Weekly HIGHLIGHTS

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

The PPPL Highlights for the week ending June 29, 2019, are as follows:

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

Recovery (R. Hawryluk):

TF Bundle — PPPL's sample fabrication activity is nearing completion. The second vacuum pressure impregnation (VPI) of the quadrant-to-quadrant samples was completed, and samples are being cut from the laminates. Short beam shear (SBS) turn-to-turn sample testing is underway at the Element Materials Technology lab in California; all static tests are complete, with the turn-to-turn cyclic test to come next. After that, the quadrant-to-quadrant tests can begin once the samples are completed and shipped from PPPL. The turn-to-turn tensile sample fabrication (VPI and cure) was successfully completed by Composite Technology Development (CTD) in Colorado, validating the change to the stainless-steel mold and the inclusion of O-rings on the copper parts.

The CTD tensile sample testing is about to begin. Fabrication of the quadrant-to-quadrant copper tensile samples awaits the delivery of copper samples from PPPL to support the fabrication of the sample. Modulus and coefficient of thermal expansion (CTE) tests as well as modulus tests by CTD are complete and preliminary data has been sent to PPPL. The fracture mechanics (FM) sample testing is underway at the PPPL Materials Test Lab. The high-fidelity analysis has been completed to the extent possible with available data and has been documented and submitted for checking. The delamination simulation model continues to be refined. The delamination growth rate calculation awaits the FM data so that it can be finalized, documented, and checked. An interim report is being prepared, and a dry run of the presentation for the director's review was completed. Once the remaining material test data becomes available, the calculations will be finalized prior to the Stage 2 review scheduled for August 7-8.

Central Instrument & Control — The NSTX-U NTC Network Expansion (CWDM) final design review (FDR) was held on June 24. The purpose of the review was to present sufficient information to demonstrate a Course Wave Division Multiplexing (CWDM) design is mature enough to proceed to execution and commissioning. During its last operation period, NSTX-U had nearly exhausted the supply of Ethernet network fibers that provide connectivity for many CI&C, diagnostic, and other systems. It was also determined during the design verification and validation review (DVVR) that adding more penetrations to the gallery wall was undesirable. A more efficient technology of fiber utilization was identified that uses a multiplexed light spectrum and allows up to 16 channels of Ethernet to co-exist on a single fiber optic line. The review was deemed successful, pending resolution of chits.

Personnel Safety System — A preliminary design review (PDR) was held on June 26 for the personnel safety system. The review was held to examine the progress of the design for a new safety system since the conceptual design stage, and included additions and modifications since the CDR. During last year's director's review, it was noted that the existing NSTX-U hardwired interlock system required a redesign in order to be consistent with accelerator community and industrial standards. A peer review was held earlier this year. The review was successful, pending resolution of a small number of chits.

Research (S. Kaye):

Publications

A paper titled, "Experimental and synthetic measurements of polarized synchrotron emission from runaway electrons in Alcator C-Mod," by R. Tinguely, M. Hoppe, R. Granetz, B. Mumgaard, and S. Scott has been accepted for publication in *Nuclear Fusion*.

The paper, "Hollow Pellet Injection for Magnetic Fusion," by Z. Wang, M. Hoffbauer, E. Hollmann, Z. Sun, Y. Wang, N. Eidietis, J. Hu, R. Maingi, J. Menard, and X. Xu was published this week in *Nuclear Fusion*: https://iopscience.iop.org/article/10.1088/1741-4326/ab19eb
Motivated by edge-localized mode (ELM) control in H-mode plasmas, disruption mitigation, and other applications in magnetic fusion, the report details the progress and new possibilities in mass delivery based on hollow pellets. Here, a hollow pellet refers to a spherical shell mass structure with a hollow core. Based on an empirical model of pellet ablation and BOUT++ simulations of the ELM triggering threshold, hollow pellets are found to be attractive in comparison with solid spheres for ELM control. By using hollow pellets, it is possible to tailor mass delivery to certain regions of edge plasmas while minimizing core contamination and reducing the total amount of mass needed.

U.S. ITER FABRICATION (H. NEILSON)

The Low Field Side Reflectometer (LFSR) physics team at design partner General Atomics (GA) has begun testing the effects of a mockup double window and a PPPL-fabricated mockup antenna assembly on frequency-modulated continuous wave (FMCW) reflectometry performance. Data from the window test will quantify effects on beam transmission of the LFSR vacuum window as well as effects due to stray reflections at the antenna. The testing will confirm the capability of the instrumentation, transmission line, and the front-end antenna array in resolving the electron current density in a

realistic ITER geometry. LFSR team leader A. Zolfaghari traveled to GA to take part in the testing and in reviewing the status of GA contract deliverables.

Tolerancing strategies are critical for achieving required aiming accuracy of the LFSR antennas. Statistical methods are being applied toward defining critical tolerances for antenna installation and diagnostic performance. In addition, progress was made this week in resolving water routing interfaces between LFSR and Equatorial Port 11 in preparation for next week's final design review of Port 11 Integration. Agreement between the two design teams will assure adequate water flow properties for both LFSR components and the in-vessel port structure.

E. Nassar and H. Neilson attended the DOE Office of Project Assessment review of U.S. ITER, held June 26-28 at the Project Office in Oak Ridge, Tennessee. Neilson made a presentation summarizing progress in diagnostics design since 2016, the impacts of reduced funding since then, and future plans.

ITER & TOKAMAKS (R. NAZIKIAN)

S. Scott presented a proposal for MSE calibrations at the KSTAR Research Opportunities Forum covering three proposals: a beam-into-gas MSE calibration, a plasma-sweep calibration, and a validation of the use of the background channels in the MSE background polychromator to measure the Zeff profile.

