

PRINCETON PLASMA PHYSICS LABORATORY

WEEKLY highlights



The PPPL Highlights for the week ending December 12, 2014, are as follows:

U.S. ITER FABRICATION (D. JOHNSON):

Three port plug related meetings were held this week in Cadarache, France. The Generic Diagnostic First Wall was reviewed in a Final Design Review, with one class 1 chit - to complete an ongoing prototype prior to closeout.

This diagnostic first wall final design effort, featuring work done jointly by a team at PPPL, lead by D. Loesser, and the ITER Organization, was recognized in an ITER Improvement Ceremony at the IO.

A one-day Diagnostic Shield Module Workshop was held with participation by the IO and all the DAs producing port plugs, and highlighted the challenges facing the designers of these components, and several different concepts for addressing these issues.

In addition, a System Integration Review was held for the US Equatorial Port Plug 9. This review highlighted the latest designs for the integration of the various tenants in the plug, and reported no major clashes. The integration team at PPPL is led by R. Feder.

NSTX (M. ONO):

The paper "Erosion of lithium coatings on TZM molybdenum and graphite during high-flux plasma bombardment" by T. Abrams (formerly Princeton U., currently General Atomics) et al., was published in Fusion Engineering and Design 89 (2014) 2857–2863. This paper is based on experiments conducted at the Magnum-PSI linear plasma device at FOM-DIFFER in the Netherlands. One key finding of the work was that under the divertor-like plasma conditions in the Magnum-PSI device, the total erosion yields derived from optical emission spectroscopy and Thomson scattering measurements were found to be much lower than might be calculated from Langmuir-law evaporation into vacuum. These latter evaporation rates have long been used as a baseline for estimating temperature limits of liquid lithium PFCs and these new measurements indicate those temperature limits may require revision.

On December 8-10, S. Kaye and R. Maingi of PPPL participated in the ITPA Coordinating Committee Meeting at ITER Headquarters in Cadarache, France. The purpose of the meeting was multi-fold, and it included updates to the ITER Research Plan and system development, Annual Reports and Plans by each ITPA Topical Group, reports by each ITER Partner on their programs to address ITPA needs, a discussion among program representatives to indicate the

level of their commitment to each ITPA Joint Experiment and Activity, and finally a discussion of other items. Maingi, Chair of the Pedestal Physics ITPA Topical Group gave a summary of past year work and next year plans, and Kaye gave an overview of the new U.S. DOE data sharing guidelines that will impact collaborations between U.S. and non-U.S scientists.

J.-W. Ahn (ORNL) visited Professor Masahiro Kobayashi, NIFS, Japan, December 8-12, and led an experiment on LHD for the effect of RMP on divertor footprints and divertor plasma characteristics. Measurements of divertor strike line heat flux were made using the IR camera for the first time in LHD, and a systematic variation of density, NBI power, and RMP phase was performed. Initial data showed that applied $m/n=1/1$ RMP fields significantly altered footprints pattern mainly in the helical direction, and no strike line splitting in the poloidal direction was observed unlike the case in tokamaks. High collisionality condition produced plasma response leading to penetration of RMP fields and the growth of islands, for which enhanced asymmetry of heat flux footprints in the helical direction was observed. This data is consistent with the present understanding of the role of plasma response in island formation and edge stochastization.

Peter Beiersdorfer of the Lawrence Livermore National Laboratory (LLNL) visited NSTX-U for discussions with PPPL personnel and onsite LLNL collaborators. Spectrometers that cover three spectral ranges at extreme ultraviolet (EUV) wavelengths have arrived from LLNL for NSTX-U, and details of installing them were reviewed. There was also a discussion of the layout of a laser blowoff system from LLNL for impurity transport studies. The laser will be located in an enclosure outside of the NSTX-U Test Cell (NTC) for convenient access when NTC entry is not permitted. The laser will be directed to a compact chamber on NSTX-U with a target array that enables impurity injection at multiple times during a single discharge.

ITER & TOKAMAKS (R. HAWRYLUK):

R. Hawryluk participated in the ITPA Coordinating Committee and CPT meetings in the IO Headquarters. He then participated the ITER External Management Advisory Committee meeting.

