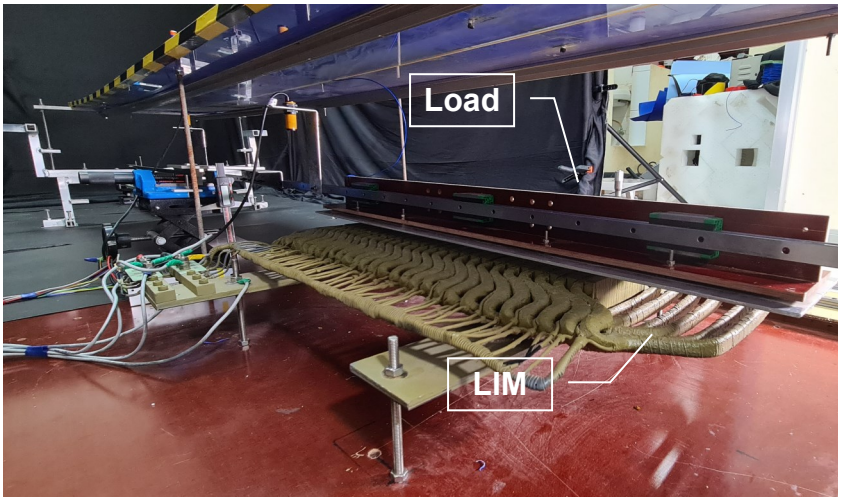
Images from the tree-planting drive organized at the ITER-India office premises.

R&D in Electromagnetic Acceleration Systems @ IPR

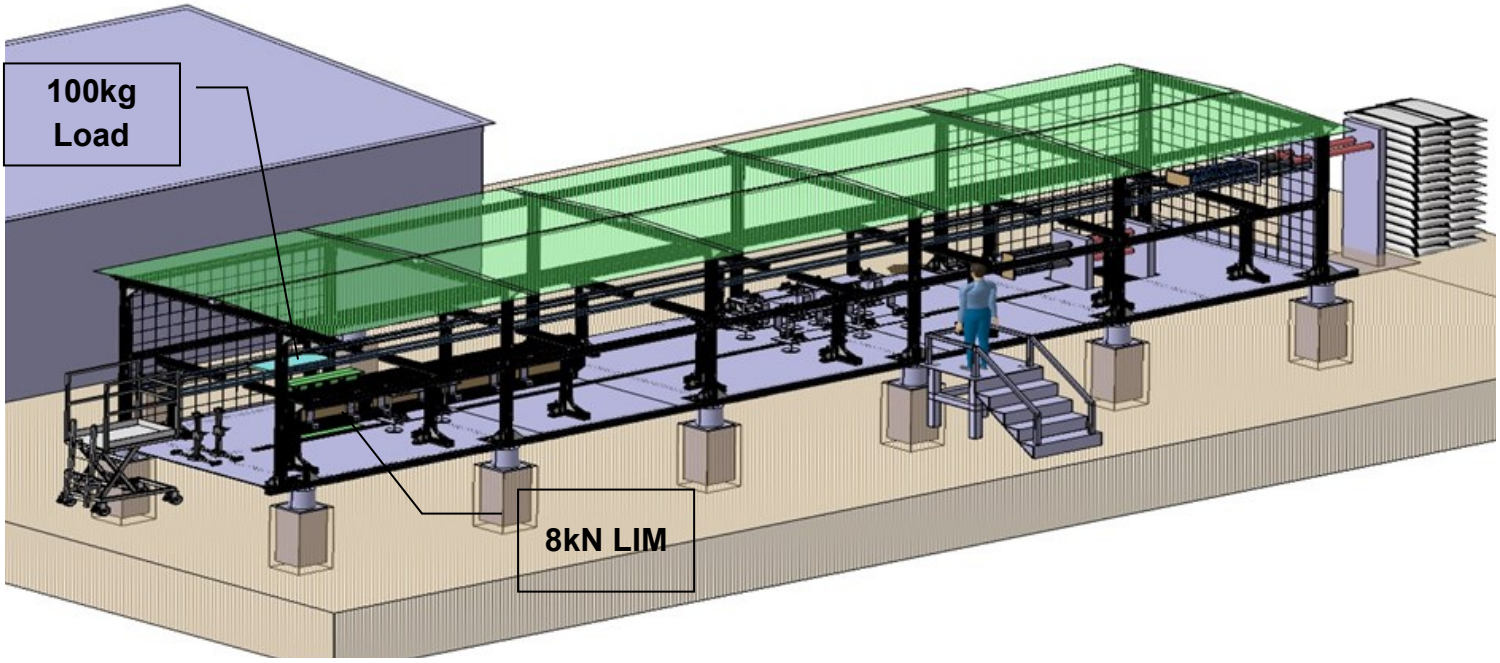
Linear Induction Motors (LIM) are one of its kind that can produce sizeable thrusts in linear direction, using normal three phase utility power. Non-contact acceleration of heavy metallic objects with reasonable velocity, easy braking and direction reversal by interchanging two phases are its main advantages. The LIM consists of a stator with a poly-phase winding on a laminated core and a rotor (Load) which is a conducting sheet placed at certain air-gap over the core.