International PMI (R. Maingi):

An experiment to test if real-time boron powder injection into mixed helium-deuterium plasmas in EAST was led remotely by PPPL staff (A. Diallo, R. Maingi, Z. Sun), in collaboration with ASIPP staff (B. Zhang, X. Gong, J. Qian, X. Wei, Y. Qian, and the EAST team). Boron powder injection clearly suppressed ELMs in mixed helium-deuterium plasmas (at approximately a 50/50 mixture) with 5.3 megawatts of radio-frequency heating, and a fine boron injection rate scan identified a clear threshold rate for suppression. Characteristics of a low-frequency edge mode with multiple harmonics were seen in the ELM-suppressed discharges, but not in the ELMy ones, mirroring results obtained by boron powder ELM suppression in deuterium plasmas in May 2019.

The paper, “A Promising High-Confinement Regime for Steady-State Fusion,” by G. Xu, Q. Yang, N. Yan, Y. Wang, X. Xu, H. Guo, R. Maingi, L. Wang, J. Qian, X. Gong, V. Chan, T. Zhang, Q. Zang, Y. Li, L. Zhang, G. Hu, B. Wan, was published this week in *Physical Review Letters.* The research was supported by the US-PRC collaboration on PMI. The paper abstract reads as follows: “A reproducible stationary high-confinement regime with small ‘edge-localized modes’ (ELMs) has been achieved recently in the

Experimental Advanced Superconducting Tokamak, which has a metal wall and low plasma rotation as projected for a fusion reactor. We have uncovered that this small ELM regime is enabled by a wide edge transport barrier (pedestal) with a low-density gradient and a high-density ratio between the pedestal foot and top. Nonlinear simulations reveal, for the first time, that the underlying mechanism for the observed small ELM crashes is the upper movement of the peeling boundary induced by an initial radially localized collapse in the pedestal, which stops the growth of instabilities and further collapse of the pedestal, thus providing a physics basis for mitigating ELMs in future steady-state fusion reactors."

ADVANCED PROJECTS (D. GATES)

Stellarators (D. Gates)

The powder dropper team packed up the latest 4-channel powder dropper ready to go to LHD. This dropper was fabricated in parallel with supporting the NB210 rotation installation. It carries a new powder catcher that extended horizontally and eliminates any throughput leaks, and a new TIV protector that guides the powder in a tube inserted through the open TIV. The unit will be installed on LHD in mid-July and made ready for Aug. experiments. This marks the fourth unit that has been produced for worldwide distribution by the PPPL dropper team. The package was shipped on June 27.

C. Zhu attended the second US/Japan Workshop, "Progress on Advanced Concept Optimization and Modeling in Stellarator-Heliotrons," in Madison, Wisconsin, from June 19 to 21. He presented a talk entitled, "Stellarator designs with permanent magnets," In his talk, he introduced the recent research work at PPPL on designing new stellarators using permanent magnets and simple coils. He showed the design of permanent magnet together with TF coils for a half-Tesla C09R00 configuration. The results demonstrated the feasibility of using permanent magnets to extremely simplify stellarator coils.

S. Lazerson gave a talk at the Wendelstein 7-X (W7-X) Power Balance and Heating Topical Group meeting on June 24. Lazerson presented work using the STELLOPT code to optimize W7-X magnetic configurations for improved turbulent transport, specifically ion temperature gradient turbulence. In these simulations, newly developed capabilities to run STELLOPT on full NERSC Cori nodes were leveraged to conduct simulations scanning the 7-dimensional parameter space of the W7-X superconducting coil set. The talk demonstrated some of the difficulties in interpreting "proxy" values in terms of real physical gains in turbulence. These simulations are being supported by linear runs of the GENE code at the Max-Planck Computational Data Facility system Cobra. This work was done in collaboration with P. Xanthopoulos, J. Proll, and H. Mynick.

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THEORY (S. HUDSON)

D. Schaeffer, W. Fox, J. Matteucci, A. Bhattacharjee, and co-authors published a paper in *Physical Review Letters* titled, "Direct Observations of Particle Dynamics in Magnetized Collisionless Shock Precursors in Laser-Produced Plasmas." Combining measurements of density, temperature, flow speed, and magnetic fields in expanding supersonic laser plasmas, the results show that laboratory experiments can probe particle velocity distributions relevant to collisionless shocks, which can complement similar measurements undertaken by spacecraft.

E. Belova submitted a paper to *Physics of Plasmas* journal titled, "Numerical Simulations of Global Alfvén Eigenmodes Excitation and Stabilization in NSTX-U."

The letter titled, "Self-driven current generation in turbulent fusion plasmas," by W. Wang, T. Hahm, E. Startsev, S. Ethier, J. Chen, M.G. Yoo and C.H. Ma, has been published in *Nuclear Fusion.* Results show that plasma self-generated current plays a fundamental role in magnetic fusion.

DIRECTOR'S OFFICE (S. COWLEY)

On June 24, S. Cowley presented the PPPL Annual Laboratory Plan (ALP) and C. Ferguson presented the PPPL Campus Plan to the U.S. Department of Energy Office of Science at DOE headquarters at the James V. Forrestal Building in Washington, D.C. J. Menard and K. Fischer also attended the meeting.

On June 25, S. Cowley hosted a PPPL all-hands meeting to discuss the results of our annual laboratory and campus plans that were presented to the U.S. Department of Energy Office of Science on June 24.

On June 26 and 27, C. Ferguson visited Oak Ridge National Laboratory to observe the independent project review of U.S. ITER.

This report is also available on the following web site:

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