DIII-D (R. Nazikian):

R. Maingi represented the 2014 work of the ITPA Pedestal and Edge Physics Topical Group at the ITPA Coordinating Committee meeting in Cadarache, France. Several DIII-D contributions were highlighted, including ones with substantial PPPL leadership and participation, e.g. the work on $n=2$ rotating fields used for the physics of ELM suppression, and ELM pacing with Lithium granule injection.

A one-day experiment led by PPPL staff (A. Bortolon, E. Gilson, B. Grierson, R. Maingi, D. Mansfield, A. Nagy, L. Roquemore) was run on DIII-D, with the goal to assess the ability to trigger ELMs by controlled injection of Lithium pellets. Substantial contributions were made by on-site DIII-D staff from GA, LLNL, and ORNL. The experiments successfully demonstrated ELM pacing in H-mode using granules of 0.3 and 0.5 mm nominal diameter, injected at approximately 110 m/s, with close to 100% ELMs taking place in response of Li granule ablation events. The granule ablation was recorded by a fast color camera aligned with the injection axis.

During LGI injection phases, a four-fold increase of ELM frequency could be obtained, with a concurrent decrease of the divertor peak heat flux. No degradation of plasma performance associated with the LGI operation was observed. A second experimental day is being prepared to extend the results to 0.7 and 0.9 mm nominal diameter granules.

LGI corrective maintenance task was successfully completed. The granules from the old hopper were recovered, sifted, and reloaded. In addition, granules from the LGI dropper catcher attached to the LGI were recovered, an unexpected bonus. All of the available granules sizes were loaded into the new dropper hopper installed this past weekend. The next experiment with LGI is presently scheduled for December 17.

W. Solomon co-led a joint experiment between DIII-D and EAST with Guosheng Xu (ASIPP), aimed at exploring high performance inductive operation with $q_{min} > 2$ and reduced torque. The recent experiments extended the previous high beta P non-inductive regime to significantly higher normalized fusion performance at higher (inductively-driven) current (0.8 MA) and demonstrated high confinement $H_{89} \sim 3.6$ with $\beta_N \sim 3.2$ and an ITB at large minor radius $\rho \sim 0.7$.

C-Mod (R. Hawryluk):

Assembly and alignment of the MSE background polychrometer is complete. Fabrication of all filter-heater assemblies and the control/instrumentation box is complete. Integration of the control/instrumentation system with the polychrometer assembly and integrated testing will begin the week of December 15.

F. Poli gave the PSFC Colloquium on Friday entitled "Secrets of ITER revealed by advanced modeling". This talk summarizes the main results of her work on steady state exploration: (a) ITER will need LH to achieve its goals, (2) a combination of EC and LH is compatible with the ITER goals and (3) the combination of the HCD sources and the ramp-up evolution are crucial for the access to steady-state and high performance discharges.

Poli worked with P. Bonoli and with the LH group on the analysis of discharges with TRANSP for validation of LH codes in time dependent, free-boundary simulations, and on methods to reduce uncertainties in the calculations through cross-validation between diagnostics and simulations.

ADVANCED PROJECTS (D. GATES):

D. Gates and N. Pablant traveled to IPP-Greifswald, Germany to meet with the W7-X assembly team and discuss the installation of the PPPL built XICS diagnostic. The meeting was very successful and there was general agreement that as long as the planned delivery schedule of the diagnostic is met that there would time to install it on W7-X. Installation work will be performed during the third shift, but IPP will provide technical support as necessary. The final delivery of parts for the XICS diagnostic is currently planned for April 2015. There were numerous other discussions held about the role of U.S. scientists during the upcoming initial operation of W7-X.

