Weekly HIGHLIGHTS

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

The PPPL Highlights for the week ending June 22, 2019, are as follows:

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

Recovery (R. Hawryluk):

TF Bundle — Fabrication continues on samples for the material testing that will be performed at PPPL. The turn-turn samples were cut from the laminates. The short beam shear (SBS) samples were sent to the Element Materials Technology lab in California for testing. The fracture mechanics (FM) samples are being prepared for testing at the PPPL Materials Test Lab. The second vacuum pressure impregnation (VPI) of the quadrant-quadrant samples was completed and the final two cure cycles are underway. The PPPL machine shop completed the machining of the stainless steel molds and modified Cu parts for tensile test samples, and the parts have been received by Composite Technology Development (CTD) in Colorado so that the tensile sample fabrication and testing can proceed. 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. 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 included in an interim report and 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 scheduled for August 7 and 8.

Inner PF Coil — The inner PF coil fabrication kick-off meeting with the vendor was held on June 21, signaling the start of developing the tooling for this part of the project.

Research (S. Kaye):

Publications — The paper, "Modeling of high harmonic fast wave scenarios for NSTX Upgrade," by N. Bertelli, M. Ono, and E.F. Jaeger was published in *Nuclear Fusion*. By making use of the full wave code AORSA, this work explores different HHFW scenarios for two possible antenna frequencies (30 and 60 MHz) and with and without NBI. The impact of the hydrogen species is also studied showing that, for hydrogen concentration below 2%, the hydrogen absorption is not significant. However, a larger hydrogen concentration could open up new HHFW heating scenarios in NSTX-U. A copy of the paper can be found in https://iopscience.iop.org/article/10.1088/1741-4326/ab1d7f/pdf

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U.S. ITER FABRICATION (H. NEILSON)

A period of intense interactions between the Laboratory's and the Russian Federation's (RF) ITER Diagnostics teams continued with a focus on finalizing interface details between the Low Field Side Reflectometer (LFSR) in-vessel assembly and the enclosing port structure. Both systems are currently in final design, with final design reviews planned in the near future. Since both systems will experience intense volumetric heat loads from fusion neutrons, both are designed with dense networks of water cooling passages throughout their volumes, therefore pipe connections between the two systems' cooling networks are required. Choosing an optimal location for these connections within a complex network inside the port plug involves multiple factors including access for remote maintenance tooling, management of water flow through parallel paths, and minimization of costly re-design. This week, the Laboratory's LFSR team, working with detailed models of both systems, developed a solution that can satisfy all requirements, and forwarded its proposal to the RF team. Further meetings are planned as necessary to reach agreement on a mutually acceptable solution.

ITER & TOKAMAKS (R. NAZIKIAN)

DIII-D (B. Grierson):

Research:

Experiments lead by J.-K. Park, N. Logan, and Q. Hu were conducted at DIII-D this week. The experiments tested a number of physics hypothesis that potentially explain error field (EF) data from COMPASS & KSTAR that do not conform to the EF penetration threshold scaling developed to estimate tolerances for non-axisymmetry in ITER. The data pushed DIII-D ohmic densities further than any previous EF scan had obtained. At these extreme densities, the EF threshold scaling with density did indeed change sign (higher densities disrupted with lower EFs). H-modes with marginal power above the LH threshold were also investigated and showed a high tolerance to EFs. This high tolerance is presumably due to low plasma amplification of the external EF. Detailed analysis of these DIII-D discharges will provide important information for the predicted tolerances of future ITER L and H mode scenarios.

R. Maingi visited DIII-D for planning of upcoming powder dropper and granule injector experiments. Maingi also gave a talk at the DIII-D Friday Science Meeting with the title, "ELM suppression by boron powder injection in EAST."

