Weekly HIGHLIGHTS

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

The PPPL Highlights for the week ending October 17, 2020, are as follows:

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

Recovery (J. Galayda):

Coils — All six production coils (PF1B#1, PF1C#1, PFC#2, PF1A#1, PF1A#2, and PF1B#2) are at PPPL in preparation for machining. All coils have passed low-power electrical tests on site. In France at Sigmaphi, PF1C-S (spare) has been demolded and electrically tested. PF1A-S and PF1B-S are having the flags brazed on.

Center Stack Casing (CSC) — The CSC was in Camden, New Jersey, for the final five weeks of finish machining. Additionally, welding of the organ pipes occurred at Turtle Creek and welding of the mockup bellows to the flange was completed. The production bellows were shipped to Turtle Creek for installation into the CSC when it returns to Turtle Creek.

IVPS — Parts were cleaned in the vacuum prep lab and leak testing was completed. Installation was started and will continue for approximately three more weeks.

Machine Core Structure (MCS) — Many fabrication activities continued at the three facilities currently making sling parts. Precision Boring in Michigan continued fabrication of the PF1A and PF1B capture and common flanges. The PF1C capping flanges were completed and have arrived at PPPL. In South Carolina, Carolina Fabricators continued production of PF1A sling parts. All hanger parts were received at PPPL and machining of base plates continued. G. J. Oliver delivered the lower PF1C support so that PPPL could perform helium leak testing on the can. The upper PF1C support was sent for coating. The ceramic break flange was machined and the outer skirt forging is due next week. The on-site mockup activities continued as preload was applied to the slings, and the engineers and techs fine-tuned the application of the preload. Qualification of the sling welding procedure was completed, and PF1B lower slings began the assembly and welding process, with PF1A lower slings to follow.

PF1A and PF1B Coil Sling Weld Grinding Peer Review — A peer review (PR) was held Oct. 9 to review the grinding requirements and acceptance of the weld surface finish on the PF1A and PF1B slings to ensure any potential reduction on sling thickness was acceptable and verified by analysis for fatigue resistance.

PF1A Sling Belt and Belt Buckle Modification Peer Review — A peer review was held Oct. 13 to review the design modification on the PF1A sling belt and the belt buckle attachment in the PF1A coil sling assembly. The material testing for the PF1A sling belt performed by the vendor (KT-880GF-30) showed a ~25% lower tensile strength than the

catalog data used in the analysis for the sling belt peer review held on Dec. 11, 2019. As a result, the design of the PF1A sling belt has to be modified to accommodate the lower strength effect.

Pf-4/5 Coil Realignment Metrology with Fiducialization Peer Review — A peer review (PR) was held Oct. 14 that outlined the final metrology plan of a fiducialized coil re-positioning system for realigning the PF-4/5 coil pairs to the tolerance requirements compared to those used in the CDR and previous peer reviews. This review also addressed engineering details on fiducializing the coils per the updated metrology plan, the sequence of field work scope needed to enable the coil repositioning per the fiducialized coil metrology used to guide repositioning, and how to verify that the final position meets updated tolerance requirements.

Research (S. Kaye):

On Oct. 15, A. Kleiner (PPPL) gave a dry run of his AAPPS invited talk entitled, "Peeling-ballooning modes in low-aspect ratio — Towards a predictive edge pedestal model for spherical tokamaks."

The abstract of the talk is below:

"Edge-localized modes (ELMs) are a major concern for tokamak devices, and their control is crucial for the operation of future reactor-scale machines. ELMs can be triggered when strong gradients are present in the edge transport barrier (edge pedestal). The width and height of the pedestal is often constrained by the occurrence of ideal-MHD peeling-ballooning modes as well as kinetic ballooning modes (KBMs) in the pedestal region; this model has been successfully applied by the EPED model to predict the pedestal height and width in conventional aspect ratio tokamaks. The predictions of the EPED model, however, often do not accurately describe observations in machines with low aspect ratio (e.g., spherical tokamaks). For ELMing discharges in NSTX, the EPED model predicts stability. The reasons for this discrepancy might be associated with the limitation to ideal-MHD computations or the breakdown of the assumption that local ballooning theory well approximates the stability limit of kinetic ballooning modes in the edge of low aspect ratio plasmas.

With the goal of obtaining a model to predict ELMs in spherical tokamaks and to find the limiting values for pedestal width and height, we model peeling-ballooning modes, including non-ideal effects. The extended-MHD code M3D-C1 is applied to determine the stability thresholds of peeling-ballooning modes in NSTX discharges. We mainly focus on the influence of plasma resistivity and rotation on edge stability, but also consider two-fluid effects. By varying pedestal parameters such as the pressure gradient

and current density for given (ELMing) discharges, we are able to locate these discharges in parameter space relative to the stability boundary. In this context, we also identify the physics mechanisms that are important to describe these macroscopic edge modes in spherical tokamaks.

