Weekly HIGHLIGHTS

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

The PPPL Highlights for the week ending June 1, 2019, are as follows:

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

Recovery (R. Hawryluk):

ASO Implementation — The NSTX-U training and qualification plan and the activity certification plan were approved this week.

TF Bundle — For the TF Bundle investigation, fabrication continues on samples for the material testing that will be performed at PPPL. The first vacuum pressure impregnation (VPI) and first cure cycle were successfully completed. The sandwich of laminates was removed from the mold and those to be used for turn-turn samples were separated from those for quadrant-quadrant samples. Next, the turn-turn samples will be subject to two additional cure cycles and the quadrant-quadrant samples will be subject to a second VPI and two additional cure cycles. After that, the impregnated glass layers will be removed from the plates to form flat laminates, and test samples will be cut from the laminates. PPPL visited the vendor (CTD) that experienced a setback in production of tensile samples whereby neither the first nor second set of six samples could be removed from the mold. A revised sample design has been developed to prevent recurrence and the remaining sample parts have been shipped back to PPPL for modification. In addition, PPPL will fabricate two new molds, this time from stainless steel to match the coefficient of thermal expansion of the copper samples. As a back-up for tensile testing, additional tensile samples will be cut out from spare area on the laminates being produced at PPPL. Modulus and coefficient of thermal expansion (CTE) tests are CTD are underway with no issues and some preliminary data has been sent to PPPL. Analysis efforts continue to refine the high fidelity and delamination models. The aim is to have the models all working and in alignment using estimated property data so that preliminary findings can be presented at the director's review. Then, once the material test data becomes available, the results will be finalized prior to the Stage 2 review.

Research (S. Kaye):

D. Boyer attended the 2nd International Conference on Data-Driven Plasma Physics in Marseille, France during the week of May 13, and presented an invited talk titled, "Accelerated Predictive Models for Scenario Optimization and Control of Tokamaks."

During the week of May 20, Boyer visited MAST-U to discuss potential areas of collaboration on real-time control development, including profile control, detachment control, shape control, and beam control as well as real-time software and hardware development [A. Thornton, A. Kirk, J. Mitchell, K. Cave-Ayland, G. McArdle]. He also

visited Tokamak Energy to discuss opportunities for collaboration on real-time control and control room visualization tools [O. Asunta, P. Buxton].

During the week of May 27, Boyer attended the 3rd IAEA Technical Meeting on Fusion Data Processing, Validation, and Analysis to present a talk titled, "Real-Time Control and Estimation in Tokamaks with Machine Learning Accelerated Predictive Models."

U.S. ITER FABRICATION (H. NEILSON)

This week the Laboratory's Low Field Side Reflectometer (LFSR) team and ITER Central Team (CT) colleagues reviewed the design status of captive waveguide supports. The term refers to ceiling-mounted structures that must be installed early in the assembly phase to be accessible when LFSR waveguides are installed several years from now. PPPL engineer M.-A. de Looz presented a multi-faceted analysis, examining the option of using a commercial off-the-shelf (OTS) support system proposed by the CT in lieu of the custom design developed by the U.S. team. The OTS system would reduce cost and simplify the construction process, offering benefits in ease of installation, positioning, maintenance, and disassembly. The presentation included a side-by-side comparison of the OTS and custom designs and addressed the behavior of the design as a result of dead weight, operating conditions, fire, and earthquake. Based on the presentation, a consensus was reached to adopt the OTS solution.

ITER & TOKAMAKS (R. NAZIKIAN)

DIII-D (B. Grierson):

Research:

The manuscript titled, "Ablation of solid pellets induced by supra-thermal ions in the far scrape-off layer of DIII-D plasmas" by A. Bortolon et al, has been accepted as a *Nuclear Fusion Letter*. The letter reports results of DIII-D experiments with lithium granule injection in which the injected granules were observed to ablate well before reaching the plasma boundary. The ablation prior to entering the confined plasma is ascribed to the non-negligible beam ion density present in the outboard far scrape-off layer, particularly when auxiliary heating includes counter-current injected neutral beams.

The article, "Feedback control of stored energy and rotation with variable beam energy and perveance on DIII-D" by D. Boyer et al. has been published in *Nuclear Fusion:* https://doi.org/10.1088/1741-4326/ab17f5. The paper describes the first use of DIII-D's recently added capability to modify beam energy and perveance in a feedback control algorithm. The algorithm uses constrained real-time optimization to avoid limits on the magnitude and rate of change of actuators that would lead to beam blocks, and enable

smooth feedback control of stored energy and rotation without the need for pulse width modulation of the beam power.

