PRINCETON PLASMA PHYSICS LABORATORY
WEEKLY highlights

PPPL
U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the week ending March 11, 2016 are as follows:

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

Steady State Electric Network (SSEN):

6.6kV Switchgear Lots #2, #3, and #4: Fabrication is underway. Shipments are scheduled for May 20 (Lot #2) and June 10 (Lot #3). Production of Lot #2 switchgear is on schedule.

Power Transformers: Manufacturing is completed and FAT is completed for Groups 3 and 4 dry-type units (Lot #3). Punch-list of corrective measures was developed and agreed upon with supplier. Delivery planning meeting was convened. Shipping was postponed until April 7 to allow time for the supplier to complete punch-list and for ITER to prepare facilities for receipt and storage. Groups 1 and 2 transformers are in fabrication. Shipments are re-scheduled for May 27 (Lot #1) and June 3 (Lot #2).

Diagnostics:

Toroidal Interferometer and Polarimeter (TIP): For monitoring fluctuation amplitudes, it is important to minimize the TIP interferometer phase noise arising from the two lasers. Researchers using a TIP laboratory prototype at General Atomics have found that the quantum cascade laser (5.22 microns) phase noise was significant, unless the total path length of the probing and reference beams are closely matched. This was not a problem with the CO2 laser (10.6 microns), reflecting a longer coherence length for this laser.

Upper Port Wide Angle View Vis-IR Cameras (UWAVs): Structural results for the integrated FEOT model, without heat generation, were evaluated by General Atomics (GA). These results showed a positive margin of safety for all cask fasteners, rams and pads. Sensitivity to friction factor for the cask fasteners is low, with dominant stresses stemming from the preload and not external loads. These results provide confidence in the fastening scheme and overall structure. SDC-IC evaluation of the combined thermal/mechanical loads is planned for the upcoming week. Thermal analysis of the FEOT Cask is underway.

Equatorial Port 9 Integration and DSM Engineering: EP09 integration for this period is nearing conclusion of thermohydraulic analysis for the ECE DSM2 structure. Analysis is showing coolant paths are sufficient for both operational cooling and bakeout temperatures. This cooling solution now enables design of pipe routing to port Closure Plate and reserves cooling path volumes to properly constrain further design of the structure. Additionally, the defined cooling path now provides a DSM2 temperature profile that guides many aspects of DSM design going

forward. With guidance from the analysis group, DSM3 (TIP) design has progressed to a whole concept for mounting of the TIP optics cartridge into its DSM host. The concept as modeled in CATIA accounts for static load support of the cassette and provides electrical conduction paths to minimize EM loads.

Upper Port 11 and 14 Integration and DSM Engineering: A. Jariwala discussed the use of bellows in the TCWS system with Jay Brizendine (TCWS design) from ORNL. Jariwala states: "During the IBED design assessment, flexible piping was presented and could be used as a design solution for IBED pipe layout, if fully certified by the ANB and evidence of reliability and functionality for the confinement is justified. An assigned action was accepted by U.S. ITER during the closeout of PCR-701, IBED design assessment, regarding qualification of flexible hose assembly as a viable design solution to piping stresses in L3 IBED piping." This piping is outside the vacuum while the bellows UP#11/UP#14 wants to use the piping inside the vacuum and is inaccessible during the operation. So, the flexible piping, which the TCWS team at Oak Ridge is planning to develop and qualify for ITER usage, is probably not beneficial for Upper Port use as they are not a VQC1A component.

Core Imaging X-Ray Spectrometer (CIXS): CIXS detector nuclear testing contract preparation and subcontractor selection is in progress. A power supply for magnetic testing is being brought online this week. Drawing and designs have started for the support bracket used to support the X-ray detector inside the magnetic coil during testing. Also this week, a titanium foil was purchased for wavelength calibration testing to occur alongside the testing at MIT of the Xenon crystal.

