Weekly HIGHLIGHTS

PPPL PRINCETON PLASMA PHYSICS LABORATORY

U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the week ending January 13, 2018, are as follows:

NSTX-U RECOVERY AND RESEARCH (J. MENARD)

Recovery:

A preliminary design review (PDR) was held on Jan. 11 for the gas piping of the helium bake system. A final design review was held on Jan. 12 for the torus vacuum pumping system (TVPS) backing pump and chiller system. A manufacturing readiness review (MRR) for Tesla Engineering, one of the poloidal field coil prototype fabricators, was held. Completion of a checklist authorizing commencement of winding is being finalized. Metrology of the center-stack casing inner diameter was completed.

Research:

An NSTX Upgrade Research Program Advisory Committee (PAC) meeting was held on Jan. 9 and 10 at PPPL. The PAC provided comments and assessments of four topics, including the quality and importance of recent NSTX/NSTX-U research results and highlights, the uniqueness and timeliness of important questions NSTX-U will answer for fusion science, how and whether NSTX-U will lead the world in scientific areas when operation resumes in 2020, and important scientific and technological findings since the original physics design of NSTX-U and the last five-year plan and how such findings influence the impact of medium-term and long-term research on NSTX-U.

U.S. ITER FABRICATION (H. NEILSON)

Low-field-side reflectometer (LFSR): In a successful exchange of technical data between the LFSR diagnostic group and the ITER Organization (IO), the results of the neutronic heating analyses (commissioned by the IO) were obtained for the LFSR front end and plasma facing components. The heating results were incorporated into the PPPL thermal hydraulics cooling analyses and loads were qualified.

Motional Stark effect (MSE) mirror cleaning R&D: The Nova Photonics team continued to measure sputtering rates in magnetized helium plasmas. At 100 watts of radio frequency power, 5 milli-torr of fill pressure, and a magnetic field of approximately .1 tesla, an aluminum sputtering rate of approximately 13 nanometers per hour and a stainless steel sputtering rate of 20-30 nanometers per hour were measured. This is larger than the aluminum sputtering rate of around seven nanometers per hour found in unmagnetized helium plasma. As was found in neon, the stainless steel sputtering rate was asymmetric, with around 30 nanometers per hour on one side of the aluminum coating and around 20 nanometers per hour on the other side.

Upper wide angle viewing (UWAV): A report has been submitted by Bertin Technologies, which is working under a subcontract to develop the adaptive image recognition instrumentation and control software for the UWAV system. Titled, "Inputs for system-level design: performance assessment from optical design," the report describes performed simulations and the corresponding results on measurement performance assessment based on the provided divertor geometry, on assumptions on plasma scenarios, on the optical design for the UWAVS infrared (IR) channel, and on the pre-selected IR camera model characteristics.

ITER & TOKAMAKS (R. Nazikian)

R. Maingi hosted a program committee meeting (Jan. 4-5) for the 2018 International Plasma-Surface Interactions Conference to be held on the Princeton University campus June 17-22, 2018. Ten committee members from all over the world participated in person, with one remote participant, to discuss the nearly 500 abstracts submitted for consideration. Evaluations on the technical abstracts were conducted, and updates on the conference planning and organization were reviewed.

DIII-D (B. Grierson)

Research:

A new article titled, "Multi-Scale Transport in the DIII-D ITER Baseline Scenario with Direct Electron Heating and Projection to ITER," by B.A. Grierson has been accepted for publication in *Physics of Plasmas*. In this article, turbulent fluctuations and quasi-linear modeling indicate that multi-scale fluctuations are present in the DIII-D ITER baseline discharges with direct electron heating. These fluctuations appear to determine the scale length of the temperature and density profiles, and are successfully reproduced by the TGLF transport model. Projections to ITER indicate that multi-scale fluctuations will also be present, and result in density peaking. Analysis for ITER indicates that this mechanism for density peaking should not cause impurity accumulation of tungsten.

A. Bortolon has been selected for an oral presentation at the 23rd international conference on plasma surface interactions (PSI). The title of the talk is "Real-time wall conditioning by controlled injection of boron and boron nitride powder in the full tungsten wall ASDEX-Upgrade." S. Haskey was selected to give an invited talk on main ion charge-exchange recombination (CER) spectroscopy at the high-temperature plasma diagnostic conference to be held in San Diego in April 2018.

S. Haskey has been working with R. Groebner, B. Johnson, and C. Chrystal to improve the realtime CER analysis routines (CERREAL) on DIII-D. Changes have been

implemented which allow the fitting routines to timeout after two milliseconds, which is particularly important for the recently implemented real-time edge CER chords where low signal levels can causing significant problems for the fitting routine. The changes have been tested and show that the CERREAL analysis provides a good approximation to the typical between-shot analysis. With these upgrades, the edge chords are now available for real-time control purposes.

R. Nazikian and W. Suttrop (IPP) participated in an experiment led by C. Paz-Soldan (GA) aimed at understanding the neutral beam torque threshold for resonant magnetic perturbation ELM suppression as a function of plasma shape. Suttrop participated in this experiment by remote connection from ASDEX-U in Germany.

