Weekly HIGHLIGHTS

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

The PPPL Highlights for the week ending October 27, 2018, are as follows:

NSTX-U RECOVERY AND RESEARCH (J. MENARD)

Recovery:

Vacuum Vessel — A conceptual design review (CDR) was held on Oct. 25 for the PF-4/5 vacuum vessel coil supports. The CDR examined the design, fabrication, and procurement of a re-positioning system that will realign the PF-4/5 supports according to project specifications. The CDR was also held to verify that the proposed realignment strategies were ready to progress to the next design phase and achieve key performance parameter (KPP) goals. The CDR was deemed successful, pending resolution of chits.

Management — On Oct. 26, Project Manager R. Feder presented the new organization structure for the NSTX-U Recovery Project. Effective Nov. 1, the newly created Associate Project Manager (APM) role will act as a Control Account Manager (CAM) for each assigned scope of work. The new organization structure will allow the project to be more responsive to its stakeholders and to project teams as it moves toward a CDE-2/3A review.

Central Instrumentation & Controls (CI&C) — The installation procedure for the data acquisition room (DARM) to the NSTX-U test cell course wave division multiplexing was approved this week. Work to install the test system will commence with assistance from ITD network engineers. The Phase 3 CAMAC (Computer-Automated Measurement and Control) replacement pilot work has concluded this week with LabView software and a procedure tested and accepted. National Instruments CDAQ equipment has been deemed a viable CAMAC replacement technology outside of the NSTX-U test cell and will undergo further testing in the NTC utilizing the aforementioned procedure once operations resume.

Research:

Presentations — J. Menard, L. Delgado-Aparicio, A. Diallo, N. Ferraro, M. Podesta, F. Poli, and R. Maingi attended the 27th Annual IAEA Fusion Energy Conference in Ahmedabad, India, Oct. 22-27. Menard presented the following papers: “Overview of Recent Progress in Understanding NSTX and NSTX-U Plasmas,” and “Overview of New MAST Physics in Anticipation of First Results from MAST Upgrade,” (rapporteured overview presentation by S. Kaye and J. Harrison), “NSTX-U Theory and Modeling Results,” (overview poster by S. Kaye), “Fusion Energy Development Applications Utilizing The Spherical Tokamak and Associated Research Needs and Tools,” (overview poster by J. Menard), “Electromagnetic Particle Injector (EPI) as a Fast Time Response Disruption Mitigation Concept,” (poster by R. Raman), and “Overview of the NSTX-U

Recovery Project Physics and Engineering Design," (poster by S. Gerhardt).

At the same conference, Delgado-Aparicio presented the paper, "Rotation-Induced Electrostatic-Potentials and Density Asymmetries in NSTX," and A. Diallo presented "ELMs Onset Triggered by Mode Coupling Near Rational Surfaces in the Pedestal." N. Ferraro presented the papers, "Nonlinear 3D Simulations of Vertical Displacement Events in Tokamaks," (poster by I. Krebs), and "Error Field Impact on Mode Locking and Divertor Heat Flux in NSTX-U." R. Maingi presented, "Amelioration of Plasma-Material Interactions and Improvement of Plasma Performance with a Flowing Liquid Li Limiter and Li Conditioning on EAST," and "Experiments on FTU with a Liquid Tin Limiter," (poster by G. Mazzitelli). M. Podesta presented the papers, "Reduced Energetic Particle Transport Models Enable Comprehensive Time-Dependent Tokamak Simulations" and "Global Alfven Eigenmode Stability Dependence on Fast-Ion Distribution Function," (poster by E.D. Fredrickson). F. Poli presented, "The ITER Plasma Current Termination Phase: Physics Constraints on Control" and "Effects of Microtearing Modes on the Evolution of Electron Temperature Profiles in High Collisionality NSTX Discharges," (poster by T. Rafiq).

S. Sabbagh gave the presentation, "Disruption Event Characterization and Forecasting (DECAF) in Tokamaks," at the 27th IAEA Fusion Energy Conference. The poster showed analysis of data from NSTX, MAST, and KSTAR on automated, detailed physics-based disruption event chain characterization along with single event characterization from large databases for these devices (several thousands of shot-seconds).