Motional Stark Effect (MSE): Nova Photonics and PPPL have been working through a design loop between MSE optical ray tracing and then checking the fit of the optical design into the EP3 DSM-1 structure and port plug closure plate. This initial preliminary design loop is complete and the PPPL EP3 DSM engineering team will develop the preliminary design of the mechanical packing for the MSE mirrors.

NSTX (M. ONO):

A FY 2016 NSTX-U plasma operations update: The department has completed 4.81 run weeks and 482 plasma shots. The total operation targets are to be decided.

Vlad Soukhanovskii (Lawrence Livermore National Laboratory Collaboration on NSTX-U) visited DIII-D at General Atomics last week. He served as a session leader of an experiment aimed at studying heat transport and radiation distribution in the snowflake-plus divertor configuration. A Princeton University postdoctoral researcher, D. Eldon (on assignment at DIII-D), and a Princeton University graduate student P. Vail (remote participation), served as deputy session leaders and assisted with plasma control system aspects. Progress in plasma control enabled inter-null distance variations in the snowflake-plus configuration on a slow (transport) time scale. Deuterated methane divertor puffing was used to achieve a radiative snowflake divertor with up to 60% of the SOL power exhausted via carbon and deuterium divertor radiation. Good H-mode confinement with H98y2 factors in the range 1.0-1.2 was retained. Initial results suggest that radiation was broadly distributed in the snowflake-plus divertor. Analysis of scrape-off layer power widths in the snowflake-plus configurations versus inter-null

distance is underway. While at DIII-D, Soukhanovskii also discussed installation and data analysis aspects of the divertor near-infrared and core extreme ultraviolet spectrometers operated by LLNL on DIII-D. Similar spectrometers are being installed by LLNL on NSTX-U.

John Rice of the MIT Plasma Science Fusion Center visited PPPL on March 9-10. The primary purpose of the visit was to work with PPPL X-ray physicists and engineering to develop a concept for implementation of an imaging X-ray crystal spectrometer for measurement of ion temperature and rotation velocity profiles in NSTX-U. An attractive concept was found: a system could be implemented at Bay J that would provide spatial coverage of nearly the entire plasma diameter with the high spectral resolution needed for these measurements. It appears that there is space for the required ex-vessel hardware. We plan to follow-up by doing detailed layouts of the proposed system to further develop the concept.

Dr. Ryuichi Sano (NIFS, Japan) visited PPPL this week to work with the team developing the prototype infrared video bolometer for NSTX-U, participating in bench top calibration work and discussing methods and techniques used by the NIFS group led by Professor Byron Peterson. Sano also presented research, describing methods for 3D tomography of radiated power based on results from LHD.

Dr. Ryo Yasuhara visited PPPL on March 8-11 to discuss ongoing collaboration of the development of an edge polychromator for the Thomson scattering system of interest for LHD and NSTX-U. In addition, Yasuhara and A. Diallo (PPPL) discussed plans for Yasuhara's next visit at PPPL for the commissioning of the pulse burst laser system. During his next visit, a prototype of this polychrometer will be implemented in a laboratory setup to provide detailed characteristics of this system.

Tom Osborne and X. Chen of General Atomics visited PPPL to update the Python analysis tools used for pedestal profile analysis on NSTX-U.

Professor Yoshi Hirooka (NIFS, Japan) visited PPPL this week to discuss liquid lithium collaboration and possible neutron science experimental collaboration with NSTX-U.

Alistair McGann (University of York, UK) began a three-month visit to PPPL this week for his collaboratory, offered to PhD students participating in the UK Centre for Doctoral Training on Fusion Energy—http://www.fusion-cdt.ac.uk/. He will be working with the ORNL group to interpret IR measurements in NSTX/NSTX-U, focusing on improving methods to account for the effect of surface layers, such as boron and lithium, when calculating heat flux.