Electromagnetic acceleration systems based on LIM are of particular interest in research (Reciprocating probes, Liquid metal stirrer etc.) and have various applications in industry as well (conveyer belts, mass transit systems etc.).

Magnetics & Dynamics Section is working on development of LIM based Electromagnetic acceleration system with a target to accelerate ~100kg load to 20m/s velocity. A prototype for design verification has been developed and tested, which has accelerated a mass of ~2kg (including a toy airplane) to 7m/s. In the planned experiment, there will be four double sided LIM sets of total ~5 m long. The load position and velocity data will be acquired along the travel length. Excitation of LIM sets would be synchronized with the position of the load, with the help of data acquisition and control system. Spring based absorbers would take away the kinetic energy of the load at the end. The estimated realization of the project is Sept 2022.



(L) The prototype system showing the LIM and the load (R) The model aircraft being launched using the system

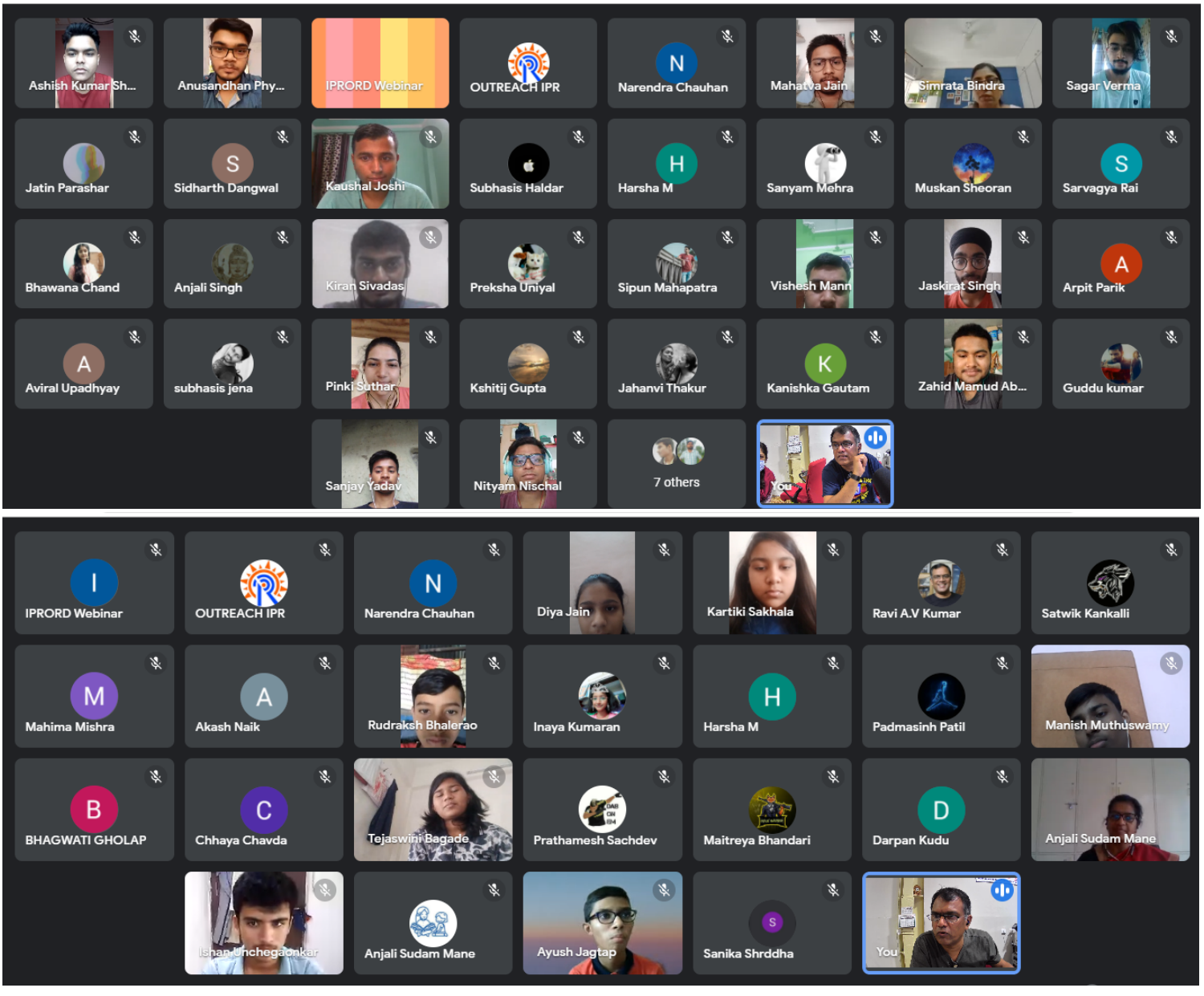


An artist's view of Electromagnetic Acceleration Experimental setup

IPR Outreach Activities

With the onset of academic sessions in schools and colleges, IPR outreach webinar programmes also have begun. The programmes conducted during the month of July, 2021 are given below.