We find robust resistive peeling-ballooning modes well before the ideal stability threshold is met. These modes thus extend the region of ideal peeling-ballooning instability in the investigated ELMing NSTX discharges. It is found that the actual NSTX plasmas are localized close to, or slightly within, the unstable side of the stability boundary calculated with our model. For large aspect ratio discharges, the model is benchmarked with the ELITE code, which is employed in the frame of the EPED model. This study of macroscopic instabilities constitutes a first step towards a model to predict pedestal width and height in H-mode discharges in spherical tokamaks."

ITER PROJECTS (H. NEILSON)

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

The TIP team has further reviewed the structural deformations of a diagnostic shield module (DSM) under operating loads. Information from the relatively mature analysis of first-plasma ports is used as a baseline approach for developing concepts for TIP mirror mounting in EP09. The team's studies show that several mounting options are available to minimize mirror tilt by design and to limit real-time compensation requirements. The cooled mirrors closest to the plasma face challenges, as the DSM structure elements deflect substantially due to non-uniform neutronic heating; alternative support options are being investigated. Mirrors further back from the plasma may be mounted to the DSM structures in that region, since they experience smaller deflections and can keep the mirrors well within beam location tolerances.

Core X-ray Crystal Spectroscopy — XRCS-Core (N. Pablant):

ITER's core X-ray diagnostic has undergone a complete redesign as a consequence of changes in port assignment for that system. The new XRCS-Core concept relies on a set of graphite pre-reflectors in the port plug in order to fit within a narrower space envelope than the previous design. While the Central Team is currently responsible for the preliminary design development, they have sought PPPL participation in view of the Laboratory's world-leading capabilities in X-ray diagnostics. This week, PPPL physicist N. Pablant briefed U.S. ITER management on a plan for U.S. participation in the work that would, if approved, be funded by the Central Team under a Task Agreement with U.S. ITER. Pablant described the basic design concept, its novel features, PPPL tasks,

budgets, and risks. The plan has been developed in close collaboration with Central Team responsible officers.

Motional Stark Effect — MSE (A. Cohen):

The MSE team is working with Central Team optical design experts who have been made available to assist in adapting the MSE optics to the DSM structures in its two equatorial port locations. A kickoff meeting was held this week to introduce them to the general port layout and MSE optical paths. Clashes with diagnostic first wall (DFW) features and in closure plate window layouts were identified as issues needing to be addressed in the optical design work. Clashes with a neighboring diagnostic system may be resolved by modest adaptations in that system.

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

While the in-vessel configuration of LFSR components within the EP11 diagnostic shield module has stabilized, the LFSR team maintains an ongoing effort in support of Russia's design integration activities in the ex-vessel EP11 regions, namely the interspace and port cell. Changes in these tightly packed regions have necessitated some re-routing of LFSR waveguides and new support arrangements. PPPL engineer M. Duco is leading the effort on the PPPL side, working closely with counterparts in the Russian team. The immediate goal is to establish a stable clash-free configuration until the U.S. team is able to resume detailed design work on its ex-vessel components.

ITER & TOKAMAKS (R. NAZIKIAN)

DIII-D (B. Grierson):

A. Nagy and R. Lee (GA) have been presenting Riverside California Science Technology Education Partnership (STEP) conference science shows for the past 20 years. This year, due to COVID-19, the conference was held as an online interactive program actively engaging students in their virtual classroom. Three shows were presented from the DIII-D facility comprising pre-recorded device explanations from young scientists, real-time physics demonstrations on electricity and magnetism, liquid nitrogen, and plasmas. Participants in the show included M. Clement (PPPL), K. Thome (GA), and G. DeGrandchamp (UCI). Students were quizzed on these subjects during the show period. The approximately 35-minute shows reached 328 classrooms and 15,000 students. This format sets a new bar for outreach. Next year an in-person live show (conditions permitting) will be broadcast to the local area schools using interactive technology for real time question responses.

International PMI (R. Maingi & A. Diallo):

The WEST Impurity Powder Dropper (IPD) fabrication, assembly, and testing is complete and the unit ready to ship from D3D to France. This unit is the sixth unit built to date. The IPD is typically used to deliver boron powder to plasma discharges that then redeposit the boron on the vessel walls, thus conditioning the walls to suppress impurity influx. The system now uses National Instruments controllers and comes with a TIV protector that prevents TIV leakage by blocking powder from the O-ring seal surface. Future upgrades are being worked on, e.g. in-vacuum scale for calibration and single granule droppers.