NSTX-U has completed the first of a two-week maintenance period, which includes a quick argon vent of the vessel to retrieve boron nitride debris from a diagnostic shutter. Installation activities during this maintenance period include the LoWeus/Zeus/Mona Lisa diagnostic systems, the Argon Dump system controls needed for future lithium operations, the SAMI diagnostic, the Lithium Granule Injection system, the new Massive Gas Injector system, the fast voltage measuring system needed for CHI operations, and new cameras/fiberoptics. Upgrades to the lower TF water fittings are in progress. The Residual Gas Analyzer (RGA) heads have been replaced, and remote system operation has been restored. Procedures/work packages for the installation of the LITER probes on the NSTX-U vessel are being developed. Repair of the Neutral Beam (NB) 2C transmission line have been completed, and NB2A transmission line

repairs are in progress. The NB2B autotransformer will be replaced with a spare unit this coming week. Weld inspections of Motor Generator (MG) #1, and a test run-up of MG#2 are scheduled for this coming week.

On March 11, the boron nitride BES shutter fragments were successfully removed from the NSTX-U inner divertor floor. The entire removal process, from venting the vacuum vessel with argon to reinstalling the Bay L rectangular port, went as planned, taking less than an hour. A positive argon pressure was applied during the removal to minimize the air contamination of the vacuum vessel plasma facing components. The insertion of the extraction tools and removal of the fragments took approximately three and one half minutes, using the vacuum suction tool and a net. During the argon vent, the FIReTIP vacuum window was also replaced.

The NSTX-U Test Cell will be in controlled access this coming week for approved work.

ITER & TOKAMAKS (R. HAWRYLUK):

DIII-D (R. Nazikian):

A paper by A. Bortolon, et al., titled "High frequency pacing of edge localized modes by injection of lithium granules in DIII-D H-mode discharges," was accepted for publication in Nuclear Fusion. This paper demonstrates the pacing of ELMs by lithium granules and also highlights issues related to achieving effective ELM mitigation with ELM pacing.

R. M. Churchill performed simulations using the fully kinetic code XGCa to explore the impact of kinetic effects on scrape-off layer (SOL) physics in DIII-D H-mode plasmas. Currently, a DIII-D sheath-limited SOL regime discharge is under investigation and several notable physics results are being observed in this simulation. First, the parallel main ion flows in the SOL are at experimentally relevant levels (ion Mach number ~ 0.5), and show a poloidal variation with strong flow into the inner and outer divertor, similar to measurements reported in J. Boedo et al., Journal Nuclear Materials, 1999. Also, parallel velocity stagnation points are seen in the simulations near the top of the plasma for a lower single null discharge. The sheath potential is solved self-consistently using a logical sheath boundary condition. The resulting sheath potentials reach normalized values $e\phi/ Te \sim 3 - 4$, much higher than standard predictions of $e\phi// Te \sim 2.2$. These elevated sheath potentials are a result of the non-Maxwellian features in the electrons and ions at the sheath entrance and are consistent with ions being subsonic at the sheath entrance. Further work of comparing the XGCa simulation results to the fluid code SOLPS, and measured observables from the divertor Thomson system.

L. Cui has performed analysis of the physics behind the observed confinement recovery in low collisionality H-mode plasmas with applied Resonant Magnetic Perturbations (RMPs). It has been seen that in the early RMP period, the global confinement first degrades and then fully recovers on a longer time scale. The early confinement degradation is correlated with the strong density pumpout but the confinement recovery takes place without any increase in the density. Initial TRANSP interpretive analysis showed the inferred ion heat diffusivity first increased and then steadily decreases. The beam ion pressure does not change significantly. The next step is to understand why the ion confinement improves and to simulate the confinement recovery with TGYRO+TGLF modeling in TRANSP.

