Weekly HIGHLIGHTS

PPPL PRINCETON PLASMA PHYSICS LABORATORY

U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the week ending February 17, 2018, are as follows:

NSTX-U RECOVERY AND RESEARCH (J. MENARD)

Recovery:

A preliminary design review (PDR) for phase 1 of the CAMAC replacement was held on Feb. 16.

The NSTX-U design review plan has been updated based on feedback from last week's OPA review.

The PPPL PF1A prototype coil VPI mold has been delivered from the external vendor. PF1A prototype coil winding has begun at PPPL and at two external vendors. The PF1 coil as-built hard-bus shapes have been documented and data provided to the engineering analysis team.

A status meeting for global heat balance calculations was held on Feb. 14. The model and heat transfer parameters were described and reviewed by those modeling local thermal behavior of tiles and polar region components, and further review of tile and attachment design is expected. Growth of the center-stack casing was presented for the five thermal scenarios defined in the requirements documents, and associated weld stresses are being assessed.

To facilitate plasma-facing component design assurance, prototype testing is being used to validate engineering analyses. In support of this validation, destructive evaluation of carbon-bonded strain gauges has been initiated. Multiple bond materials and graphite materials have been tested with samples destructively loaded at the PPPL material testing laboratory. Three of four samples maintained adhesion through fracture.

Lawrence Livermore National Laboratory (LLNL) will contribute to the NSTX-U recovery by preserving the diagnostics that were installed on NSTX-U and operated in FY2016. A number of LLNL diagnostics have been removed from the vacuum vessel and/or secured at the vacuum vessel including two charge injection device cameras (removed); three Phantom cameras (removed); one edge neutral density diagnostic camera (removed); two ultraviolet imaging lenses and fiber-holders (removed); three fiber-optic bundles for imaging spectrometers and filterscopes (secured in place); cables for AXUV diode divertor radiometer (secured in place); and three extreme ultraviolet

spectrometers (secured in place).

Research:

The paper, "Electron-Density-Sensitive Line Ratios of Fe XIII– XVI from Laboratory Sources Compared to CHIANTI," by M. Weller, et al., has been published in *The Astrophysical Journal*, 854:102, Feb. 20. Electron-density-sensitive line ratios for Fe XIII–XVI measured in the spectral wavelength range of 200-440 angstroms and an electron density range of (1–4)×1013 cm−3. The results provide a test at the high-density limit of density-sensitive line ratios useful for astrophysical studies. The measurements were performed on the National Spherical Torus Experiment-Upgrade, where electron densities were measured independently by the laser Thomson scattering diagnostic.

The paper, "Developing Physics Basis for the Snowflake Divertor in the DIII-D Tokamak," by V. Soukhanovskii, et al., was published in *Nuclear Fusion* 2018, 58, 036018. Divertor power fractions measured in the additional snowflake divertor strike points will provide guidance on power handling requirements for NSTX-U divertor plasma-facing components.

U.S. ITER FABRICATION (H. NEILSON)

Low field side reflectometer (LFSR): The LFSR design includes instrumentation and control (I&C) functions important for system operation and protection. At a recent ITER Control, Data Access and Communication (CODAC) workshop, D. Sieving of subcontractor General Atomics presented the LFSR I&C design. He also reviewed the design with the chief I&C technical officer in preparation for the preliminary design review (PDR) of LFSR, scheduled for June 2018.

The U.S. LFSR team and the Technical Responsible Office (TRO) in the ITER Central Team reached agreement on the documentation requirements and preparation plan for the upcoming preliminary design review. Document preparation is now a strong focus for both PPPL and General Atomics team members.

Weekly HIGHLIGHTS

PPPL PRINCETON PLASMA PHYSICS LABORATORY

U.S. DEPARTMENT OF ENERGY

ITER & TOKAMAKS (R. Nazikian)

DIII-D (B. Grierson)

Research:

A new featured article by B. Grierson entitled, "Multi-Scale Transport in the DIII-D ITER Baseline Scenario with Direct Electron Heating and Projection to ITER," was published in *Physics of Plasmas* **25**, 022509 (2018); https://doi.org/10.1063/1.5011387. In this article, Grierson shows that turbulent fluctuations and quasi-linear modeling indicate that muti-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 are made and indicate that multi-scale fluctuations will also be present, and result in density peaking. However, in ITER the density peaking does not cause impurity accumulation of tungsten, since the turbulent transport exists all the way to the magnetic axis and the neoclassical transport is below the turbulent levels.

A paper by A. Nagy titled, "A Quasi-Periodic Linear Feeder for the Impurity Granular Injection on DIII-D," was accepted by the IEEE and presented at the SOFE 2017 conference. The authors include student interns who worked on this project under Nagy from 2016 to 2017. The paper highlighted the conversion of a non-periodic dropper to the one presented where, below the 60-hertz feed rate, the periodicity is significant. This unit is now passing operational tests and will be installed on DIII-D for the April 2018 run.

B. Grierson traveled to the University of Wisconsin-Madison to present a seminar titled, "Advances in Measuring and Understanding Plasma Rotation." The seminar details the advancements in quantitative spectroscopy that have enabled routine measurements of the main-ion rotation in deuterium tokamak plasmas, and new insights into the generation of intrinsic rotation.