Date	Institution	Programme	Participants
13-14 July, 2021	Department of Physics, Marwadi University, Rajkot	2-day, 4hour webinar Plasma & its applications for BSc/MSc students	32 students of BSc Physics and 2 teachers
19-20 July, 2021	Department of Physics, Motilal Nehru College , New Delhi	2-day,4 hour webinar Plasma & its applications for BSc/MSc Physics students	56 students of BSc Physics and 10 teachers
23-July, 2021	Shivneri School, Khanapur, Pune	1-day, 2 hour webinar Plasma & its applications for class 11-12 students	39 students of class 11 and 12 and 2 teachers



Students of (Top) Motilal Nehru College, new Delhi and (Bottom) Shivneri School, Pune attending the webinar.

The webinar lectures in progress

Past Events @ IPR

- ***Talks presented at 2nd International Conference on Advances in Plasma Science and Technology (ICAPST-21), Sri Shakthi Institute of Engineering and Technology, Coimbatore, 27-29th May 2021***
  - *"Spatial variation of plasma parameters in a pulsed plasma accelerator"* by Sumit Singha
  - *"Design of the time-of-flight low-energy neutral particle analyzer for Aditya-U Tokamak"* by Snehlata Aggarwal
- ***Ms. Bhoomi Sandip Gajjar,*** gave a talk on "*Development and Qualification of Shielding Material (B4C) by IN-DA*" at 39th Meeting of the ITPA Topical Group on Diagnostics, Korea Institute of Fusion Energy, Daejeon, Korea, 31 May - 3 June 2021
- ***Dr. Sudhir Kumar Nema,*** gave an invited talk on "*Solid Waste Management using Environment Friendly Thermal Plasma Technology*" at ATAL Faculty Development Program on "Emerging Technologies for Sustainable Environmental Management" on 2nd June 2021
- ***Ms. Bharathi Magesh,*** gave a talk on "*Diagnostics progress of IN-DA*" at 39th Meeting of the ITPA Topical Group on Diagnostics, Korea Institute of Fusion Energy, Daejeon, Korea, on 3rd June 2021
- ***Mr. Darpan Bhattacharjee,*** SRF, CPP-IPR, gave a talk on "*Particle-in-cell Simulation of Plasma Species in an Inertial Electrostatic Confinement Fusion Device at High Voltage Operation*" at National Conference on Emerging Trends in Physics (NCETP-2021), Tezpur University, Assam, on 16th June 2021
- ***Talks presented at 47th Conference on Plasma Physics by European Physical Society, 21-25 June 2021***
  - *"The study of unconventional boundary driven mechanism for generating magnetic field"* by Devshree Mandal
  - *"Landau damping in 1D periodic inhomogeneous collisionless plasmas"* by Sanjeev Kumar Pandey
  - *"Effect of Ion Population in a Toroidal Electron Plasma"* by Swapnali Khamaru
  - *"Sheet simulation of upper-hybrid oscillations in an inhomogeneous cold plasma in the presence of inhomogeneous magnetic field"* by Nidhi Rathee
  - "*Effect of external plate biasing and diverging magnetic field on radial characteristics of a back-diffused plasma column*" by Satadal Das
  - *"Can a small fraction of mass inhomogeneity decide the fate of Rayleigh-Benard convection cells in 2D Yukawa liquids?"* by Pawandeep Kaur
  - "*Lower Hybrid Heating in Laser Plasma Interaction"* by Ayushi Vashistha
- ***Dr. Mukesh Ranjan,*** gave an invited talk on "*Nanopatterning induced Surface Wettability and its Applications*" at E-Workshop on Energetic Beam Technology: From Materials Engineering to Diagnostics, Amity Institute of Nanotechnology, Uttar Pradesh, on 22nd June 2021
- ***Dr. Anuj Ram Baitha,*** Indian Institute of Technology, Kanpur, gave a talk on "*Production and study of a plasma confined in a dipole magnetic field and Studies on plasma diffusion and transport using probe and optical diagnostics*" on 23rd June 2021
- ***Dr. Mayank Rajput,*** gave a talk on "Radiation *damage in fusion reactor materials (DI BSCCO superconducting tape and Beryllium)*" on 25th June 2021
- ***Dr. Praveen Devangad,*** Manipal Academy of Higher Education, Karnataka, gave a talk on "*Study of Laser Induced Plasma Spectroscopy coupled with machine learning methods for various analytical applications*" on 25th June 2021
- ***Mr. Vinay Menon,*** gave a talk on "*CHF and OFI Experiments at the High Heat Flux Test Facility at IPR*" at IAEA Technical Meeting on Advances in Numerical and Experimental Analysis of Critical Heat Flux in Rod Bundles, on 30th June 2021
- ***Dr. Anirban Polley,*** National Centre for Biological sciences, Bangalore, gave a talk on "Soft *Matter Physics with emphasis on Biological systems*" on 1st July 2021 (Colloquium # 303)
- ***Dr. Rasila Hirani,*** SVNIT, Surat, gave a talk on "*Design, Optimization and Fabrication of Leaky Mode Plasma Antenna for Wideband Application at 2.45 GHz*" on 2nd July 2021
- ***Dr. Paramita Maiti,*** Institute of Physics, Bhubaneswar, gave a talk on "*Molecular Beam Epitaxy (MBE) grown Molybdenum Oxide Nanostructures: Growth, Characterizations and Applications*" on 9th July 2021
- ***Mr. Pranjal Singh,*** gave a talk on "*Study of In Situ Measurement of Work Function and Caesium Dynamics*" on 15th July 2021
- ***Dr. Deepa Verma,*** gave a talk on "*THz radiation generation during laser plasma interaction*" on 19th July 2021