International (R. Hawryluk):

R. Ellis, J. Hosea, and G. Taylor attended the KSTAR Conference in Daejeon, South Korea, on February 24-26. At the conference, Ellis presented a talk, "Design study of a two-channel steady-state ECH launcher." On February 26, the group visited KSTAR, where Ellis presented a successful conceptual design review of a two-channel steady-state ECH launcher. On February 29, Hosea presented a talk on recent PPPL analyses of RF losses in the scrape-off layer, and the implications of this work for the Helicon antenna on KSTAR.

ADVANCED PROJECTS (H. NEILSON):

D. Gates participated in experiments on the DIII-D tokamak designed to investigate the causes of the tokamak density limit. The experiments, which were conducted March 1-3, were granted run time on DIII-D as part of the Torkil Jensen Award, given to the first authors of the proposal by E. Kolemen and L. Delgado-Aparicio. The General Atomics award is bestowed on the basis of: 1) potential for transformational new results, 2) potential for producing high visibility, high impact science, and 3) collaborative effort (national or international partners). The goal of this experiment was to test ideas put forward in a recent series of papers, which have proposed that radiation driven magnetic islands are responsible for the density limit. The experiments were successful in reaching the density limit and varying both the impurity levels and the local electron cyclotron heating inside the island.

The Laboratory submitted a report to South Korea's National Fusion Research Institute (NFRI), covering work performed from March 2015 through January 2016 under a research agreement between NFRI and PPPL, in which PPPL performs physics and engineering analysis tasks supporting NFRI's design study for a fusion demonstration facility, K-DEMO. The report includes results of configuration studies for electron cyclotron and ion cyclotron heating and current drive, as well as time-dependent simulations, using combinations of multiple heating and current drive techniques to represent their respective effects on total current driven per unit power and the spatial profile of driven current. In addition, PPPL has continued to develop a machine configuration model of the K-DEMO tokamak, supported by engineering analyses. Design activities focused on critical configuration drivers such as piping, structural support systems, and horizontal port interface. Analyses focused on structural analyses of the vacuum vessel and blanket modules. Of particular note, this work included development and application of methodologies to treat the static magnetic forces resulting from the use of magnetic materials in the blanket modules and potentially in the vacuum vessel. Disruption simulation methods were also advanced, and the combined effects of disruption-induced eddy currents and magnetic forces were treated.

THEORY (A. BHATTACHARJEE):

Y.-M. Huang and L. Comisso attended the 2016 US Japan Workshop on Magnetic Reconnection, March 7-11 in Napa, California. Huang gave an invited talk on "Plasmoid Instability Mediated Turbulent Reconnection," and Comisso contributed a poster on "Ion diffusion region physics and reconnection rate."

BUSINESS OPERATIONS (K. FISCHER):

Procurement:

RFP 15-097C was issued for the PPPL Infrastructure and Operational Improvements (IOI) Project per PPPL Statement of Work (SOW) for Construction Services. A pre-proposal meeting is scheduled for March 24 at PPPL and the RFP close date is April 15.

A Sources Sought notification was posted in FedBizOpps for the PPPL Business Systems Upgrade Project. Responses are due April 13.

BEST PRACTICES & EXTERNAL AFFAIRS (J. DELOOPER):

Science Education (A. Zwicker):

On March 12, Professor David Spergel of Princeton University gave a Science on Saturday lecture entitled "Taking the Universe's Baby Picture."

OFFICE OF ACADEMIC AFFAIRS (N. FISCH):

An article entitled "Sudden Viscous Dissipation of Compressing Turbulence," by graduate student S. Davidovits and Professor N. Fisch, was published in the March 11 issue of Physical Review Letters and was highlighted as an "Editor's Suggestion." The article points out that turbulent kinetic energy in compressible plasma or gas, amplified by compression, can suddenly be converted to thermal energy. Apart from the academic interest in compressible gas dynamics, this paradigm suggests a speculative but tantalizing approach to fast ignition in inertial confinement fusion devices. The full article can be viewed online at http://journals.aps.org/prl/abstract/10.1103/PhysRevLett.116.105004.

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