PRINCETON PLASMA PHYSICS LABORATORY
WEEKLY highlights

PPPL
U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the week ending December 11, 2015 are as follows:

U.S. ITER FABRICATION (C. NEUMEYER):

Steady State Electric Network (SSEN):

The department received three budgetary cost estimates for the ITER SSEN Uninterruptible Power Supply system that were solicited via the FedBizOpps "request for expression of interest" modality. The information, which separates the cost of the battery banks from the other components, will be used to revise the project cost estimate and also to develop a plan to separate the battery procurement and transfer its scope to the ITER IO. This will facilitate the timely completion of the remaining SSEN procurements under the flat funding constraints, and will reduce the shelf storage life of the batteries before they are actually put into service.

Diagnostics:

Low Field Side Reflectometer (LFSR): The front-end antenna layout report was issued in draft by GA/UCLA. The report describes the location, orientation, launch diameter, and placement of the 2 x 3 array and the Doppler antenna. A layout of the LFSR components in the DSM is being finalized and entered into ENOVIA. The Gaussian telescope optics are being tested currently on the GA/UCLA waveguide TL test stand. Finally, FPGA data acquisition and phase processing hardware and software, developed as R&D for LFSR, are being tested on DIII-D reflectometer, taking data on live DIII-D plasmas this week.

Equatorial Port 9 Integration: Y. Zhai traveled to ITER to discuss several diagnostic port plug electromagnetic and structural analysis issues with IO staff. Electromagnetic analysis is at the core of the diagnostic port plug designs. It is critical the DAs and the IO coordinate analysis work to ensure results are correct and consistent between analysis teams.

Core Imaging X-ray Spectrometer (CIXS): N. Allen and K. Hill visited Indiana University to evaluate the Neutron Radiation Effects Facility for testing the CIXS X-ray detectors. The CIXS DECTRIS Pilatus detectors will be subject to high neutron influence levels when operating on ITER and it is critical to show the detectors can survive the environment. Allen and Hill are meeting with NREF engineers to discuss operating procedure, costs, and safety controls.

Post Plug Test Facility (PPTF) and D-Site Operations: A. Carpe, P. Efthimion, and R. Feder of PPPL met with Jeff Parrot to start planning Port Plug Test Facility logistics. There will be several large, heavy, and expensive components that will need to be transported to PPPL from northern New Jersey shipping docks. The team wants to make sure all aspects of the logistics are

folded in to current Port Plug Assembly and PPTF operations plans and budgets.

NSTX (M. ONO):

Axel Winter from the ITER Control, Data Access, and Communication (CODAC) group visited PPPL for the week of November 30. He met with the PPPL IT/CODAC groups to discuss NSTX-U and ITER goals, EPICS usage and implementation, diagnostic systems, cyber issues, and real-time data frameworks. NSTX-U team-members provided information on NSTX-U plans for advanced scenarios, active feedback control, disruption detection, and TRANSP applications. The NSTX-U digital coil protection system framework and potential applicability to ITER was also discussed. Joshua Stillerman from MIT also visited PPPL from December 2-4 to discuss MDSplus issues and future applications with NSTX-U researchers, CODAC personnel, and A. Winter. On December 3, A. Winter gave a seminar entitled "Tools and implementation strategy for real-time control at ITER."

An article by J. M. Muñoz Burgos (Johns Hopkins University) entitled "Applications of advanced kinetic collisional radiative modeling and Bremsstrahlung emission to quantitative impurity analysis on the National Spherical Torus Experiment" was published in Physics of Plasmas, 22, 122301 (2015). The article is available on http://scitation.aip.org/content/aip/journal/pop/22/12/10.1063/1.4936953. Quantification of plasma impurities derived from charge-exchange emission spectroscopy will become important when high-Z metallic tiles are introduced into the lower divertor. This kind of measurement will become important when analyzing transport of metallic impurities during high plasma rotation regimes. A Transmission Grating-based Imaging Spectrometer (TGIS) designed and built by the Johns Hopkins University plasma spectroscopy group will operate on NSTX-U to measure impurity lines on the XUV/VUV regions from charge-exchange emission. Combined with advanced beam into plasma charge-exchange collisional radiative modeling, impurity densities will be estimated from TGIS measurements.

