Weekly HIGHLIGHTS

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

The PPPL Highlights for the week ending September 8, 2018, are as follows:

NSTX-U RECOVERY AND RESEARCH (J. MENARD)

Recovery:

Director's Review — The NSTX-U Recovery Project Director's Review was held Sept. 5-7 at PPPL. The recovery team participated in two days of plenary and breakout presentations and discussions with the review committee, and the third day was used for review committee debrief report writing and presentation to the NSTX-U team. The 15-person review committee evaluated the recovery project's readiness to proceed to a project baselining review. The Director's Review is the fourth of five NSTX-U Notable Outcomes successfully completed in FY2018.

Research:

Collaborations — N. Bertelli and M. Ono attended the 2018 US-EU-Japan RF Heating Technology Workshop / US-Japan Workshop on RF Heating Physics in Gotemba Kogen, Shizuoka, Japan, Sept. 4-7, 2018. Bertelli presented a talk entitled, "The Effect of the Hydrogen Species on the HHFW Performance in NSTX/NSTX-U Plasmas," and a second talk on behalf of Eun-Hwa Kim, entitled "Full-Wave Simulations of High Harmonic Fast Wave in the Scrape-Off Layer of NSTX." Ono presented a talk entitled, "Modeling of 2nd Harmonic ECH and ECCD Solenoid-free Start-up Experiment in QUEST."

U.S. ITER FABRICATION (H. NEILSON)

A paper by G. Kramer, E. Valeo, A. Zolfaghari, and N. Bertelli titled, "Antenna-plasma coupling calculations for the ITER low-field-side reflectometer," was accepted for publication in the journal *Nuclear Fusion*. The paper reports on LFSR coupling studies using the hybrid 3D reflectometer simulation code FWR3D, in which full-wave, paraxial, and free-space solvers are used for speed and accuracy. Reflections from equilibrium plasma density profiles were simulated to study and optimize the power that is coupled to the receiving antenna. At optimal coupling, the effects of density fluctuations were also calculated, showing that the density fluctuations decrease the average coupling by as much as 6 dB. This study indicates that after some minor changes to the location of the proposed antennas, the antenna-plasma coupling of the ITER LFSR is sufficient to design and build a reflectometer system that meets ITER requirements.

Prototyping and design work on the data acquisition and analysis portion of the upper visible and infrared viewing system is progressing under a subcontract with Bertin Technologies. Revisions of the Instrumentation and Controls (I&C) System Requirements Specification (SRS) and System Design Specification (SDS) documents have been

reviewed by the ITER CODAC group and their substantial feedback is currently being evaluated by Bertin. The progress made on the analysis prototype will be the subject of a paper and poster presentation at the upcoming 30th Symposium on Fusion Technology (SOFT) in Giardini Naxos, Italy.

ITER & TOKAMAKS (R. NAZIKIAN)

A paper by Jong-Kyu Park, et al., titled, "3D field phase-space control in tokamak plasmas" appeared online in *Nature Physics* on Sept. 10. The paper outlines a highly successful principle for optimizing resonant 3D fields for the control of MHD instabilities in tokamaks. Further information can be found in the following links as well as on the PPPL home page and FES web highlights: https://doi.org/10.1038/s41567-018-0268-8, https://doi.org/10.1038/s41567-018-0281-y

Machine Learning (W. Tang):

W. Tang visited San Diego from Aug. 27-30. He presented a plenary talk titled, "Deep Learning Acceleration of Progress Toward the Delivery of Fusion Energy" at the NSF San Diego Supercomputing Center (SDSC) at the University of California-San Diego (UCSD). He was hosted by M. Norman, SDSC Director and Distinguished Professor of Physics at UCSD, and had stimulating discussions on potential future collaborations with Norman and machine learning experts at SDSC. He also visited General Atomics, where he had productive collaborative discussions on the deployment of Princeton's new multi-machine deep-learning disruption predictor on the DIII-D plasma control system.

DIII-D (B. Grierson):

Research:

A new paper by A. Nagy, et al. entitled, "A Multi-Species Powder Dropper For Magnetic Fusion Applications" has been accepted for publication in *Review of Scientific Instruments*. This paper details a new device for controlled injection of impurities (boron, boron nitride, carbon) in powder form. The system implements four independent feeder units arranged to share a single drop tube. Each unit advances the powder by piezoelectric agitation, at a speed proportional to the applied voltage, until the powder is delivered into the drop tube. A calibrated LED flowmeter measures the drop rate during operation. The fast time-response of the four feeders and the control systems allow for combinations of steady and pulsed injection of powders in a single discharge.