A. Nelson (PU), E. Kolemen (PU), and M. Austin (UT-Austin) published a description of a novel method to determine the q-profile and magnetic equilibrium of a tokamak discharge using only a single ECE diagnostic in *Plasma Physics and Controlled Fusion*. This work details methods to combine the ECE symmetry constraint with q profile information from multiple magnetic island oscillations on ECE to solve Grad-Shafranov equation to determine an estimate for the plasma equilibrium. Such an approach has important applications not only as added value for existing equilibrium solver techniques, but also as a potential stand-alone process to determine the equilibrium in future tokamaks where diagnostic access may be limited due to high-intensity neutron bombardment. The accepted manuscript is available online here: https://doi.org/10.1088/1361-6587/ab24a4

A. Bortolon has been selected as a recipient of the 2019/2020 Torkil Jensen Award. This award, which consists of up to one day of experimental time on the DIII-D National Fusion Facility sponsored by General Atomics, is given in recognition for outstanding proposals for innovative experiments using the capabilities of DIII-D. Bortolon and co-proposer and award recipient A. Marinoni (MIT-PSFC) devised the experiment titled, “LH power threshold, confinement scaling in carbon plasmas,” in which high-frequency injection of sub-millimeter carbon spheres is used to create and sustain a plasma with carbon concentration ~100%.

International Long Pulse (F. Poli):

W. Choi continued his visit to the Experimental Advanced Superconducting Tokamak (EAST) in China for the week of May 27. In collaboration with EAST colleagues, lower hybrid current drive (LHCD) with electron cyclotron heating (ECH) experiments were performed at low density to avoid an anomalous decrease in LH efficiency previously observed [Li et al, PoP 2016]. The desired outcome is to observe synergistic effects between the two different frequencies of LH as well as EC in both experiment and simulation. Several discharges achieved stable plasma conditions with good diagnostic coverage, which will support numerical validation of LH physics models.

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ADVANCED PROJECTS (D. GATES)

Stellarators (D. Gates)

D. Gates visited the National Institute for Fusion Science (NIFS) on May 24. While there, he met with NIFS research staff members to discuss a variety of issues. In particular, he discussed: 1) NIFS participation in the China First Quasi-symmetric Stellarator (CFQS), 2) issues associated with the planned delivery of a powder dropper to be installed on the Large Helical Device (LHD), and 3) ongoing collaborations with NIFS on stellarator design and optimization.

On May 25, Gates participated in the NIFS 30th anniversary celebration. The event was attended by numerous Japanese dignitaries as well as representatives of the international fusion research community. Gates gave a short speech highlighting the importance of the NIFS-PPPL relationship and the long-standing nature of the interaction.

A manuscript entitled, “Tuning of the rotational transform in Wendelstein 7-X” has been submitted by S. Lazerson and co-authors to *Nuclear Fusion*. This manuscript details experiments performed on Wendelstein 7-X to measure and correct changes in rotational transform caused by elastic deformation of the superconducting coils under electromagnetic loads.

A manuscript entitled, “Development of a Faraday cup fast ion loss detector for keV particle detection” has been submitted by Lazerson and and a co-author to *Reviews of Scientific Instrumentation*. This work details the development and testing of a new type of fast-ion loss detector capable of detecting low energy lost ions. into matter codes. These detectors could eventually be installed in Wendelstein 7-X. This work is part of and supports Dr. Lazerson's early career research award.

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THEORY (S. HUDSON)

Y. Zhou, H. Zhu, and I. Dodin published a paper titled, "Formation of solitary zonal structures via the modulational instability of drift waves" in *Plasma Physics and Controlled Fusion*: https://doi.org/10.1088/1361-6587/ab16a8. The paper employs a novel quantum-like formalism that treats drift waves as "driftons" and shows that their modulational instability can generate zonal structures that propagate in a solitary manner.

COMMUNICATIONS & PUBLIC OUTREACH (A. ZWICKER)

Communications (L. Bernard):

The Office of Communications posted one press release to the PPPL website. It focused on research by L. Gao published in *Astrophysical Journal Letters* into creating for the first time a particular form of coherent and magnetized plasma jet that could deepen the understanding of the workings of much larger jets that stream from newborn stars and black holes. The story was also posted to the *Newswise* and *EurekAlert* press release distribution services.

DIRECTOR'S OFFICE (S. COWLEY)

On May 28, S. Cowley, J. Menard, and Y. Raitses visited Applied Materials (Sunnyvale, California). On May 29, they met with people at SLAC National Accelerator Laboratory (Menlo Park) to discuss possible collaboration opportunities.

On May 31, S. Cowley attended the National Laboratory Directors Council workshop in Denver, Colorado.

This report is also available on the following web site:

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