A paper entitled 'Sorption of atmospheric gases by bulk lithium metal' by C.A. Hart (University of Maryland), C.H. Skinner, A.M. Capece (PPPL), and B.E. Koel (Princeton University) has been published online in the Journal of Nuclear Materials 468 (2016) 26-30, http://www.sciencedirect.com/science/article/pii/S0022311515303147. The paper reports on bulk chemical and morphological changes of lithium samples on exposure to ambient and dry synthetic air. For ambient air, the initial mass gain of a $1cm^2$ surface was several mg/h declining to less than 1 mg/h after an hour and decreasing by an order of magnitude after 24 h. A 9 mg sample achieved a final mass gain corresponding to complete conversion to Li_2CO_3 after five days. Exposure to dry air resulted in a 30 times lower initial rate of mass gain. The results illustrate that the oxidation of bulk lithium proceeds much more slowly than oxidation of the top few monolayers due to the transition to diffusion-dominated transport for thick films and also the importance of morphological changes (surface cracking) and water vapor in facilitating the reaction. The results have implications for the chemical state of lithium plasma facing surfaces and for safe handling of lithium-coated components.

The journal version of the talk "Simplifying the ST and AT Concepts" by R. Raman (University of Washington), T.R. Jarboe (University of Washington), J.E. Menard (PPPL), et al., presented at the FESAC Strategic Planning Meeting, Gaithersburg, MD July 8-10, 2014, has been published

on-line by the Journal of Fusion Energy http://link.springer.com/article/10.1007/s10894-015-0040-3. It describes new tools that would allow ST and AT based devices to operate at close to their projected performance levels. These are: (1) Advanced fueling based on Compact Toroid Injection for precise core fueling for density profile control and toroidal momentum injection; (2) Electron Bernstein Wave system to provide off-axis current drive capability; and (3) Solenoid-free plasma start-up capability to eliminate the central solenoid and provide greater flexibility in the device aspect ratio optimization.

E. Kolemen (Princeton University) and L. F. Delgado-Aparicio (PPPL) have won the 2015 Torkil Jensen Award (TJA) for DIII-D experimental run time in 2016. The experiments will aim at studying the stabilization of radiatively induced tearing modes (RiTMs) using off-axis ERCH heating and its connection with the density limit. (L.F. Delgato-Aparicio)

L. F. Delgado-Aparicio (PPPL) visited the TJII and TCV facilities in Spain and Switzerland. In Madrid he ran an experiment with Spanish scientists at the TJII stellarator in CIEMAT. The experiment consisted in introducing low and medium-to-high Z impurities (e.g. C, Fe and W) in a stellarator configuration with magnetic islands. Differences were observed between impurities and their accumulation around and inside the magnetic islands. Data analysis is under and a summary of the experiment will be submitted to the 2016 IAEA Fusion Energy Conference in Kyoto-Japan. Delgado-Aparicio also visited colleagues from the TCV tokamak at the Swiss Plasma Center (SPC) at the École Polytechnique Fédérale de Lausanne and exchange ideas about data analysis and the effect of impurities in (m/n)=(2/1) magnetic islands. The analysis is being conducted in neon-seeded plasmas near the density limit, which help motivating future ECRH stabilization experiments in the TCV Tokamak. Similar experiments will be also conducted at DIII-D and NSTX-U (using off-axis ECRH and NBI) as part of Delgado-Aparicio's Early Career Research award (DOE – 2015).

A Final Design Review (FDR) for the mechanical installation of the Far Infrared Tangential Interferometer/Polarimeter (FIReTIP) was conducted. Participants included PPPL personnel and collaborators from the University of California at Davis (UCD). E. Scott (UCD) gave an overview of the FIReTIP diagnostic, and I. Zatz (PPPL) reviewed the details of the installation. Four chits were generated concerning vibration isolation of the laser and receiver/mixer tables, ensuring adequate space for cylinders supplying the laser working gas, and completion of the documentation and drawings for the electrical installation. It was also recommended that a calculation be made of the power radiated from the plasma to the in-vessel laser retroreflector, to see what might happen to its surface. The review committee deemed the review successful and recommended proceeding with the installation pending resolution of the chits.