Publications — The paper, "High-Field-Side RF Injection for Excitation of Electron Bernstein Waves," by R. Yoneda, et al., was published on-line in *Plasma and Fusion Research*. This work was performed under the QUEST/NSTX-U collaboration.

The paper, "Divertor leg filaments in NSTX-U," by F. Scotti, et al., was published in *Nuclear Fusion*. The paper presents the first observation of divertor-localized turbulence in the NSTX-Upgrade.

Collaborations — J. Menard represented NSTX-U and other U.S. STs at the 12th IEA ST Technology Collaboration Programme Executive Committee Meeting held Oct. 26 at the Mahatma Mandir convention center concurrent with the IAEA Fusion Energy Conference.

Researchers at Bridge12 Technologies, a small business company based in Massachusetts, and a UC-Davis team led by N. Luhmann are designing a compact 10 W, 693 GHz gyrotron oscillator to serve as the source for the high-k scattering diagnostic system. This work is being supported by the DOE through a Small Business Innovation Research (SBIR) grant to Bridge12 in collaboration with UC-Davis. The gyrotron system will occupy about a quarter of the space as the optically pumped FIR

laser system and provide more than 100 times the power for the diagnostic. The innovative gyrotron system is being designed to operate in the third cyclotron harmonic to use a conventional niobium titanium superconducting magnet. In a future Phase II project, the team will fabricate and test the device at Bridge12 to demonstrate that such a system will be useful for NSTX-U and other plasma diagnostic experiments in magnetic fusion experiments around the world.

U.S. ITER FABRICATION (H. NEILSON)

This week, A. Basile and H. Neilson, joined by D. Rasmussen of the U.S. ITER Project Office, visited the ITER project site in St. Paul lez Durance, France, to discuss the PPPL-led ITER Low Field Side Reflectometer (LFSR) project. In a series of meetings with ITER Central Team colleagues, the visitors discussed preparations for the LFSR preliminary design review (PDR), scheduled for Nov. 7-8. The PDR agenda was finalized in a meeting with the review chair. All deliverables have been submitted and are either approved or in review; a few are under revision to address Central Team comments and the status of those deliverables was reviewed. Discussions with the Central Team diagnostics, instrumentation and control, design integration, and safety teams supported the assessment that the PDR project is well prepared for the November PDR.

A recent Central Team proposal calls for relocating the U.S. core imaging X-ray spectrometer (CIXS) from equatorial port 17, the current baseline, to equatorial port 2. Although the change is proposed as part of an optimization to improve other capabilities, it may offer advantages for CIXS as well, reducing risks for some of its measurement requirements. B. Stratton, J. Klabacha, and K. Hill attended a meeting in which Central Team diagnostics colleagues presented the reasons for the proposed change. While the U.S. is not currently authorized to work on the CIXS system, it was agreed that the Central Team would perform an initial study of integrating the CIXS in equatorial port 2, including provisions to improved the capability for measurements near the plasma edge. Further meetings are planned to keep the PPPL team informed of progress and to assess the new configuration.

The Laboratory's ITER Diagnostics team received a briefing by F. Levinton and M. Galante from Nova Photonics summarizing Nova's work mirror cleaning for the past year. The team reported success in removing tungsten and aluminum deposited on a stainless-steel substrate using a radio-frequency-generated neon or helium discharge, but noted that substrate material is also removed. A final report is in preparation.

Weekly HIGHLIGHTS

PPPL PRINCETON PLASMA PHYSICS LABORATORY

U.S. DEPARTMENT OF ENERGY

ITER & TOKAMAKS (R. NAZIKIAN)

International PMI (R. Maingi):

Two impurity powder droppers (IPD) have started fabrication at General Atomics by D. Mauzey under the leadership of A. Nagy. One IPD is being built for LHD and the other for DIII-D. The main components of the dropper assemblies have been assembled and about half of the vacuum components have been received. These IPDs will be delivered to LHD and DIII-D in the spring of 2019.