ITER-JET (F. Poli):

M. Podestà and P. Bonofiglo visited Culham, U.K., the week of June 17 to discuss status and plans of the KA2 fast ion loss detector installed on JET. The system is routinely acquiring data during the JET recommissioning phase for the FY19 experimental campaign. Data were acquired in piggyback during discharges with combined NB and RF injection, showing qualitative correlations with RF pulses. P. Bonofiglo will be on site at JET for the next few weeks to operate the diagnostic and participate to JET experiments on energetic particle physics, in preparation for the FY20 D-T campaign. M. Podestà also discussed ongoing activities on modeling of JET discharges for EP studies.

ADVANCED PROJECTS (D. GATES)

Stellarators (D. Gates)

This week, N. Pablant implemented an important correction to the ion temperature measurements on W7-X from the XICS diagnostic. The development of this correction was enabled by the strong collaboration between PPPL, Auburn University, and the Max Planck Institute for Plasma Physics. The correction is based on the development of the X-ray ray-tracing code XICSRT (developed by Auburn University graduate student J. Kring, RSI 2018), and captures the instrumental response of the system and importantly reveals several subtle analysis errors. This correction results in a reduction of the ion temperature (Ti) from XICS by ~200 eV. The correction brings the XICS diagnostic measurements into general agreement with the CXRS system at W7-X (within the current systematic errors of the CXRS system). The details of this correction and comparison to CXRS will be reported at the next ITPA Diagnostics meeting in November.

A project to develop novel Faraday cup fast ion loss detectors for Wendelstein 7-X (W7-X) had a successful PDR on Tuesday June 18. The project, led by S. Lazerson as part of his Department of Energy early career research award, presented a plan to procure, test and deliver sensors to W7-X. The plan was presented by J. Ilagan, who developed the engineering design. These sensors are an evolutionary improvement upon previously tested prototypes. The new design incorporates a stepped pyramid design for electrical contacts which will improve manufacturability. Additionally, the new sensor will have five conducting layers, two of which will test the vendors capability to deposit 500 Angstrom layers, while the other three rely on their already demonstrated 1000 Angstrom layer thickness.

C. Zhu attended the 2nd US/Japan Workshop on “Progress on Advanced Concept Optimization and Modeling in Stellarator-Heliotrons,” held in Madison, Wisconsin, June 19 to 21. He presented a talk entitled, “Stellarator designs with permanent magnets.”

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 NCSX C09R00 configuration. The results demonstrated the feasibility of using permanent magnets to simplify stellarator magnets.

THEORY (S. HUDSON)

M. Churchill attended the 3rd IAEA Technical Meeting on Fusion Data Processing, Validation and Analysis in Vienna, Austria, May 28-31. Churchill served on the planning committee and chaired the deep learning session. He also presented two talks: "A Framework for International Collaboration on ITER Using Large-Scale Data Transfer to Enable Near Real-Time Analysis" and "Deep Convolutional Neural Networks for Long Time Series Classification."

Churchill also gave a talk at the Princeton University TensorFlow and PyTorch User Group Kickoff Meeting on June 13 entitled, "Training deep convolutional neural networks for classification of multi-scale, nonlocal data in fusion energy, using the PyTorch framework."

P. Fan and H. Qin published a paper that generalizes the standard field theory in theoretical physics to particle-field systems for plasma physics; it was published on June 17 in *Physics of Plasmas*. As an application, the well-known momentum conservation law for the Vlasov-Darwin system given by Kaufman and Rostler in 1971 was shown to be incorrect, and the correct momentum conservation law was derived systematically using the generalized field theory.

On June 12, I. Dodin gave a plasma theory seminar at the University of Maryland titled, "Understanding the dynamics of zonal flows through quantum-like modeling of drift-wave turbulence." The seminar is related to the research done together with Y. Zhou (PPPL) and H. Zhu (Princeton University).

DIRECTOR'S OFFICE (S. COWLEY)

On June 18 and 19 J. Menard participated in the International Energy Agency Technical Collaboration Program (IEA TCP) Universal Meeting in Paris, France. On June 20 and 21, he made a site visit to ITER in Cadarache, France.

This report is also available on the following web site:

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