Weekly HIGHLIGHTS

PPPL PRINCETON PLASMA PHYSICS LABORATORY

U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the week ending March 10, 2017 are as follows:

U.S. ITER FABRICATION (H. NEILSON):

ITER Steady State Electrical Network (J. Dellas):

Power Transformers: All shipments have arrived at the ITER site. The supplier visited the IO on February 27 to inspect the accessory items for which some minor water infiltration occurred.

Reactive Power Compensators: Manufacturing at the Schneider Pringy, France, factory is ongoing. Documentation towards achieving RFS approval for the first two shipping lots is being received from the supplier but extra effort continues to be required, as the supplier has been very slow in producing. However, documentation is now close to completion and the supplier's upper management has been engaged to help facilitate the final preparation. The packaging inspection for the first two shipping lots (1 & 2) and the FAT for the last two lots (3 & 4) have been scheduled for March 14-17 at the supplier's factory in Pringy, France.

UPS, DC Distribution: Regular coordination meetings for both contracts are ongoing. For UPS, testing will be required to be performed at two locations. The factory in Wettingen, Switzerland will perform some tests, and for the higher power testing, a facility in Montbonnet, France will be used (equipment to be shipped between locations by supplier). The DC Distribution contract was officially "Released for Manufacturing" on February 28. Documentation for the UPS RFM continues to be prepared and uploaded in iDOCS/IDM for approval.

ITER Diagnostics (R. Feder):

Upper Wide Angle View VIS-IR Cameras (UWAVs): The ITER face-to-face meetings were very productive. Many issues were resolved including port integration issues in ports 11 and 14 as well as UWAVs integration questions. The big news is that the diagnostics head, Mike Walsh agreed to allow our PDR for March 2018 for UWAVS and in vessel port 11 and 14 PDR. This is a big achievement because there was concern that the PDR would be delayed until after all port integration PDRs were successfully completed.

Upper Port Plugs 11 & 14: UP#14 team met at IO to resolve various issue and plan for a successful PDR. Face-to-Face team meeting was very productive. Mike Walsh (IO Diagnostic Department Head) has agreed to host UP14 & UP11 in-vessel PDR in March 2018. Each UP#14 Tenant is going to have their PDR within three months of Port PDRs. This strategy helps avoiding the risk of accommodating tenant's design change request very late after UP14 PDR; DMS team has agreed on a location in UP14, IO TROs (PBS 55 and PBS 18) have agreed to

proceed with port integration (PI) at current location. If ITER Project decides to move DMS location then it will be done via PCR taking into account of PI and other tenant's cost and Schedule; Document Deliverable CheckList (DDCL) was discussed with IO and agreement was received to proceed with these documents to support our PDR. We have to file this list in IDM prior to our PDR; Remote Handling (RH) team reviewed UP14 RH maintenance and assembly plan and gave feedback to the team. RH team confirmed that Feedthroughs are maintained in the PPTF so no RH compatibility is necessary; Component Cooling Water System (CCWS) has agreed on increasing the cooling capacity for all the Port Cell where UWAVs Heat Exchanges are. We have to request this via Interface Sheet with PBS 26 as an official document.

Equatorial Port 09: Scheduling for EP09 ex-vessel activity was drafted and analysis activity will begin next week. These plans were shared with the TIP diagnostic team (and subcontractor) and will also be shared with INDA (ECE diagnostic) over the next few days.

Toroidal Interferometer/Polarimeter (TIP): Since mirrors on ITER will be exposed to air for long periods, before installation and during maintenance periods on ITER, degradation due to oxidation is an issue, particularly in the UV and visible regions. An oxide coating of around 10nm thickness will form on TIP molydenum mirrors. However, absorption measurements done in the past indicate the such thin oxide coatings will not be a problem, at least at 10.6 microns.

I&C Support Team: Secured IO-served SVN repositories for diagnostics EA models. Presented I&C Support at GDAMM meeting; Participated in meetings: ECE (2), LFSR. ECE considering a s/c to Cosylab for EA work. LFSR encountered some re-work due to new EA-support software (tool) provided by IO; raised some USB VDI-control questions; concerns on SW development for 'split' I&C teams. Continued work on the how-to for EA design.

ITER Analysis Team: In preparing for the DSM Expert Design Review scheduled at the last week of April, a memo from US-DA diagnostics team on the Acceptance Criteria for the Assessment of the Modular DSM Design has been filed onto US ITER iDocs and delivered to the IO-CT team for review. The U14 ISS/PCS analysis model has been reviewed and updated with the latest tenant system design. A memo on the strategy for the ISS/PCS analysis for extracting tenant interface loads will be developed and sent out to IO_CT for review.

Hard Core Components (HCC): Visit at IO. Meeting with Design integration, safety officer and PIC Diagnostic engineer to advance in the process of the HCC.

Vacuum Electrical Integration: Visit at IO. DA's -IO meeting to update the electrical feedout requirements. Meeting with Vacuum electrical Engineering and Vacuum people to advance in the design of the electrical feed through.