A. Ashourvan gave a DIII-D Friday Science Meeting talk on gyrokinetic analysis of ELM-suppressed- and grassy-ELM-regime plasmas recently observed in DIII-D high-beta

poloidal hybrid plasmas, and published by R. Nazikian et al. in the journal *Nuclear Fusion* (https://doi.org/10.1088/1741-4326/aad20d). During ELM suppression, the pedestal has a typical Tanh structure, but during grassy ELMs the pedestal can exhibit local flattening in the electron density near the bottom of the Er well. Ashourvan uses the new C-GYRO code to show that the flat density region in the middle of the pedestal is unstable to trapped electron modes (TEMs). Nonlinear simulations show that the TEMs can produce sufficient particle transport to account for the flattening in the density profile. These conditions can occur in wide pedestal plasmas when the ExB shear is no longer sufficient to suppress electrostatic instabilities.

Operations:

This week T. Raines (a new PPPL engineer at DIII-D) presented a successful preliminary design review for the helicon transmission line in the DIII-D pit. The helicon coaxial lines will connect waveguide switches to the vacuum feed-throughs at the vessel. Taylor will prepare for a final design review, to be held in a few weeks.

The Probe-Mounted Particle Injector (PMPI) developed by the A. Nagy and his team at General Atomics (GA) has been shipped to W7-X in Germany. It will be used to launch boron carbide powder into the W7-X plasma for wall-conditioning purposes. The PMPI design uses piezo motors to agitate the powder onto an eight-paddle wheel, providing 2.6-hertz pulses of powder. The paddles are made of a plastic called PEEK and spring forward after they are dragged through a vibrating trough filled with powder. This causes the paddle to fling powder through an orifice into the plasma. If this unit works well for wall conditioning, then a vertical drop version will be forthcoming. A paper and poster are being presented at SOFT on this device.

On Aug. 7, C. Ciummo, A. Brooks and I. Zatz of PPPL visited GA to review existing and upcoming collaborations. PPPL has already delivered an absolute collimator, calorimeter sets, and multiple sets of pole shields for DIII-D's neutral beams. All of these components have already been in successful operation or are being installed during the current maintenance period. PPPL is in the process of fabricating additional calorimeter sets to be delivered this fall. In addition, PPPL has begun a new collaboration on the toroidal field reversing switches. A. Nagy hosted the visit, which was very productive and provided an opportunity to introduce Ciummo and Brooks, who are assuming responsibility for these efforts, to the DIII-D staff.

International PMI (R. Maingi):

A video conference for final planning of KSTAR powder dropper experiments between PPPL and NFRI colleagues was held on Sept. 6, with participants A. Bortolon, A. Diallo, E.

Gilson and R. Maingi from PPPL and H. Lee from NFRI. The experiments have three goals: wall conditioning, divertor power dissipation, and pedestal enhancement.

International Long Pulse (F. Poli):

A goal of the PPPL-KSTAR collaboration during the 2018 campaign is to understand the causes of Alfvén eigenmode suppression with central ECH in high-beta poloidal plasmas in KSTAR. Data has been exchanged between NFRI and PPPL researchers on profile changes associated with Alfvén mode suppression in KSTAR. Similar discharges obtained in hybrid experiments on DIII-D by R. Nazikian and C. Petty also show Alfvén eigenmode suppression using central ECCD. By comparing the DIII-D and KSTAR data, the research team hopes to develop a deeper understanding of the physics of Alfvén eigenmode suppression with central ECH/ECCD. The results of the analysis will be used to validate reduced fast ion transport models in hybrid plasmas and to guide high-poloidal-beta and energetic particle physics experiments in KSTAR planned for Nov.

International 3D (J.-K. Park):

R. Nazikian, N. Logan, and J.-K. Park participated remotely in joint PPPL-KSTAR planning meetings to develop experimental proposals for upcoming KSTAR run days with 3D fields. Logan and Park discussed plans to predict and test the profile dependence of core mode locking and edge-ELM suppression in KSTAR. Nazikian and Park discussed plans to explore n=1 ELM suppression in high-beta poloidal hybrid plasmas in KSTAR experiments planned for Nov. and Dec. Kinetic equilibria of KSTAR hybrid plasmas will be provided to PPPL researchers for GPEC analysis.

