Weekly HIGHLIGHTS

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

The PPPL Highlights for the week ending November 7, 2020, are as follows:

NSTX-U RECOVERY (J. GALAYDA) AND RESEARCH (S. KAYE)

Recovery (J. Galayda):

Bus Supports — Water testing continued for the PF1B power cable preparations. The materials required for fabrication and installation of PF extension and OH coax bus connection were on site in QC receipt inspection. Work packages were prepared to begin fabrication of some supports.

Coils — Preparations for machining the six production coils continued at PPPL. Manipulation lifts continue to be rehearsed. The PF1C-S (spare) arrived at PPPL from Sigmaphi. The PF1B-S (spare) was electrically tested and had its dimensions verified. The PF1A-S (spare) was cured after VPI (vacuum pressure impregnation).

Center Stack Casing (CSC) — The finish machining of the CSC in Camden, NJ, continued without any issues. PPPL reinstituted QA oversight in Camden and engineering oversight at Turtle Creek. At Turtle Creek, the mockup welding continued, along with stud installation prototyping. Bellows testing will be performed next week.

IVPS — Installation of piping and leak testing was completed. Installation of the pump and electrical and controls packages were being prepared during the week.

Machine Core Structure (MCS) — Precision Boring in Michigan has curtailed until Nov. 9 due to positive Covid-19 cases. The capture and common flanges neared completion. In South Carolina, Carolina Fabricators' production of PF1A sling base parts continued. G.J. Oliver delivered the lower PF1C support, and receipt inspection and preps for welding and leak testing continued. The upper PF1C support was at the vendor for coating. The ceramic break flange was machined; the outer skirt forging is due by Nov. 11 so fabrication can proceed. The on-site mockup activities are complete, and lessons learned continue to be reviewed and incorporated into assembly procedures. PF1B lower slings welding continued at a good pace.

Research (S. Kaye):

The NSTX-U paper, "Active Radiative Liquid Lithium Divertor for Handling Transient High Heat Flux Events" by M. Ono and R. Raman was published online at *Journal of Fusion Energy*: https://doi.org/10.1007/s10894-020-00253-6. The paper explores the feasibility of utilizing passive and active radiative liquid lithium divertor concepts in handling transient heat flux to protect the divertor PFCs from

the extreme transient heat flux while maintaining the normal plasma operations. The paper also suggests a possible implementation technique using inductive pellet injector for the reactor PFC protection from transient heat flux, which can be tested on NSTX-U.

ITER PROJECTS (H. NEILSON)

Low Field Side Reflectometer — LFSR (A. Zolfaghari, S. Shirey):

The LFSR team is gaining critical manufacturing knowledge through initial welding trials and inspection activities by manufacturing partner General Atomics. Multiple geometries of plugs have been welded while refining the procedure and parameters including the successful repair of a failed initial root weld pass. In parallel with the manufacturing development progress, the initial technical specifications were approved by U.S. ITER and the Manufacturing Readiness Review (MRR) planning phase is underway.

The design team received guidance from the IO Diagnostics Division supporting PPPL's proposal to use analysis results from the neighboring EP12 port for use by LFSR in closing final design review (FDR) chits. Given the expectation of anticipated delays in delivery of approved analysis for EP11, this decision removes a potential roadblock in the path to FDR closure.

Toroidal Interferometer Polarimeter — TIP (M.-A. De Looz):

The TIP team, working with multiple TROs in the Diagnostics Division, has made progress in identifying the interfaces and scope of supply for a near-term assembly package, scheduled for March, for overhead waveguide and beam tube supports. The design will build on a new IO design developed for the erosion monitor gallery supports. Interfaces with INDA scope (ECE waveguides) and IO scope (fireboxes and penetrations) have been identified, and documentation actions assigned.

Electron Cyclotron Emission — ECE (G. Paraiso):

Discrepancies between PPPL drawings and the India DA's (INDA) CAD models in the locations of some transmission line components have been resolved. PPPL's CAD model and layout drawings have been updated accordingly. The revised drawings will be shared with INDA and the IO and will soon be drafted in the ITER database.