Motional Stark Effect (MSE): The MSE mirror cleaning testing chamber is fully pumped down along with a mirror placed within. Preliminary testing will begin soon on a stainless steel mirror

NSTX-U RECOVERY PROJECT (R. HAWRYLUK):

The four-day NSTX-U Extent of Condition review was held this past week, and the review committee focused on the proposed corrective actions that were the result of the first five DVVRs. The review panel debriefed the Project debrief on Thursday afternoon and is in the process of writing their report. Tom Todd, the head of the Extent of Condition (EOC) Committee and former chief of technology at the Culham Centre for Fusion in England chaired the meeting. Members of the committee were: Richard Callis, of General Atomics National Laboratory; John Smith, project manager at General Atomics; Martin Cox, of the Culham Centre for Fusion Energy; Rem Haange, former ITER technical director; Michel Huguet, former head of ITER EDA site in Naka; Brian LaBombard, of MIT's Plasma Science and Fusion Center; Ronald Parker, emeritus professor at MIT's Plasma Science and Fusion Center; and Dennis Youchison, of Oak Ridge National Laboratory. In addition, some of the EOC members, F. Cassella and Graeme Murdoch from the US ITER Project Office and Ursel Fantz from IPP, Garching, participated remotely. Also attending was Josh King, program manager for Spherical Tokamak at the DOE's Fusion Energy Sciences (FES) program along with Mark Foster and Matthew Lanctot who participated remotely.

The next Design Verification and Validation Review (DVVR) will review the NSTX-U Test Cell, and will be held this coming Thursday.

Regarding test cell work, the Poloidal-CHERS diagnostic passive plate tiles have been removed from the vessel in preparation for upgrades to the passive plates and mounting structures. Installation and alignment of waveguides for the FIReTIPS diagnostic continues. Recommissioning of the coil winding facility also continued with the mounting of a PF1a Lower mandrel on the winding table and the completion of testing of recent adjustments to the conductor-tensioning skid. The procedure for the flow testing of the spools of copper conductor is in final approval. Installation of power components for the PF1 coil test stand in the Field Coil Power Conversion Building has started.

Maintenance of the motor generator (MG#1) continues to make good progress with the reinstallation and successful testing of the thrust bearing heat exchangers. Team Industrial reps were brought on site this week to re-inspect MG#1 rotor welds, with no issues found. An inspection of the MG#1 lower guide bearing revealed more wear than expected after 576 hours of run time, and Voith Hydro and PPPL Engineering will meet this coming week to further evaluate.

NSTX-U RESEARCH (J. MENARD):

Members of the LLNL-NSTX-U Collaboration travelled to General Atomics to work with the DIII-D Team on divertor diagnostics and divertor research topics from 27 February to 3 March. Vlad Soukhanovskii (LLNL Group Leader) worked with LLNL staff on the divertor vacuum ultraviolet spectrometer SPRED scheduled for installation later this year. He also discussed with DIII-D physicists divertor detachment and snowflake divertor experiments planned for the NSTX-U Experimental Campaign on DIII-D. Filippo Scotti (LLNL Research Staff) worked on data acquisition and software upgrades for the divertor tangential cameras operated by LLNL. The radiation hardened cameras, originally developed by LLNL on DIII-D,

were installed and operated by LLNL on NSTX-U in 2016. Filippo Scotti also discussed planning of lithium transport and divertor experiments with DIII-D researchers.

The article "Exploration of magnetic perturbation effects on advanced divertor configurations in NSTX-U" by H. Frerichs, O. Schmitz, I. Waters, G. P. Canal, et al. in Physics of Plasmas 23, 062517 (2016) has been selected as one of 2016's Most Read Articles in Physics of Plasmas.

Matthew Reinke visited the WEST facility at CEA-Cadarache from March 5 through March 10. This visit developed a plan to deploy and adapt the THACO software for x-ray crystal spectroscopy analysis on WEST, looking forward to eventual use NSTX-U, in collaboration with MIT. Additionally, he met with a variety of diagnosticians and engineers responsible for IR thermography, calorimetry, bolometry and fiber Bragg grating diagnostics and discussed the design and plans for the WEST wall monitoring system to help protect the plasma facing components.

C. Myers traveled to General Atomics to participate in DIII-D magnetics calibration efforts. The purpose of this trip was to apply broadband AC chirp waveforms to the DIII-D poloidal field and ohmic coils (the F and E coils, respectively) with the aim of improving real-time 3D magnetic sensor calibrations on both DIII-D and NSTX-U. In collaboration with E. Strait (GA), A. Hyatt (GA), S. Munaretto (GA), and J. Hanson (Columbia U), all 19 of the required AC vacuum field shots were obtained. Data analysis is underway.

R. Raman remotely participated in the ITER Disruption Mitigation Workshop (March 8 to 10) held at ITER headquarters. The meeting reviewed the physics basis for the ITER disruption system (DMS), reviewed the current baseline design for the DMS, and discussed alternate mitigation concepts. The Electromagnetic Particle Injection Concept (EPI) was discussed as one of the alternate injection concepts considered at the meeting.