A short development session led by E. Kolemen and N. Eiditis (GA) was held to test a newly developed off-normal event and fault response (ONFR) algorithm in DIII-D. The algorithm uses a new machine learning-based disruption predictor that has been installed and successfully tested in DIII-D. The algorithm calculates the likelihood of an off-normal fault and issues a command to initiate a slow plasma shutdown to avoid a major disruption.

Operations:

A. Nagy and A. Bortolon completed the fabrication, assembly, and testing of a powder dropper for EAST. The unit is packaged and ready to ship once the export is approved. This four-chamber powder dropper can deliver any one of four different powders without a vacuum break. This is a similar dropper to the one provided to ASDEX-U last fall. The dropper has an upgraded flow meter that provides real time indication of the powder flow rate from 0 to 200 milligrams per second. The next powder dropper in assembly will be installed on DIII-D in March.

EAST/KSTAR Scenarios and Control: (R. Nazikian)

J-K. Park was selected to give an invited talk on predictive modeling for ELM suppression in KSTAR at the next European Physical Society EPS meeting on plasma physics and controlled fusion.

The EAST radio-frequency team has been collaborating with PPPL (J. Hosea and the Lab's radio-frequency team) to upgrade the capabilities of the ICRH system on EAST. Steps have been taken to improve radio-frequency coupling to plasma by moving the decouplers closer to the antenna and by adding a quarter-wavelength transformer to reduce high voltages on the transmission line. These steps were taken after discussions with PPPL staff regarding methods to enhance power coupling to the plasma and to

improve reliability of the ICRH system. These system upgrades should be available for EAST experiments in FY18.

ADVANCED PROJECTS (H. NEILSON)

Stellarators (D. Gates)

The Laboratory hosted the quarterly management meeting for the Wendelstein 7-X (W7-X) collaboration program. Representatives from Oak Ridge National Laboratory (ORNL) and PPPL briefed the Office of Science's Fusion Energy Sciences program manager on research highlights from the recently concluded OP1.2a campaign. Pellet injection and divertor heat load symmetrization with the U.S. supplied trim coils enabled the achievement of high performance discharges with stored energy exceeding 1 megajoule. The campaign included detailed investigations of heat and impurity transport, with the X-ray imaging crystal spectrometer (provided by PPPL) and a 72-channel array of filterscopes (provided by ORNL) playing key roles. The two laboratories reported progress on a joint conceptual design study for a continuous pellet fueling system which, if implemented, would be a valuable capability for density profile control and particle balance studies in the long pulse (≤30 minutes) operating campaigns planned for W7-X.

Systems Studies (C. Kessell)

A paper titled, "Survey of heating and current drive for K-DEMO," by D.R. Mikkelsen, C.E. Kessel, F. Poli, N. Bertelli, and K. Kim has been accepted for publication in the journal *Nuclear Fusion*. The manuscript summarizes the results of heating and current drive calculations for burning plasma conditions in the proposed K-DEMO tokamak reactor configuration. The multi-parameter surveys cover five types of auxiliary systems: lower hybrid waves, ion cyclotron waves, helicon waves, electron cyclotron waves and neutral beam injection. Scans over launcher position and parallel wavenumber show that 5-gigahertz lower hybrid waves are able to drive a variety of current profiles in the outer third of the plasma radius. ICRF fast-waves are suitable for driving current near the magnetic axis, $r/a < 0.3$. The current drive efficiency of helicon fast waves exceeds that of neutral beams and electron cyclotron waves, which can efficiently drive current for any radius in the range $0 < r/a < 0.6$. However, the radial location of helicon fast wave absorption can not be significantly altered by choice of frequency, launcher position or launched wavenumber when coupling to suprathermal alpha particles is required to be small (of order 1% or less). Localized neutral beam current drive is possible with off-midplane injection paths which never pass near the magnetic axis. Scans over electron cyclotron wave frequency, launcher position, and initial wave direction show that off-midplane launchers have no current drive efficiency advantage over carefully chosen midplane launch conditions.

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THEORY (A. BHATTACHARJEE)

An article titled, "Modeling of reduced secondary electron emission yield from a foam or fuzz surface," by C. Swanson & I. D. Kaganovich was published [J. App. Phys. **123**, 023302 (2018)]. An American Institute of Physics (AIP) scilight on this research was prepared. It was titled, "Whiskered foam surface traps secondary electrons in simulations." A link to the scilight can be found at http://theory.pppl.gov/news/seminars.php?scid=8&n=in-the-media

A theory seminar titled, "A moment approach to plasma fluid/kinetic theory and closures," was presented by J-Y Ji, from Utah State University. The abstract and a copy of the presentation are available at http://theory.pppl.gov/news/seminars.php?scid=1&n=research-seminars

A research and review seminar titled, "Metriplectic dynamics — a framework for plasma kinetic theory and numerics," was presented by PPPL's E. Hirvijoki. A copy of the presentation is available at http://theory.pppl.gov/news/seminars.php?scid=2&n=rr-seminars

COMMUNICATIONS & PUBLIC OUTREACH (A. ZWICKER)

COMMUNICATIONS (L. BERNARD)

The Communications Office posted a news story titled, "10 Stories, plus a bonus, you may have missed in 2017" to the PPPL website, and to press release distribution services *Newswise* and *EurekAlert!*. The press release is a compilation of 11 PPPL news stories from last year that may be of interest to a broad audience. The story may be viewed here, or on PPPL's external website at www.pppl.gov.

This report is also available on the following web site:

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