Know Your Colleagues

Mr. Manoah Stephen M joined IPR as a TTP in 2008 and was subsequently appointed as Engineer - SC in Vacuum Vessel (VV) and Cryopump Division in 2009. He holds a Bachelor's degree (Mechanical) from Anna University and an M.S. degree from HBNI. In the initial years of his career, he was responsible for the design, optimization, analysis of sub-components, integrated system of cryopump, and welding analysis to optimize the parameters by sensitivity studies on VV coupons. Further, he was involved in the R&D into borated steel machining and HAZ studies for shielding materials. He was deputed to CCFE, UK, as an Analyst were, he successfully executed and completed the CDR of in-vessel ELM coils. He has also successfully executed and completed a CDR of the ITER-IO task agreement (Concept Design and System Analysis of the Multi-Purpose Deployer). Currently, he is with the Remote Handling and Robotics Technology Development Division (RHRTD). His areas of expertise include static structural, MBD, structural topology optimization, modal, response spectrum, seismic, welding analyses, and conceptual design & development of RH systems (light & heavy payload) for fusion machines for high temperature and high vacuum application. As a part of academics, He has supervised several graduate and postgraduate engineering students.

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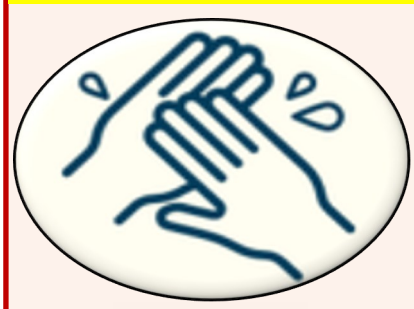
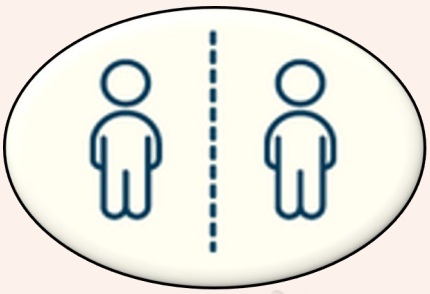
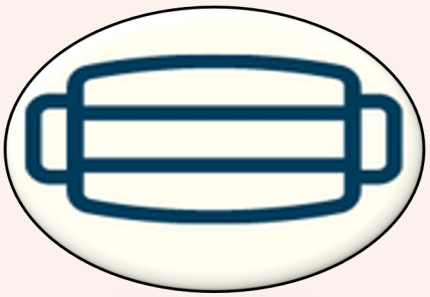
Help Fight The Covid-19 Pandemic



Wash Your Hands frequently With Soap



Ensure Social Distancing At ALL times



Always WEAR a Mask When you go outside

- Avoid touching your eyes, nose and mouth
- If you have fever, cough and difficulty in breathing, seek medical care early
- Stay informed and follow advice given by your healthcare provider
- Inform Office immediately if you or any family member tests positive
- Follow SMS - **S**ocial Distancing : **M**ask : **S**oap/ Sanitizer
- Strictly follow social distancing while outdoors, especially at work.

Please get yourselves vaccinated against Covid-19

कृपया अपने आप को कोविड -19 के खिलाफ टीकाकरण करवाएं

For your safety and for the safety of your co-workers, ensure that you always use Arogya Setu App

The IPR Newsletter Team

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