The PPPL Highlights for the week ending August 24, 2019, are as follows:

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

**Recovery (J. Galayda):**

The recovery project finalized preparations this week for the independent project review (IPR) scheduled for Aug. 27-29. Project leads have contacted the review committee members to discuss the format and content of the review, and to ensure that the committee receives the information they need.

PPPL issued a request for proposal (RFP) for fabrication services on a BOA (Basic Ordering Agreement) subcontract this week. Removal of interferences for the construction of the NSTX-U Test Cell (NTC) labyrinth also began this week.

**TF Bundle** — The TF bundle review team chaired by T. Todd has submitted its final report. Team members concluded as follows: “The review panel has high confidence that the overall NSTX-U TF bundle assembly will be capable of accommodating the full tokamak shot spectrum elaborated in the general requirements document, albeit seemingly now with an almost inevitable degree of (self-limiting) delamination in the flag regions which will most likely occur when the high-performance (large toroidal field for long durations) shots begin to be run.” The committee provided six recommendations, which the project is addressing.

**Passive Plates** — A final design review (FDR) was held on Aug. 21. The FDR reviewed as-built deficiencies and addressed the loads under various operational conditions on the passive plate structures and network of helium tubing and fittings. The FDR also showed the design and analysis progression of design solutions presented during prior conceptual and preliminary design reviews. The FDR was successful, pending resolution of chits.

**Aerodag Alternative CDR** — A conceptual design review (CDR) was held on Aug. 22 to examine possible alternatives to the Aerodag spray-on coating. Aerodag was previously used to darken areas of the vacuum vessel, and it was discovered during the 2016 NSTX-U run campaign that the Aerodag spray-on coating did not remain intact after exposure to lithium. Since multi-point Thomson scatter (MPTS), toroidal-viewing charge exchange recombination spectroscopy (CHERS), and real-time velocity (RTV) all rely on dark targets to produce accurate results, the proposed redesign uses blackened stainless-steel plates. The proposed plates would be treated with Mil-C-13924 Class 3 oxide. The CDR reviewed this Aerodag alternative and agreed to conduct a peer review after conducting more market research.
Research (S. Kaye):

Researchers at Bridge12 Technologies, a small business company based in Massachusetts, and the University of California-Davis led by N. Luhmann, Jr., are developing novel plasma diagnostic systems for burning plasmas. In 2018 under a DOE Small Business Innovation Research (SBIR) Phase I project grant (J. Sirigiri, Principal Investigator), they designed a compact 10 W, 693 GHz gyrotron oscillator to serve as the source for the NSTX-U high-k, collective scattering diagnostic system. This was intended to determine the importance of small-scale turbulence, e.g., turbulence that is driven by electron-temperature-gradient-driven (ETG) modes, which have been proposed as a source of rapid electron heat loss in both spherical and conventional tokamaks. The gyrotron system will occupy about a quarter of the space as the optically pumped FIR laser system and will provide > 100 X times the probe power for the diagnostic. The innovative gyrotron system was designed to operate in the third cyclotron harmonic to use a conventional niobium titanium superconducting magnet. Recently, the team was awarded an SBIR Phase II award by DOE to fabricate the gyrotron.

The same team was also awarded an SBIR Phase I project grant to design a 693 GHz, 50 mW traveling wave tube (TWT) for use with a local oscillator (LO) in the receiver section of the high-k scattering system. The combination of a high-power transmitter and availability of sufficient LO power for the receiver are a key step to the success of such diagnostic systems that are being actively pursued by Princeton researchers such as Y. Ren, who has been advising the Bridge12 and UC-Davis team. In addition, the successful development of such TWTs offers the prospect of a viable divertor reflectometer for burning plasmas where the required frequency range extends to ~1 THz.