The paper titled, "ELM suppression by boron powder injection and comparison with lithium powder injection on EAST" by R. Maingi, J.S. Hu, Z. Sun, et al. was published online in the *Journal of Fusion Energy*: https://rdcu.be/b8qv3. The paper documents the use of boron powder injection to eliminate edge-localized modes (ELMs) over a wide range of conditions in EAST (heating power and mechanism, density/collisionality, deuterium or He main ion, and grad-B drift direction). An edge mode increases plasma transport and eliminates hitting the ELM stability boundary, while global energy confinement increases modestly. A modest or no recycling reduction was observed, differentiating boron powder injection from lithium powder injection, which also suppresses ELMs over narrower operating windows and with a substantial recycling reduction.

International JET/EU (M. Podestà, F. Poli):

P. Bonofiglo gave a presentation titled, "Improved lost alpha Faraday cup measurements on JET relevant to ITER" at the fall ITPA-Diagnostics virtual meeting. The presentation discussed recent improvements to the Faraday cup system at JET as well as capabilities and limitations of the system, and how a similar system may perform on ITER to monitor the loss of energetic ions. One of the biggest questions ITER would like answered is the noise level expected in the transmission cabling due to radiation. Extensive modeling would be required to design a Faraday cups system for ITER, including the expected signal-to-noise and sensitivity in terms of energetic ion energy and pitch angle.

ADVANCED PROJECTS (D. GATES)

Stellarators (D. Gates):

F. Nespoli, R. Lunsford, and E. Gilson participated remotely in the first experiments of the 2020-2021 LHD campaign. The PPPL impurity powder dropper (IPD) was operated locally by collaborator S. Masuzaki (NIFS) and was used to

inject tens of milligrams of 150-micron-diameter boron powder into LHD discharges. The objective was to investigate the effect of IPD-delivered boron on wall conditioning in an unbaked and not-boronized machine. Early indications suggest that the vacuum conditions and NBI/ECH conditioning were not good enough to support discharges of sufficient duration to transport boron powder to all relevant surfaces in the vessel. However, the IPD was able to demonstrate the ability to drop precision bursts of powder into LHD. Further experiments are planned later in the campaign on feedback control, detachment, and long-pulse operation.

THEORY (S. HUDSON)

A paper co-authored by C. Dong titled, “When the Moon had a magnetosphere” was published in *Science Advances*:
https://advances.sciencemag.org/content/6/42/eabc0865/tab-article-info

I. Kaganovich and his collaborators delivered 12 presentations at last week's GEC conference. These included invited talks by A. Powis (“Low-temperature kinetic plasma simulations for new and future supercomputer architectures”), I. Kaganovich (“Integrated modeling of carbon and boron nitride nanotubes synthesis in plasma of high-pressure arc”), and J. Chen (“Validated two-dimensional modeling of ablated carbon arc”), who was a Student Excellence Award finalist.

BUSINESS OPERATIONS (K. FISCHER)

Procurement (H. Qualls):

K. Gencarelli has officially assumed the role of PCard Program Administrator. M. Zara will operate as back-up. We want to thank Zara for her many years of service and commitment to the PCard Program. Within the coming weeks, Gencarelli will be scheduling the annual refresher training with all PCard holders and approvers.

Thank you to all who responded to the annual Procurement Customer Satisfaction Survey. Your feedback is invaluable and allows us to improve our processes to support lab operations.

Industry Day will be held on Oct. 27.

COMMUNICATIONS & PUBLIC OUTREACH (A. ZWICKER)

Communications (L. Bernard):

The Office of Communications posted one press release to the PPPL website. It reported on an invention by C. Gentile and K. Silber to apply plasma to frequently touched items for continuous disinfection. The method could provide a safe, effective, non-chemical way to reduce pathogens on various surfaces such as keypads, escalator handrails, and other high-touch surfaces. The story was also posted to the *Newswise* and *EurekAlert* press release distribution services.

DIRECTOR'S OFFICE (S. COWLEY)

A virtual colloquium was presented by the University of Wisconsin's C. Forest on Oct. 14 titled, "The Wisconsin HTS Axisymmetric Mirror (WHAM) on a faster path to lower cost fusion energy."

J. Menard participated in the virtual WDMApp all-hands meeting that was hosted by A. Bhattacharjee on Oct. 14-16.

S. Cowley participated virtually in the bi-weekly National Laboratory Directors Council (NLDC) coordination meeting on Oct. 16.

J. Menard participated in the monthly National Laboratory Chief Research Officer (NLCRO) conference call and the bi-weekly National Virtual Biotechnology Laboratory (NVBL) working group call on Oct. 16.

This report is also available on the following web site:

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