Weekly HIGHLIGHTS

PPPL PRINCETON PLASMA PHYSICS LABORATORY
U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the week ending April 13, 2019, are as follows:

NSTX-U RECOVERY (R. HAWRYLUK) AND RESEARCH (S. KAYE)

Recovery (R. Hawryluk): An external review of the analysis and testing plans for the TF bundle to address technical issues was held April 9. This was a valuable review and provided overall support for the plan and identified specific areas that require more emphasis.

Research (S. Kaye):

O. Asunta, P. Buxton, and S. McNamara from Tokamak Energy Ltd, U.K., visited PPPL during the week of April 8. As part of a developing NSTX-U/ST40 collaboration, the three worked with S. Kaye, J. Sachdev, and M. Gorelenkova to set up and learn to run TRANSP. They also had discussions with other NSTX-U physicists concerning other areas of the proposed collaboration in the areas of transport, macrostability, and energetic particle and boundary physics.

F. Poli attended the spring meeting of the ITPA-IOS topical group, organized by QST, in Naka, Japan, from April 9 to 12. She reported on a joint activity on the modeling of the ITER plasma ramp-down phase, focusing on identifying trajectories that are more robust to disruptions and that are manageable by the plasma control system. The activity considered simulations with CORSICA, TRANSP, DINA, and JINTRAC, looking at H-L transition between 15MA and 7.5MA. Preliminary results indicate that an exit from H-mode at a current around 10-13MA is preferable because it is compatible with leaving the control system sufficient time for exception handling. Discussion at this meeting has focused on re-defining the priorities of the group as they align to the ITER research needs.

For Career Day at The Center School in Somerset, NJ, S. Sabbagh gave a fusion outreach presentation titled, “Fusion Energy: Plasmas, Scientists, and Innovation.” The presentation was given three times to three different levels of students in small groups for better engagement to answer questions.

A paper entitled, “A scalable real-time framework for Thomson scattering analysis: Application to NSTX-U,” by F. Laggner, A. Diallo, B. LeBlanc, R. Rozenblat, G. Tchilinguirian, E. Kolemen, and the NSTX-U team has been published in *Review of Scientific Instruments* (https://doi.org/10.1063/1.5088248). The paper presents a detailed description of a prototype setup for real-time Thomson scattering analysis, which was implemented in the multi-point Thomson scattering diagnostic system. The setup includes upgraded data acquisition hardware as well as a new analysis software to

allow for a rapid calculation of the electron temperature and the electron density profile.

The paper, "Electron inertial effects on linearly polarized electromagnetic ion cyclotron waves at Earth's magnetosphere," by E.-H. Kim, J. Johnson, and D.-H. Lee was published in the *Journal of Geophysical Research: Space Physics, 124*. (https://doi.org/10.1029/2019JA026532). Kim, et. al discovered that linearly polarized electromagnetic ion cyclotron waves can be generated near the Buchsbaum resonance and ion-ion hybrid resonance locations at the magnetopause. It was also discovered that the wave normal angle of the mode-converted electromagnetic ion cyclotron waves in the magnetosphere is between 30 and 80 degrees, which is consistent with research observations.

The paper, "Initial transport and turbulence analysis and gyrokinetic simulation validation in NSTX-U L-mode plasmas," by W. Guttenfelder et al. has been published in *Nuclear Fusion*: https://doi.org/10.1088/1741-4326/ab0b2c. The paper describes transport analysis, turbulence measurements from the beam emission spectroscopy diagnostic, and local nonlinear gyrokinetic simulations focusing on high density NSTX-U L-mode plasmas. The theoretical results suggest that both electrostatic and electromagnetic ion scale turbulence, as well as electron scale turbulence, may all be important at different regions in the plasma. The results indicate a transport interpretation for the low-aspect-ratio NSTX-U L-modes that is distinctly different than that predicted for conventional aspect ratio L-mode plasmas.