U.S. ITER FABRICATION (H. Neilson)

In preparation for conducting trials of critical welds for its in-vessel ITER diagnostic components, the Laboratory took delivery on a forged block of 316L(N)-IG stainless steel, a custom material that is required for the fabrication of ITER in-vacuum equipment. The carbon and nitrogen content of this material are tightly controlled to provide resistance to cracking of base metal and welds as well as an adequate level of strength. Low cobalt content (0.05% by weight) reduces activation of components and radiation dose rates to personnel. The material will be machined by PPPL into a test piece with geometrical features that exactly mimic the most critical welds on the low field side reflectometer (LFSR) antenna support block. Those welds are required to seal holes left by cross-drilling of water-cooling channels at a chamfered corner of the block. Since welding can be highly sensitive to the exact chemistry of the base material as well as the geometry, it was decided to use exactly the same material for the tests as will be
used for the actual component, rather more conventional grades of 316-series steel. The material was supplied by Rolf Kind GmbH of Gummersbach, Germany.

ITER & TOKAMAKS (R. NAZIKIAN)

DIII-D (B. Grierson):

Research:

Two experiments lead by A. Bortolon were executed on DIII-D to investigate real-time wall conditioning by means of boron powder injection. The experiments, exploiting the upgraded impurity powder dropper, were supported by a group of PPPL collaborators including A. Nagy, R. Lunsford, F. Effenberg, B. Grierson, R. Maingi, and F. Nespoli. The first DIII-D experiment aimed at evaluating the effectiveness of the technique by monitoring the evolution of wall conditions figures of merit during a progression of plasmas with increasing amounts of injected boron. Reduction of wall fueling and carbon concentration were observed correlating with the boron injections. The second DIII-D experiment focused more specifically on the physics of the dynamical growth of a boron layer on plasma-facing components. To this end, tungsten-coated samples were inserted in plasmas with boron powder injection using the DiMES sample manipulator. The exposed samples showed direct evidence of coating layers, which will be analysed with material diagnostics. Interestingly, the observed coatings show clear striation patterns, which are likely to be associated with uncompensated error fields, strongly indicating the local nature of phenomena of erosion and re-deposition.

S. Abe (Princeton U.), a postdoctoral research associate working in the Surface Science and Technology Lab at PPPL of B. Koel (Princeton U.), visited DIII-D this week to collaborate on the AMV DiMES experiment titled, “Unravelling incident ion dynamics with engineered DiMES targets.” Access for this experiment was provided by the successful proposal by C. Skinner (PPPL), B. Koel (Princeton U.), A. Lasa (UTK) and collaborators in response to the DIII-D Research Opportunities Forum (ROF) for the 2019-2020 Experimental Campaigns from the Boundary and Plasma Materials Interaction Center (BPMIC) Advanced Material Validation (AMV) group. Two specially engineered DiMES samples containing 100 nm coatings of aluminum and 30x30x3 micron trenches fabricated via focused ion beam (FIB) milling in a silicon target to capture re-deposited Al were exposed to 8 repeat L-mode DIII-D discharges. The silicon targets will now be analyzed and imaged using several techniques, including the scanning auger microprobe (SAM) instrument in Koel’s Surface Imaging and Microanalysis Laboratory (SIML) at PPPL. The results will inform PMI understanding of polar and azimuthal ion impact angle trajectories near the outer strike point. The experiment was guided by modeling simulations by Lasa and input from J. Coburn
(ITER), FIB engineering by Y. Wen (Rutgers U.), Al coating by R. Akhmechet (PRISM, Princeton U) and the DIII-D staff, T. Abrams and I. Bykov, et al. (GA).