The team continues to work on the integration of the push-rod assembly into the new diagnostic shield module DSM configuration. The push-rod is being redesigned to allow for a modified method of installation that will be needed to adapt to the new DSM structure.

Continued progress has been made in formalizing the ECE system requirements. The PPPL team's review of the draft system requirements document (SRD) is nearly finished. Feedback will be provided to the IO soon for inclusion into the formal SRD.

Motional Stark Effect — MSE (A. Cohen):

The MSE team has made progress in analyzing the thermal deformations of the large (~400 mm square) front mirrors and their effect on the optics. The team recently developed a capability to decompose a deformed mirror into perturbed biconic parameters. It is intended that the perturbed biconic and the residuals will enable a timely assessment of the impact on the optics and a judgment whether more aggressive cooling should be implemented.

Equatorial Port Integration — EP03/09 (A. Basile):

Design progress in port plug integration has been greatly aided by the availability of mature analysis of the EP12 DSMs performed by the IO. It is clear that now that diagnostic first wall (DFW) data are also needed to expedite work on, e.g. MSE and TIP, which have front-end mirrors close to the DFW. The IO has agreed to deliver the EP12 DFW data in a few days.

H. Neilson chaired an ITER preliminary design review of Equatorial Port 17, a diagnostics port for which the IO has responsibility. The review panel attended presentations over three half-days, scheduled to facilitate remote participation across multiple time zones. Advances in methods for safely opening vacuum vessel extensions during maintenance operations were a highlight of the design team presentation. Neilson presented a debriefing report of the panel's findings on the last day. It was agreed to keep the review open for an additional two weeks in order to facilitate a more complete documentation package and to complete the analysis of chits submitted.

ITER & TOKAMAKS (R. NAZIKIAN)

International PMI and Liquid Metal PFC Concept Development (R. Maingi & A. Diallo):

R. Maingi hosted a periodic meeting of the domestic liquid metal PFC concept development program. A. Khodak (PPPL) presented his ideas and analytic/numeric calculations on a porous liquid lithium wall concept using liquid lithium as the coolant.

The exhausted heat flux is at least 10 MW/m^2 while the MHD pumping requirements

were found to be acceptable. D. Youchison (PPPL) presented his idea for a thin-walled (0.5mm or less) liquid lithium wall/divertor concept that can exhaust between 10-60 MW/m2, depending on operating conditions.

The paper, "Suppression of edge localized modes with real-time boron injection using the tungsten divertor in EAST" by Z. Sun et al., was accepted for publication as a letter in *Nuclear Fusion*. Continuous boron powder injection in EAST suppressed edge-localized modes over a wide range of operating conditions. Edge harmonic oscillations appear during boron powder injection, providing sufficient particle transport to maintain constant density and avoid impurity accumulation in ELM-stable plasmas.

ADVANCED PROJECTS (D. GATES)

Stellarators (D. Gates):

StellReactorPy, a Python toolkit for performing rudimentary fusion systems calculations, was developed by K. Hammond based on an Excel spreadsheet written by M. Zarnstorff. The code determines self-consistent parameters for stellarator-based fusion reactors according to empirical scaling laws and tabulated reaction rates, allowing the option to optimize for targets such as net electric output or engineering Q. The code has been used to help direct more detailed design studies for a stellarator pilot plant.

The paper, "First impurity powder injection experiments in LHD" by F. Nespoli, et al. was accepted for publication in *Nuclear Materials and Energy* on Nov. 3. The article reports on the first series of experiments on LHD employing the Impurity Powder Dropper, designed and built by PPPL. The plasma response to the injection of controlled amounts of boron and boron nitride powder has been characterized. As a result, low-density plasmas appear to be more favorable for boronization applications, since the powder penetrates deeper into the ergodic layer, and the created impurities are pushed outwards by the radial electric field. The experimental observations are supported by simulations with the SFINCS code.