U.S. ITER FABRICATION (H. NEILSON)

The Low Field Side Reflectometer antenna assembly faces the plasma directly and therefore is exposed to threats typical of first-wall components. Stainless steel components such as the LFSR antenna tips must have sufficient wall thickness between the exposed surface and cooling channels to withstand some erosion due to thermal flashes associated with mitigated disruptions. Yet they must be thin enough to avoid overheating of the surface and resulting thermal strains in the material. The water-cooling network is defined by pipe diameters, wall thickness, and circuit configuration within the front-end assembly, and must be optimized with the constraints of cooling water flow rate allocated to the LFSR components. The design evolution is guided by ongoing thermal-hydraulic analysis. Based on an optimization study by PPPL engineers W. Wang and M. Duco, a design that satisfies cooling and longevity requirements with the available water supply and a 6-mm antenna tips wall thickness has been selected.

Fabrication of a stray radiation prototype test article was completed by PPPL shops. The unit is designed to mock up the local geometry of the antennas and surrounding metallic surfaces and will be used to study the effects of stray reflections on signal quality. It will

be installed on the LFSR microwave test stand at General Atomics, where the tests will be carried out. The study will refine the results of earlier tests that were performed using simpler, non-prototypical reflectors.

ITER & TOKAMAKS (R. NAZIKIAN)

DIII-D (B. Grierson):

Research:

The new Lyman-alpha diagnostic has been installed on DIII-D. The installation marks a milestone for the collaboration between PSFC and PPPL that was designed to develop a new experimental tool for advancing the understanding of the structure of the H-mode pedestal. The diagnostic, which is expected to be commissioned and operational during the upcoming DIII-D experimental campaign, measures the deuterium Lyman-alpha emission from the plasma boundary to infer the neutral density and local particle source, two key parameters for quantitative pedestal transport predictions.

A paper titled, "Inter-ELM pedestal localized fluctuations in tokamaks: Summary of multi-machine observations," by F. Laggner, A. Diallo, M. Cavedon, and E. Kolemen has been published in *Nuclear Materials and Energy* (http://dx.doi.org/10.1016/j.nme.2019.02.030). This paper reviews and summarizes a variety of experimental studies from several tokamaks on pedestal-localized fluctuations appearing between edge-localized modes. The onset of the inter-ELM fluctuations is correlated with the evolution of the pedestal gradients. The researchers found that the pedestal fluctuations can be sorted into at least three distinct categories, and similar observations on multiple machines may point to an underlying generation mechanism that acts similarly for presently accessible pedestal parameter ranges.

Operations:

K. Erickson completed a two-week visit to DIII-D to work with B. Penaflor and H. Shen to integrate a new real-time computer purchased by Princeton University that will calculate stability analysis during a shot in less than 250ms. The hardware integration was completed in advance of the experiment startup in the coming weeks. This system will enable new algorithms later in the year to make use of the stability analysis to better control the plasma. Investigations continue into optimizing the performance to yield more frequent results. As the first use of Concurrent RedHawk at DIII-D, the hardware platform will also serve as a testbed for future use of the real-time operating system in support of future upgrades of existing DIII-D systems.

Additionally, Erickson worked with PPPL researchers and collaborators at DIII-D to understand their high-performance computing needs. A working group identified areas for improvement with an action plan to address open issues in key areas of managing computing resources as well as data storage and transmission.

The adaptor duct for the co/counter steerable off-axis neutral beamline was installed and shown to fit in accordance with the design specifications without adjustments needed. The installation was led by A. Nagy, Lead Engineer for Construction during the Long Torus Opening (LTO) activities on DIII-D. This adapter weighs approximately 300 pounds and was in fabrication for seven months. Significant effort was spent on planning and review to ensure the adapter met specifications. The adapter was finalized with laser-scanned port locations in situ with the neutral beam in the raised position, rotated in both co- and counter-positions. The co-duct is now mounted to the neutral beam and will be connected to the vessel next week once the chain clamp parts, fabricated at PPPL, are received to make up the vessel-side seal.

International PMI (R. Maingi):

R. Maingi attended the ITPA pedestal group meeting in Daejeon, S. Korea, and presented "ELM elimination with impurity powder injection in KSTAR," on behalf of E. Gilson. A series of initial experiments were carried out using an impurity powder dropper (IPD) to introduce small, precise, controllable amounts of boron and boron nitride into ELMy H-mode KSTAR discharges. The results show that the dropping of boron powder mitigates ELMs and reduces recycling. ELM stability and edge fluctuations are altered when boron nitride is dropped, with ~5-second-long periods of ELM quiescence observed.