KSTAR Disruption and Control (S. Scott):

On Monday, the NFRI/PPPL MSE team performed a beam-into-gas calibration of the MSE Background Polychromator, which was fabricated over the winter and installed at KSTAR this spring. This task follows a successful beam-into-gas calibration of the existing KSTAR diagnostic last week. The calibration consisted of so-called “filter-offset” scans at each of four values of toroidal field, in which the center wavelength of the diagnostic’s optical filters were successively moved relative to the wavelength of the beam-generated MSE spectrum. Five beam pulses were obtained in each ~15 second shot, yielding data at each of five different magnetic-field pitch angles. Technically, the run was a complete success: TF, PF, and beam performance were all flawless (150 requested beam pulses, no failures). The originally-requested shot list was completed 45 minutes ahead of schedule, which allowed time for a bonus run at interleaved PF values, which may improve interpolation accuracy.

Weekly HIGHLIGHTS

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

THEORY (S. HUDSON)

The Fusion Power Associates (FPA) Board of Directors has selected N. Fisch for its 2018 Distinguished Career and Leadership Awards. FPA Distinguished Career Awards have been given annually since 1987 to recognize individuals who have made distinguished lifelong career contributions that have benefited fusion energy development. N. Fisch is recognized "for your many years of dedication to plasma science and its applications in many fields and to advancing the prospects for fusion power, and especially for your decades of career contributions as a scientist and your role as an educator of a generation of younger scientists, upon whose shoulders the future of plasma science and fusion depends."

On Aug. 27, T. Stoltzfus-Dueck presented an invited talk titled, "Intrinsic rotation in axisymmetric devices," at the Joint Varenna-Lausanne International Workshop on the Theory of Fusion Plasmas. The talk pedagogically reviews the fundamentals of intrinsic rotation in tokamaks, including both experimental observations of edge and core intrinsic rotation, as well as theoretical fundamentals such as momentum conservation, symmetry-breaking, and the relation of nontrivial rotation profiles with nondiffusive momentum fluxes.

On Aug. 30, F. Ebrahimi presented an invited talk titled, "Three-dimensional coherent plasmoids in current-carrying plasmas" at the Max Planck Institute for Solar System Research, Göttingen, Germany.

Ebrahimi also presented a talk titled, "Onset and nonlinear relaxation of reconnecting current-carrying edge filaments during transient events in tokamaks" at the magnetic reconnection workshop held this week (Sept. 4-8) at the Princeton Center for Theoretical Sciences: (https://sites.google.com/a/pppl.gov/magnetic-reconnection-in-space-solar-astrophysical-and-laboratory-plasmas-mr2018/conference-schedule)

OFFICE OF ACADEMIC AFFAIRS (N. FISCH)

C. Swanson successfully earned his Ph.D. on Sept. 5 by presenting his thesis project titled, "Measurement and Characterization of Fast Electron Creation, Trapping, and Acceleration in an RF-Coupled High-Mirror-Ratio Magnetic Mirror." His committee members were S. Cohen, I. Kaganovich (Chair), and Y. Raitses. His adviser was S. Cohen.

ENGINEERING (V. RICCARDO)

A. Khodak and co-authors P. Titus, T. Brown, and J. Klabacha received approval for their DCLL paper titled, "Numerical Model of Dual-Coolant Lead-Lithium (DCLL) Blanket" for publication in the *Journal of Fusion Engineering and Design*.

Weekly HIGHLIGHTS

PPPL PRINCETON PLASMA PHYSICS LABORATORY

U.S. DEPARTMENT OF ENERGY

COMMUNICATIONS & PUBLIC OUTREACH (A. ZWICKER)

Communications (L. BERNARD)

The Office of Communications posted one press release to the PPPL website. It focused on the inaugural plasma physics summer school for graduate students from across the country. For one week, the 18 students listened to a series of lectures, interacted with other students in the field, and presented research in a poster session. The story was also posted to the *Newswise* and *EurekAlert!* press release distribution services.

DIRECTOR'S OFFICE (S. COWLEY)

From Sept. 5-7, the Director's Office hosted a Director's Review of the NSTX-U project. Independent consultants were charged with providing an assessment of whether the recovery project is ready for review by the DOE Office of Performance Assessment (CDE-2/CDE-3A). The assessment team reviewed the project scope, cost, and schedules.

This report is also available on the following web site:
http://www.pppl.gov/publication-type/weekly-highlights