The manuscript titled, "A Multi-Species Powder Dropper For Magnetic Fusion Applications," by A. Nagy et al., has been published in *Review of Scientific Instruments*. The article describes the working principles, main design features and calibration techniques of the impurity powder dropper (IPD) recently developed by PPPL at General Atomics. The device allows controlled injection of a variety of materials in powder form including lithium, boron, boron nitride and silicon. Dedicated IPD systems are presently installed on ASDEX-Upgrade, DIII-D, EAST and KSTAR, where they have been and will be used to investigate novel solutions in the areas of wall conditioning, divertor power exhaust and pedestal control.

R. Maingi presented a rapporteured oral at the IAEA Fusion Energy Conference on flowing-liquid-metal limiter results from EAST and FTU. The title of the EAST portion was, "Amelioration of plasma-material interactions and improvement of plasma performance with a flowing liquid Li limiter and Li conditioning on EAST." Maingi also chaired a session on fusion technology. R. Lunsford also presented an oral at the same conference, "Active conditioning of ASDEX-Upgrade tungsten PFCs through boron particulate injection."

DIII-D Research (B. Grierson)

Seven first-author contributions to the 2018 IAEA FEC meeting were presented on material from the PPPL DIII-D collaboration. A highlight oral presentation was given by M. Podesta on comprehensive time-dependent predictive simulations of energetic particle transport in DIII-D and NSTX-U using reduced fast-ion transport models integrated into TRANSP. Podesta's presentation is the capstone to the notable outcome in support of the FES JRT on the validation of fast-ion transport models. A new result presented at the IAEA is that there is a synergistic effect of fishbones and TAEs on fast-ion transport that is captured by the fast-ion kick model developed by Podesta. Poster presentations were given by D. Boyer on the use of variable beam energy for plasma control, A. Diallo on magnetic instabilities at the pedestal top, B. Grierson on rotation profile hollowing in ITER baseline conditions driven by Reynold's stress, R. Hager on density pumpout induced by RMPs in coupled gyrokinetic-(XGC) and MHD simulations, F. Laggner on the universality of inter-ELM fluctuations from DIII-D and ASDEX-Upgrade

data, and M. Okabayashi on tearing mode entrainment by external magnetic perturbations.

A. Bortolon presented a seminar at the Department of Nuclear Engineering of the University of Tennessee at Knoxville titled, "Real-time wall conditioning through low-Z dust injection in tokamak plasmas," reviewed the wall conditioning principles and most established techniques, and showed results of recent experiments on real-time wall conditioning with boron dust injection in ASDEX-Upgrade and DIII-D. The seminar was part of the Guest Plasma Lectures series, intended to increase the UTK students' exposure to active fusion research being carried out by experts in the field from around the world.

DIII-D Operations and Control (A. Nagy, K. Erickson):

PPPL engineer K. Erickson, working with A. Glasser and E. Kolemen, has made progress in the implementation of a real-time version of the DCON MHD stability code. The project goal is to develop a real-time computation of delta_W and delta_prime on the DIII-D plasma control system. The previous parallelized implementation of DCON was unsuitable for real-time calculations. The code has been reengineered, including a new method for handling threads and additional optimizations to reduce computational overhead. The original code ran in approximately 15 seconds. The PCS version now runs in 500 ms and further tune ups are planned to get this down to 250 ms in FY19.

The cantilever shelf support structure for the 210 offaxis beam project is now being welded in situ and is about 50% complete. Nagy leads the engineering construction effort for the off-axis beam project. The welding is expected to finish by Nov. 13. Double shifts and weekend work are being evaluated to regain schedule delays.

Nagy and his team successfully tested old RF dummy loads on the new ~500 MHz Helicon system. The tests showed low reflections, indicating the suitability of the loads for use in the system. Existing 9-inch coaxial transmission line was tested and also found to be suitable for the Helicon system, as well as high-power feed-throughs salvaged from the mothballed Fast Wave system. Nagy led the assessment of these old components and the positive test results have resulted in major savings for the project.

International Scenarios and EP Physics (F. Poli, M. Podesta):

F. Poli attended the IAEA FEC meeting to present a poster on a joint ITPA-IOS activity on the modeling of the plasma current ramp-down phase in ITER for safe, controlled plasma termination with reduced disruptivity. The joint activity aims at developing a plasma termination scenario that is vertically stable over a range of parameters including impurity fraction and the density/auxiliary power step down. Simulations with DINA, CORSICA, TRANSP and JINTRAC are compared with different physics assumptions.