THEORY (A. BHATTACHARJEE):

On December 9-11, the Theory Department hosted an informal workshop on the PIC method of simulation of the electromagnetic gyrokinetic equation system, focusing in particular on the so-called "cancellation problem" that arises at large spatial scales. High quality talks by our guests and our own department members as well as vigorous audience involvement and discussion made this an interesting and engaging several days. In more detail: Alexey Mishchenko from the Max Planck Institute for Plasma Physics (IPP) Greifswald, Germany presented on how to model global electromagnetic modes with gyrokinetic codes, focusing on algorithmic development in the Gygles and Euterpe codes that has allowed the simulation of previously inaccessible parameter regimes, including the $n=1$ internal kink mode. Dovetailing with this, Roman Hatzky of the IPP Garching then discussed the reduction of the statistical error in electromagnetic PIC simulations. These two talks focused in on the two algorithms used to mitigate the cancellation problem in the IPP codes. Yang Chen (University of Colorado-Boulder) presented on challenging problems with kinetic electrons, describing how the cancellation problem arose in many different formulations of the electrons. The key to mitigating the problem was consistent evaluation of the large, equal skin-term and adiabatic current terms on both the left-hand and right-hand side, which required an iterative evaluation via a sum over the markers at each timestep. E. Sonnenduecker presented the variational Monte Carlo PIC-Finite Element discretisation of the gyrokinetic equations, focusing in on an alternate view of the mathematical foundations underlying the PIC method as a Monte Carlo evaluation of the density and current moment integrals, combined with a finite-element representation for the fields. E. Startsev discussed gyrokinetic simulation of the tearing mode instability, presenting his recent successful simulation of tearing modes in cylindrical geometry, using an analytical evaluation of the grid error in evaluation of the adiabatic current to modify the skin terms on the left-hand side and achieve the necessary consistency to simulate the modes. C.S. Chang discussed verification of the E&M capabilities for gyrokinetic ELM simulation in XGC1: focusing in on the one hand on the many needs and challenges of simulating the edge and SOL of the tokamak, and on the other hand on the current approach for electromagnetic simulation in XGC1 via treating the electrons as a fluid but the ions as gyrokinetic. A significant fraction of the workshop time was left for open discussion, which led to concrete plans for further collaboration, especially in the area of inter-code comparisons for benchmarking.

A. Bhattacharjee, W. Fox, and collaborators at the University of Rochester Laboratory for Laser Energetics obtained a renewal of the National Laser User Facility proposal, "Dynamics of Magnetic Reconnection and Instabilities of Current Sheets in High-Energy-Density Plasmas". The project will support ongoing research on laboratory astrophysics with colliding laser-produced plasmas led by Fox and Bhattacharjee. The grant will fund research in the Princeton Department of Astrophysical Sciences and includes shot time on the OMEGA EP Laser Facility at the University of Rochester in FY15 and FY16. The program is funded through the DOE NNSA.

PLASMA SCIENCE AND TECHNOLOGY (P. EFTHIMION):

Five members of PS&T Department (P. Efthimion, K. Hill, H. Ji, I. Kaganovich, and W. Fox) visited Sandia National Laboratories on December 12. Hill and Fox presented a seminar on

recent high energy density laboratory plasmas (HEDLP) activities at PPPL. The PPPL group had very productive discussions about recent MagLIF experiment at Sandia.

C. Myers successfully defended his PhD on December 5. He designed, built and carried out a new, exciting experiment on solar flare physics. The central result of his thesis is the first identification of toroidal field forces, which are traditionally neglected in the analysis of coronal flux ropes, for the equilibrium and the stability of line-tied flux ropes. By measuring the $j \times B$ force in his flux rope plasma, he showed that a tension force derived from a self-generated paramagnetic toroidal field exerts a restoring force on the line-tied plasma and suppresses eruptive behavior in a significant portion of the parameter space. These results propose a new condition for the prediction of line-tied magnetic flux rope eruptions and could lead to a new paradigm in the solar physics research.

The PS&T Department seminar was presented by He-Ping Li from Department of Engineering Physics, Tsinghua University, Beijing, China on "Application-Oriented Research on Atmospheric Gas Discharge Plasmas in Plasma Health Sciencetech Group". Abstract of the talk was "In recent years, research on atmospheric-pressure gas discharge (APGD) plasma sources driven by different types of power supplies with frequencies ranging from 0 (direct current) to gigahertz (microwave) has attracted much attention of the scientists and engineers. The unique features of the APGD plasmas with lower capital cost, operation flexibility and non-limitations on the sizes of treated materials would create many novel applications, e.g., plasma bio-medical science and technology, waste treatment, gas purification and PM2.5 removal, etc. In this presentation, the recent application-oriented research concerning the atmospheric DC arc thermal plasmas, kilohertz driven warm plasmas and RF glow discharge plasmas in the Plasma Health Sciencetech Group (PHSG) are presented, including the studies on the fundamental processes in the plasma systems and their applications, e.g., the genome mutation of industrial microbes and plants using the RF APGD plasma jets."