C. Zhu attended the 4th AAPPS-DPP meeting remotely from Oct. 26 to 31. He gave an invited talk on Oct. 28 entitled, "Design of a permanent magnet stellarator." In this talk, he introduced the recent activities in the lab on designing a permanent magnet stellarator, which lead to a DOE ARPA-E award supporting the construction of half-period permanent magnets. Zhu showed the development of the FAMUS code and the applications to design permanent magnets for a half-Tesla quasi-axisymmetric stellarator.

The PM4STELL project (Stellarator simplification using permanent magnets, funded by DOE ARPA-E & FES) has conducted several kick-off meetings with a series of tutorials, including "Introduction of FAMUS for optimizing permanent magnets" on Oct. 7th by C. Zhu; "Introduction of the MAGPIE code" by K. Hammond on Oct. 9; "ANSYS OptiSlang" by S. Kalnas from ANSYS, Inc. on Oct. 14; "Properties of Permanent Magnets & Error Field Correction" by B. Lown from SABR Enterprises, LLC. on Oct. 21; "Error field identification using Hessian matrix method" by C. Zhu on Oct. 27; and "Force calculation in permanent magnets" by K. Corrigen on Oct. 28. Project members from both PPPL and SABR Enterprises LLC, together with ANSYS technicians, have attended the series of tutorials.

THEORY (S. HUDSON)

R. Kube published a paper titled, "Comparison between mirror Langmuir probe and gas-puff imaging measurements of intermittent fluctuations in the Alcator C-Mod scrape-off layer" in *Journal of Plasma Physics*: https://doi.org/10.1017/S0022377820001282

A. Wright gave a talk titled, "Resistive stability of cylindrical MHD equilibria with radially localized pressure gradients" at the AAPPS-DPP 2020 conference. The presentation described a comparative study of properties of continuous and discontinuous MHD equilibria using a new equilibrium model, to determine the physical interpretation of a discontinuous (mathematical) class of MHD equilibria.

M.-G. Yoo gave two invited talks at AAPPS-DPP 2020 last week as follows: on Oct. 30 (on behalf of Weixing): "Gyrokinetic study of plasma transport and global profile evolution in stochastic magnetic fields;" on Oct. 31: "Understanding of the ohmic breakdown physics in a tokamak by considering the multi-dimensional plasma responses."

A. Kleiner gave an invited talk on Oct. 30 at the 4th Asia Pacific Conference on Plasma Physics entitled "Peeling-ballooning modes in low aspect ratio — towards a predictive edge pedestal model for spherical tokamaks."

COMMUNICATIONS & PUBLIC OUTREACH (A. ZWICKER)

Communications (L. Bernard):

L. Bernard remotely moderated a panel, "An Engine of Innovation: The Princeton Plasma Physics Laboratory" at Princeton University's ENGAGE 2020 entrepreneurship and innovation conference on Nov. 4.

L. Bernard participated remotely in the U.S. Department of Energy Office of Science, Communications and Public Affairs monthly meeting with National Laboratories communications officers on Nov. 5.

DIRECTOR'S OFFICE (S. COWLEY)

On Nov. 3, J. Menard hosted and participated in the International Energy Agency Spherical Tori Technology Collaboration Programme executive committee meeting on Nov. 3.

S. Cowley participated in a Princeton University Andlinger Center Executive Committee (ACEE) meeting on Nov. 4.

On Nov. 4, J. Jenkins from Princeton University presented a virtual colloquium titled, "Decarbonizing Electricity: The Critical Role of Firm Low-Carbon Resources."

S. Cowley and J. Menard participated as panelists, along with L. Bagley and A. Zwicker, on Nov. 4 at the Princeton University ENGAGE 2020 entrepreneurship conference. Cowley provided a PPPL overview and Menard provided an update regarding PPPL research innovation areas and the Princeton Plasma Innovation Center. Bagley described the technology transfer program, and Zwicker described innovation in online STEM education.

S. Cowley participated in a Princeton University student podcast called Policy Punchline on Nov. 6. During the podcast, Cowley discussed the future of nuclear technology and the potential for this technology to play a large role in both the U.S. and global energy mix in the coming decades.

This report is also available on the following web site:

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