JINTRAC simulations indicate that Neon seeding is needed for maintaining acceptable divertor power loads. TRANSP simulations indicate that NTMs may be difficult to control in the current ramp down phase while in H-mode. Initial comparison between the codes indicates that ramping down the plasma current after the H-L back transition may have advantages.

JET

An important step in preparing for JET DT experiments is adequately simulating target plasmas in deuterium and then using these validated models to develop optimized DT scenarios. An important activity for JET modeling is reproducing the evolution of the current profile during the dynamically evolving period of the current ramp-up phase. TRANSP simulations show that the predicted central safety factor in JET ITER-like baseline plasmas can drop below unity during the current ramp-up, in contrast to experiment where sawteeth begin to appear in the current flattop. A. Teplukhina, a PPPL postdoc, is working on improving the simulations of the current profile evolution by combining available data in the current ramp with analytic profiles. She has been successful in slowing the drop in the simulation's central safety factor, but experimental and modeling uncertainties remain. Efforts are ongoing to improve these simulations.

Machine Learning and Control (W. Tang, E. Kolemen):

E. Kolemen gave a talk at IPP, Munich, Germany, on the physics and machine-learning based approaches to stability control and disruption avoidance. He attended the ITPA in Napoli, Italy, and gave a talk on how these approaches can be improved to satisfy the needs of ITER. He will be giving an invited talk at APS DPP on this topic. He will give an invited talk at the MHD workshop on data-based approaches to stability analysis and control.

THEORY (S. HUDSON)

The paper, "Direct observation of nonlinear coupling between pedestal modes leading to the onset of edge localized modes," which was authored by A. Diallo, J. Dominski, K. Barada, M. Knolker, G. J. Kramer, and G. McKee, was accepted on Oct. 22 by *Phys. Rev. Lett.*

A paper titled, "Relativistic-electron-driven magnetic reconnection in the laboratory," was published in *Phys. Rev. E* on Oct. 24. PPPL co-authors include C. Dong, A. Bhattacharjee, and W. Fox.

On Oct. 22, F. Ebrahimi was invited to present the Fifth Annual Dalton Schnack Memorial Seminar at the Physics Department University of Wisconsin-Madison, entitled "Three-dimensional coherent plasmoids in current-carrying plasmas." During the same visit, Ebrahimi presented a second invited talk at the Center for Plasma Theory and

Computation, entitled, “Instability-Driven Large Scale Magnetic Fields in Flow-Dominated Astrophysical Plasmas.”

SITE PROTECTION (M. COHEN)

Platoons completed their annual physical agility testing. Annual testing of fire hose and ground ladders was completed. All SPD and ESU personnel completed lock-out/tag-out training. Engine 66 responded to two mutual aid assignments in Princeton Township.

COMMUNICATIONS & PUBLIC OUTREACH (A. ZWICKER)

S. Greco, science education program leader in the Science Education Department, arranged for three PPPL volunteers — C. Smiet, J. Ilagan, and V. Skoutnev — to represent PPPL at National Chemistry Week in Frick Laboratory on campus. The theme was outer space, so the team demonstrated plasmas and connected them to space propulsion, fusion energy for a colony, and using spectra to study the cosmos.

DIRECTOR’S OFFICE (S. COWLEY)

On Oct. 24, S. Cowley and D. Gates hosted a meeting at PPPL, with the University of Wisconsin to discuss stellarators.

From Oct. 22-27, M. Zarnstorff and R. Hawryluk attended the International Atomic Energy Agency (IAEA) conference in Gandhinagar, India. This conference aims to provide a forum for the discussion of key physics and technology issues as well as innovative concepts of direct relevance to the use of nuclear fusion as a source of energy.

D. Carle and T. Brog attended a Campus Strategy meeting at Brookhaven National Laboratory on Oct. 23-25. R. Hawryluk participated remotely. Brog attended the Office of Science COO meeting, also held at Brookhaven National Laboratory, and Hawryluk participated remotely.

This report is also available on the following web site:

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