A design review was also held for the first phase of the high-Z upgrade to the NSTX-U plasma-facing components (PFCs). M. Jaworski (PPPL) reviewed the Systems Requirements Document (SRD) for the TZM (titanium, zirconium, molybdenum) tiles. K. Tresemer (PPPL) reviewed the design and analysis of the TZM tiles and configuration in the vacuum vessel, where the new tiles will replace the row of graphite tiles at a single radial location on the outboard divertor. Several chits were generated during the review concerning additional analysis, tolerances, installation considerations, thermocouple and calorimeter implementation, and documentation requirements. The review committee deemed the review to be sufficient for a Preliminary Design Review (PDR), with a Final Design Review (FDR) to be conducted pending resolution of the chits. The review committee also recommended that a separate peer review be held for special non-TZM

test tiles that are also under consideration for the PFC upgrade task.

ITER & TOKAMAKS (R. HAWRYLUK):

R. Maingi presented the Pedestal and Edge Physics (PEP) Topical Group Annual activity report, and summary of joint experiment proposals, at the ITPA Coordinating Committee meeting from Dec. 8-10 at the IO headquarters in Cadarache, France. R. Hawryluk participated in the ITPA meeting and the subsequent IEA-CTP meeting.

DIII-D (R. Nazikian):

The completed 32 channel main-ion CER system has been calibrated using beam into gas shots and is currently acquiring high spatial resolution measurements of deuterium temperature, toroidal rotation, and density on DIII-D discharges. Initial analysis of the data from the edge chords during a L to H transition shows significant differences between the impurity and main ion toroidal rotation profiles. In L-mode the rotational velocity of both carbon and deuterium is monotonic. In H-mode the carbon profile has a stationary non-monotonic feature with a localized profile dip in the region of steep pressure gradient; however the deuterium toroidal velocity is still monotonically decreasing. Momentum balance would indicate qualitative differences in effective diffusivity using the carbon profile compared to the deuterium profile, highlighting the importance of the deuterium measurements. Additionally, significant progress has been made streamlining the workflow required to analyze the spectra and compare it to a simulated diagnostic using the FIDASIM code. These improvements allow a much faster turnaround from raw measurements to physical observations.

The ECE-Imaging diagnostic has been reinstalled on DIII-D for the FY16 experimental campaign. A new postdoctoral researcher, Chen Luo (UC Davis) has joined the team, and will assist in operations and implement upgrades to the system in the coming year.

The LGI team is working to bring together all of the LGI upgrades and install the unit on DIII-D vessel. The last test is to calibrate the drop tubing using lithium in the new configuration. The available granular materials will now include lithium, as well as carbon, boron, and potentially boron carbide. One of the best new features is that the type of granules can be selected between shots via movement of the drop tube location relative to the impeller.

ADVANCED PROJECTS (H. NEILSON):

The Laboratory joins the world fusion community in congratulating the Max Planck Institute for Plasma Physics on the achievement of First Plasma in Wendelstein 7-X (W7-X) on December 10. Laboratory staff members observed the live broadcast of the event from several locations including PPPL and Oak Ridge National Laboratory. Three members of the Laboratory's W7-X collaboration team—D. Gates, S. Lazerson, and N. Pablant—attended in person at the Greifswald, Germany site. PPPL has made significant contributions to W7-X research preparations, including equipment and analyses. Lazerson participated in vacuum magnetic field mapping experiments and reported results at the recent APS Division of Plasma Physics meeting. Pablant led the design and implementation of an x-ray imaging crystal spectrometer (XICS)

which will be used to make high-resolution plasma temperature and velocity measurements. The XICS gate valve was opened to the main W7-X vacuum for the first time this week. The system is fully ready to detect x-ray emission when plasma operation continues next week.

Laboratory staff reported progress on engineering and physics analysis tasks for the K-DEMO reactor study, performed in collaboration with South Korea's National Fusion Research Institute. At a joint team meeting, D. Mikkelsen reported final results of a parametric scan of electron cyclotron current drive configurations. Scans were performed in frequency, elevation of the launcher above the outboard midplane, and launch angle. The total driven current and radial distribution were evaluated using ray-tracing methods. C. Kessel reviewed time-dependent simulation results for K-DEMO; he plans to update these analyses using the results of parametric scans for neutral beam, lower hybrid, electron cyclotron, and ion cyclotron current drive schemes to identify one or more optimized heating and current drive system configurations for K-DEMO. T. Brown reviewed the status of K-DEMO machine configuration development and recommended priorities for future work.