Operations:

The fifth four-feeder powder dropper has been installed on DIII-D and operated successfully this week for two experiments supported by A. Nagy and R. Lunsford. This powder dropper has been advanced in three significant ways: 1) new powder catcher design, eliminating powder leaks to the torus isolation valve (TIV), 2) a TIV protector tube, which connects the top powder drop tube past the TIV (when open) to the vessel drop tube, which functioned as designed 3) A new National Instruments controller that eliminates potential errors in routing signals to feeders and interlocking with the vessel vacuum control system. The new LabVIEW programmed, cRIO based system provides additional flexibility to the operations of the IPD. By transitioning from a signal-generator-based system to a programmable controller the IPD now has the flexibility to deliver powders independently from any of the four feeder assemblies. The new system can deliver an arbitrary number of drive pulses of varying lengths from 10 ms to multi-second from either a single or multiple feeders. Safety interlocks within the system also prevent inadvertent release of powders either onto exposed valves or into the empty vacuum vessel. This upgraded version also incorporated a granule feeder, that can drop single granules or more into plasma during a shot (capacity ~60 (1mm granules)). This powder dropper version is an improvement in the maturity level of this design configuration.

ADVANCED PROJECTS (D. GATES)

Stellarators (D. Gates)

A paper entitled, “Development of a Faraday cup fast ion loss detector for keV beam ions,” by S. Lazerson has been accepted for publication in Reviews of Scientific Instruments. This paper documents the initial development of Faraday-cup-style fast-ion-loss detectors for fusion devices. These detectors are an evolution of thin-foil-based detectors developed for the Joint European Torus. The new detectors replace the discrete foils with sub-micron layers deposited on a substrate using vacuum deposition techniques. This allows for detection of particles in the sub-100 keV range. This also reduces the overall size of the detectors, allowing them to be mounted inside of first-wall structures. The paper documents the design of the detectors and testing of a two-channel detector in a tunable linear accelerator. The motivation of this work has been to develop fast-ion-loss detectors capable of resolving the energy spectra of lost neutral-beam-generated fast ions in Wendelstein 7-X.
The Laboratory’s Plant Instrumentation and Controls (I&C) group has made significant advances in the design of I&C hardware and software for the W7-X Continuous Pellet Fueling System (CPFS) project. The PPPL team has stepped up to play a leadership role in coordinating I&C work among the partners in this project, which is led overall by Oak Ridge National Laboratory. Software engineer B. Smith has advanced the design of the human-machine interface (HMI) based on the W7-X team’s requirements. The design features the screens that will be displayed in the control room and which will enable the operators to see critical data in real time and to control the system. The implementation plan addresses alarms, archiving of data, navigation among the displays and controls, and user administration. A test plan is under development. The Laboratory, together with ORNL and other partners, is making steady progress in retiring risks in preparation for a preliminary design review in the next fiscal year.

THEORY (S. HUDSON)

D. Schaeffer presented an invited talk titled, “Thomson Scattering Measurements of Particle Dynamics in Magnetized Collisionless Shocks,” on recent measurements from laser experiments on collisionless shocks at the International Thomson Scattering Workshop at the Laboratory for Laser Energetics at the University of Rochester.

COMMUNICATIONS & PUBLIC OUTREACH (A. ZWICKER)

Communications (L. Bernard):

The Office of Communications posted one news story to the PPPL website. It focused on research led by C. Zhu into a new mathematical technique that could simplify the design and production of stellarator coils. The story was also posted to the Newswise and EurekAlert press release distribution services.

DIRECTOR’S OFFICE (S. COWLEY)

S. Cowley, C. Ferguson, K. Fischer, J. Menard and A. Zwicker traveled to Trenton on Aug. 21 to meet with staff of New Jersey Governor P. Murphy, the Economic Development Authority, New Jersey Higher Education, and the New Jersey Department of Labor. The purpose of the meeting was to provide an update on PPPL activities and plans. The meeting was successful and highlighted the value and contributions of the Laboratory to the state and the governor's innovation economy.

On Aug. 22, S. Cowley, A. Dominguez, M. Zarnstorff and J. Klabacha met with Andrej Trkov (IAEA) and Mitja Trkov (Rowan University) to discuss nuclear fusion.

This report is also available on the following web site:

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