ITER & TOKAMAKS (R. NAZIKIAN):

M. Knolker lead an experiment on DIII-D dedicated to the investigation of type I ELM heat loads in low collisionality plasmas. Very high pedestal temperature were achieved at the low collisionality range of the experiment, down to 0.06 electron temperatures at the top of the pedestal near 2000 eV. The experiment was successful in resolving the trend of the peak heat flux with collisionality in well-patched plasma conditions and in imaging both the inner and outer strike points.

R. Nazikian led an experiment on DIII-D to explore the low torque limit for ELM suppression in ITER relevant plasmas. Co and counter beams were used to vary the torque while maintaining constant beta. ELM suppression was maintained over a range 6 Nm to 3 Nm of injected torque for both co-only and co+counter beam injection. Extensive data was obtained on the transition dynamics in and out of ELM suppression, which will form the basis for detailed theoretical analysis.

A paper titled: "Improving fast-ion confinement in high-performance discharges by suppressing Alfven eigenmodes" by G.J. Kramer at al. was accepted for publication in the journal Nuclear Fusion. In this paper it is shown that the degradation of fast-ion confinement in steady-state DIII-

D discharges is quantitatively consistent with predictions based on the effects of multiple unstable Alfven eigenmodes. A comparison between the experiments and a critical gradient model show that the model reproduces the measured neutron rate well.

L. Delgado-Aparicio visited General Atomics (GA) to meet several GA, LLNL, ORNL and PPPL scientists to discuss the possibility of installing a multi energy SXR imaging diagnostic on DIII-D. The new enhanced low-energy sensitivity of the Pilatus3 camera will allow diagnosing the strong emission from medium- to high-Z impurities (e.g. from Si, Ar and Ca to Mo and W).

ADVANCED PROJECTS (H. NEILSON):

Stellarators (D. Gates):

Drawings for a project to develop prototype Lost Ion Detectors (LID) for the W7-X project have been produced. These sensor elements are made from 20-200 nm thick layers of Aluminum and Aluminum Oxide layers forming a Faraday Cup. Designed to measure the 55 keV and 27.5 keV protons, these sensors are made using thin film deposition. The prototype will undergo testing on a tunable accelerator before design begins on higher resolution sensors to be used in future campaigns on W7-X. The prototype detector will now go to procurement.

On March 6, D. Gates presented a seminar at the National Institute for Fusion Science in Toki, Japan entitled "Summary of the Stellcon Report". The talked summarized the contents of the report that was recently issued by the National Stellarator Coordinating Committee. The basic science points outlined in the report were described and the proposed research roadmap for stellarators that is contained in the report was discussed.

On March 7, Gates participated in the first deuterium plasma inauguration event for the Large Helical Device, which is also located at the National Institute for Fusion Science in Toki, Japan. The event marked the end of an extended effort to obtain permission to run in deuterium on the LHD, a task that is considerable due to the stringent rules for radiation producing facilities in Japan. Numerous local elected officials and representatives of the national government were on hand for the ceremony. Dr. Gates gave some brief congratulatory remarks at the event.

THEORY (A. BHATTACHARJEE):

On March 7, D. Stotler, B. Davis and G. Tchilinguirian ran the *"Robot Arm"* competition at the New Jersey Science Olympiad. Each of the twenty-five high school teams participating in Robot Arm designed and built a robot capable of picking up stacks of pennies and distributing them out over a printed target. Robot Arm was just one of twenty-three events, covering a wide array of topics, in this year's high school competition; the overall winning team will travel to Wright State University in May to compete in the 2017 National Science Olympiad.

A paper by I. Y. Dodin and D. E. Ruiz titled "Photon polarizability and its effect on the dispersion of plasma waves" was published in Journal of Plasma Physics [J. Plasma Phys. 83, 905830201 (2017). The paper reports that high-frequency photons traveling in plasma exhibit a linear polarizability that can influence the dispersion of linear plasma waves. The authors present

a detailed calculation of this effect for Langmuir waves as a characteristic example. Two alternative formulations are given. In the first formulation, the modified dispersion of Langmuir waves is calculated by solving the governing equations for the electron fluid, where the photon contribution enters as a ponderomotive force. In the second formulation, a derivation is provided based on the concept of photon polarizability. Then, the calculation of ponderomotive forces is not needed, and the result is more general.

The Letter "General theory of the plasmoid instability", by L. Comisso, M. Lingam, Y.-M. Huang and A. Bhattacharjee, [Phys. Plasmas 23, 100702 (2016), was recognized by Physics of Plasmas as one of the most read articles of 2016 The abstract reads "A general theory of the onset and development of the plasmoid instability is formulated by means of a principle of least time. The scaling relations for the final aspect ratio, transition time to rapid onset, growth rate, and number of plasmoids are derived and shown to depend on the initial perturbation amplitude, the characteristic rate of current sheet evolution, and the Lundquist number. They are not simple power laws, and are proportional to [see mathematics at above link]. The detailed dynamics of the instability is also elucidated, and shown to comprise of a period of quiescence followed by sudden growth over a short time scale.

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