H. Neilson visited Oak Ridge National Laboratory (ORNL) for discussion with fusion researchers in the Fusion and Materials for Nuclear Systems Division. Neilson gave a presentation entitled "The Next 25 Years of U.S. Fusion Research" which highlighted opportunities for the U.S. in long-pulse fusion plasma and material science that could make major advances in the field. The presentation was followed by a prolonged discussion of the opportunities and ways in which the community could work together to identify the most important needed initiatives. In addition, ORNL staff described their plans for participation in W7-X research over then next few years.

THEORY (A. BHATTACHARJEE):

A. Bhattacharjee, Eric Blackman (University of Rochester), H. Ji, and James Stone hosted a Workshop on "The Dynamo Effect in Astrophysical and Laboratory Plasmas" from December 7-9 at the Princeton Center for Theoretical Science. This Workshop brought together a group of about 35 scientists (including postdoctoral fellows and graduate students) to discuss the current status of theory and experiments focused on the dynamo effect. Each talk was assigned 40 minutes, with 10 minutes for questions, and additional time was provided for discussions at the end of each day. Five members of the PPPL Theory Department and the Department of Astrophysical Sciences at Princeton University gave talks: F. Ebrahimi on "Shear-driven dynamos without the standard omega effect," R. Kulsrud on "A new galactic dynamo," M. Kunz on "Impact of kinetic instabilities on dynamo in weakly collisional plasmas," J. Shi on "MRI dynamo in shearing box," and J. Squire on "The magnetic shear current effect: generation of large-scale magnetic fields by small-scale dynamo." Squire completed his PhD thesis at Princeton in August 2015, and is presently a Sherman Fairchild Fellow at Caltech.

One of the participants of the Workshop, Professor Steven Tobias, Chair of the Department of Applied Mathematics at Leeds University, gave a Physics Department Colloquium on December 10. The title of his talk was "Order from Chaos: From the Solar Cycle to the Jets on Jupiter" and the abstract was as follows: "The eleven year solar activity cycle is a remarkable example of regular behaviour emerging from an extremely turbulent system. The jets on Jupiter sit unmoving on a sea of turbulent eddies. Astrophysical phenomena often display organization on

spatial and temporal scales much larger than the turbulent processes that drive them. An outstanding problem of astrophysics (and indeed other branches of nonlinear physics) is how to describe the statistics of systematic behaviour emerging from the underlying chaos, given that Direct Numerical Simulation of these objects is simply impossible. Here I shall introduce these fascinating phenomena and describe how methods from non-equilibrium statistical mechanics and many body quantum systems may be developed to give some insight into their behavior."

COMPUTATIONAL PLASMA PHYSICS GROUP (S. JARDIN):

S. Ethier gave a mini-course entitled "Introduction to Parallel Debugging" as part of the series of mini-courses hosted by the Princeton Institute for Computational Science and Engineering (PICSciE). The lecture introduced the Princeton University participants to different approaches in tackling the task of debugging parallel applications, including the use of advanced parallel debuggers, such as DDT.

BUSINESS OPERATIONS (K. FISCHER):

Budget Office:

A peer review of PPPL's Institutional Cost Report (ICR) for FY2014 was completed. The purpose of the ICR, which is submitted to DOE annually, is to provide transparency of DOE contractor institutional and functional costs by providing costs for the fiscal year by defined categories. The review team concluded that PPPL has materially met the intent of the ICR guidelines and definitions and no findings were reported.

PPPL submitted a Field Work Proposal to the DOE Fusion Energy Science program titled "Plasma Science Studies of High-Pressure Arc-Plasma Nanomaterial Synthesis." This research project will enhance the nanomaterials scope of work funded by the Basic Energy Sciences program related to the development of closely integrated plasma and atomistic materials modeling validated by a comprehensive experimental campaign for volumetric and surface synthesis of carbon and boron nanostructures. The Principal Investigator is I. Kaganovich. The requested funding is $650,000 per year for FY2016 and FY2017.

DIRECTOR'S OFFICE (C. AUSTIN):

On December 9, Dr. Nadya Shirokova, University of Santa Clara presented a colloquium entitled "Introduction to Quantum Algorithms."

On December 9, PPPL management participated in the annual Lab Appraisal meeting at DOE headquarters in Washington, DC.

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