Weekly HIGHLIGHTS

PPPL PRINCETON PLASMA PHYSICS LABORATORY

U.S. DEPARTMENT OF ENERGY

ADVANCED PROJECTS (H. NEILSON)

Stellarators (D. Gates):

A paper by N. Pablant, *et al.*, "Core radial electric field and transport in Wendelstein 7-X plasmas," has been published in *Physics of Plasmas*, and is available at https://doi.org/10.1063/1.4999842. The paper shows the first detailed comparisons between the measured radial electric field (E_r) and neoclassical calculations on W7-X. Measurements of E_r profiles were made using the PPPL-supplied X-ray imaging crystal spectrometer (XICS) diagnostic. This comparison is of particular importance since it provides the first experimental evidence that several codes that calculate neoclassical quantities provide accurate results in the final W7-X geometry. This first validation effort is an important step in evaluating whether the W7-X design optimization was successful in reducing neoclassical transport as compared to a classical stellarator. In addition to comparisons against experimental measurements, this paper also compares calculations from three different neoclassical codes with different levels of simplifying assumptions. This work is the result of a strong international collaboration with major contributions from PPPL, Max Planck Institute for Plasma Physics (Germany), University of Maryland and the National Institute for Fusion Science (Japan), and other institutions.

D. Gates participated in the the annual Physics Review Board for the Canadian Natural Science and Engineering Research Council (NSERC). The Board meets annually to rank Physics Discovery Grants submitted to NSERC. A panel of five scientists from Canada and abroad gather for 15 minutes per proposal to discuss their rankings. Gates participated in 40 such discussions which culminate in a ranking that determines the funding for the proposals. With this meeting, Gates completed a three-year term on this committee.

System Studies (C. Kessel):

C. Kessel and the national Fusion Energy System Studies team completed a 2017 year-end report for the ongoing Liquid Metal Plasma Facing Component (LM PFC) study. The report summarized progress in investigating LM properties of importance for PFC applications. Interactions between liquid metals and solid substrates, and experimental work on this topic at ORNL, are discussed. Nuclear analysis has identified the best combinations of LM PFC and LM breeder. Transient heating and electromagnetic forces on the LM are being explored. LM property data, and plant accident and tritium behavior simulations, are being prepared. Some examination of impacts of the LMs on radio frequency launchers is beginning. Temperature windows for the LM candidates, which have implications for thermal conversion of these LM loops,

are being examined. Tritium processing and extraction are being analyzed. Integration issues associated with the realistic LM loop, such as impurities and hydrogen pickup, are being explored. Simulations of flowing free-surface LM on the first wall have been performed and indicate a tub-like divertor concept as a possible design approach. In addition, LM simulations are being pursued on the ANSYS/CFX platform. Edge plasma simulations
have shown that a lithium slot divertor can radiate approximately 90% of the power entering the divertor. The study is continuing to identify the critical issues for 1) liquid metals, 2) solid substrates, 3) FW and divertor concepts, and 4) integration in order to provide focused R&D guidance.

THEORY (A. BHATTACHARJEE):

An article titled, "Collisionless Magnetic Reconnection in Curved Spacetime and the Effect of Black Hole Rotation," by L. Comisso and F. Asenjo, was published in *Physical Review D*. The abstract and a link to the article can be found on the Theory website: https://theory.pppl.gov/news/seminars.php?scid=4&n=publications

A seminar titled, "Magnetic Reconnection in Three-Dimensional Space," was presented by A. Boozer of Columbia University. The abstract and presentation are available on the Theory website:
https://theory.pppl.gov/news/seminars.php?scid=1&n=research-seminars.

A Research & Review Seminar titled, "Control of Secondary Electron Emission Flux Through Surface Geometry," was presented by C. Swanson. The abstract and presentation are available on the Theory website:
https://theory.pppl.gov/news/seminars.php?scid=2&n=rr-seminars

COMMUNICATIONS (L. BERNARD)

The Office of Communications posted two stories to the PPPL website. One focused on PPPL physicist F. Poli, who was part of a team that formulated an approach that for the first time simultaneously simulates the plasma, the magnetic islands, and the feedback control from waves that provide electron cyclotron heating and current drive. The other reported that former PPPL physicist C. Myers has won the 2018 Dissertation Prize awarded by the Laboratory Astrophysics Division of the American Astrophysical Society. The stories were also posted on the *EurekAlert!* and *Newswise* press release distribution services.

Weekly HIGHLIGHTS

PPPL PRINCETON PLASMA PHYSICS LABORATORY

U.S. DEPARTMENT OF ENERGY

DIRECTOR'S OFFICE (R. HAWRYLUK)

Maj. Gen. Charles Bolden, Jr. (USMC-retired), former NASA administrator and a former astronaut, visited PPPL on Feb. 13. D. McComas, the Princeton University vice president for PPPL, hosted meetings with Maj. Gen. Bolden, who met with PPPL's leadership team and toured the National Spherical Torus Experiment-Upgrade, the Lithium Tokamak

Experiment, and the Science Education Laboratory. He also met with Early Career Award recipients.

This report is also available on the following web site:

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