ENGINEERING AND INFRASTRUCTURE (M. WILLIAMS):

NSTX Upgrade (R. Strykowski, E. Perry, L. Dudek, T. Stevenson):

The NSTXU project conducted a Readiness for Operations review the week of December 8th, 2014. The review panel was composed of outside experts experienced with the startup and operation of similar devices. We were encouraged that the review panel concluded that NSTX processes were in place to ensure a safe startup after machine construction was completed. The committee provided valuable suggestions to strengthen our existing documentation and procedures.

Construction: Work continues on the PF and CHI bus inside both umbrella structures. The anchoring and grouting of the centerstack pedestal has been completed. The MPTS exit side TIV has been installed and the last few primary seals for the vacuum vessel are being completed so pumpdown can proceed. The gas injectors are being installed. The installation of the halo shim blocks is in progress. The installation of electrical for the MPTS on the south wall continues, as does the electrical for the TMB system in the NW corner of the test cell. The centerstack Rowgowski installation continues.

CS Upgrade: The PF buswork continues to be fit up on the machine in the NTC. Installation of the PF insulation and hipot testing continues in the CS Winding area. PF1B lower busbars were tested, one failed for a small blemish in the insulation and was repaired and retested. The OH water heater design continued the week of December 8. The bids for the water heater were received. At least one meets our requirements and a recommendation to award to the vendor was transmitted to procurement. Procurement is in the process of obtaining required documents from the selected vendor before awarding. The engineer is working out the detailed control logic sequence between the valve, heater and coil pulse for the heater system in preparation for a review meeting. The new OH hoses passed a hipot test. A hydrotest was delayed until the week of December 15 while the tooling for the swaged connectors arrives from the supplier.

NBI Upgrade: Services work continued on BL2 source SF6 delivery line installation and associated platform work between BL1 and BL2 continued. Power testing of M/Rs took place in preparation for NB PTPs; 4C M/R is complete and 4B M/R testing has started. Controls work continues with installation of cable, trays, and terminations in NTC and gallery. Work continues on the N gallery shield wall procurement. Progress continues on BL PLC software pages. Cryogenics system helium gas cleanup is underway on the entire system and the 500 horsepower compressors were restarted; maintenance on the cold box to repair instrumentation is in progress. Development of NB procedures continues and nears completion. Management participated in the NSTXU Readiness for Operations Review this week and the NBI work was viewed favorably. The committee concluded that appropriate systems and processes are in place for the project to reach CD4 successfully. Pithy and helpful input was provided for items to be completed for CD4, ISTP, operations, and for ongoing management of our processes.

Digital Coil Protection System: The Operations procedure development for setup and startup of DCPS is in progress; more input has been thought through and will be included prior to dummy load testing. The SDD reliability assessment draft has been sent out for review. Work continues on the DCPS buffer chassis implementation. DCPS integration into the PCS environment continues as part of RTC and PCS development. Development of new PTPs and the ISTP-NSTX-001 with DCPS content and methodology continues.

DIRECTOR'S OFFICE (C. AUSTIN):

A. Cohen was in Arlington, Virginia for the DOE Joint Genome Institute Review December 7-9. On December 9-13, he traveled to Albuquerque, New Mexico for the DOE Laboratory Operations Board workshop and meeting.

M. Zarnstorff traveled to Japan to participate in discussions of the Japanese fusion program and collaborated on high-beta experiments at LHD, December 8-12.

PUBLICATIONS:

Abrams, T.; Jaworski, M.A.; Kaita, R.; Stotler, D.P.; De Temmerman, G.; Morgan, T.W.; van den Berg, M.A.; van der Meiden, H.J., "Erosion Of Lithium Coatings On TZM Molybdenum And Graphite During High-Flux Plasma Bombardment" by was Fusion Engineering and Design 89 (2014) 2857–2863.

This report is also available on the following web site:
<http://www.pppl.gov/publication-type/weekly-highlights>