R. Maingi also presented, "Access to low-density RMP ELM suppression regimes through boron powder conditioning in AUG," on behalf of R. Lunsford and A. Bortolon. Results from ASDEX-Upgrade (AUG) experiments show that injecting boron nitride and pure boron powders into plasma discharges improved wall conditions in subsequent H-mode plasmas. Specifically, pure boron injection appeared to improve wall conditions qualitatively similar to boronization, and enabled access to low-collisionality plasmas needed to study ELM control with magnetic perturbations.

A. Bortolon, R. Lunsford, and Z. Sun contributed to the summary talk on pellet injection for ELM pacing, given by L. Baylor, at the same ITPA meeting. Bortolon and Lunsford described granule ELM triggering with impurity pellet injection in DIII-D, comparing lithium, boron carbide, and carbon pellets. Sun showed the efficacy of ELM suppression with dropped lithium granules in EAST.

KSTAR Stability (S. Scott):

M. Makowski has developed a FFT leakage correction that uses a weighted sum two or three FFT amplitudes whose FFT frequencies are close to a specific frequency. We have implemented Makowski's algorithm for KSTAR MSE analysis and find that it is about three times faster than the numerical lockin approach. By choosing a binning window that is a half-multiple of the PEM period, the leakage analysis yields the same signal amplitudes as the numerical lockin to better than 0.01 degrees for both plasma and in-vessel calibration data.

ADVANCED PROJECTS (D. GATES)

Stellarators (D. Gates)

A paper by C. Zhu *et al*. entitled "Identification of dangerous error fields in stellarators using Hessian matrix method," has been submitted to *Nuclear Fusion*. In this paper, the recently-proposed Hessian matrix method is enhanced to evaluate magnetic islands and quasi-symmetry in stellarators. Critical coil deviations that will cause significant error fields are directly identified.This method is applied to the upcoming CFQS stellarator. Insights of dangerous coil perturbations that should be avoided are provided. This paper is also currently available on arXiv (arXiv:1904.04147).

THEORY (S. HUDSON)

J. Dominski gave a research presentation at PPPL on April 9 titled, "Towards High-Fidelity Whole-Device-Modeling on ExascaleSupercomputers." F. Ebrahimi presented an invited talk entitled, "Plasmoid-Mediated Reconnection: From Space to Fusion Plasmas" at the Stewart Prager Symposium on April 4 and 5. B. Sturdevant attended the 19th Copper Mountain Conference on Multigrid Methods from March 24 to 28 and gave a talk entitled, "A Fully Implicit Kinetic Electromagnetic Model for Magnetically Confined Fusion Plasma Simulations."

COMMUNICATIONS & PUBLIC OUTREACH (A. ZWICKER)

Communications (L. Bernard)

The Office of Communications posted two press releases to the PPPL website. One focused on research led by scientist K. Hammond into the coaxial helicity injection technique, which eliminates the need for a central solenoid in a tokamak. The research confirmed that this technique is effective. The second press release focused on testimony by senior science education program associate S. Greco and science education program manager D. Ortiz to the joint New Jersey Assembly Science,

Innovation, and Technology Committee on March 20. They discussed the importance of exposing STEM topics to school children from kindergarten through high school, and how STEM education benefits girls and minorities. Both stories were also posted to the *Newswise* and *EurekAlert* press release distribution services.

L. Bernard attended the National Laboratories Chief Communications Officers (NLCCO) meeting at Oak Ridge National Laboratory, April 10-12. He also met with Communications and Public Affairs staff at U.S. ITER.

DIRECTOR'S OFFICE (S. COWLEY)

On April 10 and 11, S. Cowley attended the National Laboratory Director's Council (NLDC) meeting at DOE headquarters in Washington, D.C.

This report is also available on the following web site:

http://www.pppl.gov/publication-type/weekly-highlights