Weekly HIGHLIGHTS

PPPL PRINCETON PLASMA PHYSICS LABORATORY

U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the week ending December 16, 2016 are as follows:

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

ITER Steady State Electrical Network (J. Dellas):

Power Transformers: The last two of the three shipping batches of the Group 1 and 2 transformers have arrived at the ITER site. The first batch, which has already been delivered, includes the main bodies of the twelve oil-filled transformers. These last two batches include the accessories of the transformers (radiators, bushings, remaining oil, etc.).

Reactive Power Compensators: Manufacturing at the Schneider Pringy, France, factory is ongoing. The Factory Acceptance Tests for the first two lots have been completed. A re-inspection of the second lot is scheduled for Dec. 19th to verify completion of the punch list items.

ITER Diagnostics (R. Feder):

Diagnostic Residual Gas Analyzer (DRGA): We received the Hiden long-cable QMS RGA system. The next step will be to test it at ORNL. The test stand used for earlier DRGA R&D can be used for this test.

Equatorial Port 09 (EP09) Integration and Diagnostic Shield Module (DSM) Engineering: A comprehensive plan was discussed and agreed upon to complete all EP09 CATIA modeling necessary for neutronics analysis. The analysis is scheduled to begin in January and results will be critical in assessing if current EP09 integrated design meets ITER radiation dose limits in specific zones. Dosage rates and their relationship to Port Plug weight limits are a high priority issue at ITER.

Toroidal Interferometer and Polarimeter (TIP): The PPPL CAD group created a proof of concept 3D model of the TIP Cooled Mirror Assembly utilizing the new MakerBot 3D printer. It was a successful learning experience and highlighted needed design features.

Core Imaging X-Ray Spectrometer (CIXS): Nuclear testing at Indiana University has concluded and interesting results have been obtained. The detector did not last for the full duration of the test. The cause of failure was the electronics, but the front end showed very good signs of survivability.

ITER Analysis Team: Participated in Preliminary Design Review (PDR) of the Hard X-Ray Monitor (HXRM) System integrated in Equatorial Port 12 (first plasma port) as part of an existing Task Agreement (TA). A face-to-face review of US Equatorial Port 09 (EP09) Load Specification was held at ITER Office in France in preparation for the port integration PDR. A draft report of dynamic response analysis of Upper Port 14 (UP14) under the plasma Vertical Displacement Event (VDE) inertial loads was completed. The resultant vibration characteristics of UP14 in-port components provide key design input for UP14 tenant system attached schemes.

Motional Stark Effect (MSE): Calibration of the MSE diagnostic will be of extreme importance. However, without access to the vessel a unique method must be created. Work this week has been on trying to find the approximate MSE sight positioning on the Blanket Shield Modules (BSMs) and aligning it with the VisIR. The focus is to try and use the VisIR as a means to calibrate the MSE diagnostic. Work continues on the construction of the MSE mirror testing chamber, with the new half dome covers to be completed shortly.

NSTX-U RECOVERY PROJECT (R. HAWRYLUK):

The recovery project Responsible Engineer's continued preparing System Design Descriptions (SDDs) as the first step in preparing for Design Validation and Verification Reviews (DVVRs). A centralized document gathering effort continued this week. A global spreadsheet has been developed which allows each Responsible Engineer to request documentation to support their DVVR. The QA branch is supporting this effort.

The lift/removal of the NSTX-U centerstack casing from the TF/OH coil bundle was successfully completed this week. Lift and Removal procedures for the disassembly of the PF1aL coil from the centerstack casing have been developed and are out for review. The PF1A-L coil removal is planned for this coming week.

The PF1A-U coil was further disassembled in the vicinity of the fault, which will enable a detailed inspection next week.

A video-conference call was organized by J. Menard with the MAST team to compare lessons learned regarding the design and fabrication of the magnets. The discussion was very productive and a follow on meeting will be held.

C. Neumeyer had a conference call with Stefan Fink from the Karlsruhe Institute of Technology (KIT) to discuss analysis of coil impulse testing.

Magnetic testing of an ITER diagnostic Piezo Actuator was successfully completed on the Field Coil Power Conversion (FCPC) Test Stand with a scan of 18kA shots at various ramp rates and flat-tops. The Test Stand will now be reconfigured for power testing of PF Inner Coils.

NSTX-U RESEARCH (J. MENARD):

Yang Ren gave an NSTX-U physics meeting presentation on HL-2A 2017 experimental campaign opportunities and capabilities. HL-2A at Southwestern Institute of Physics in Chengdu, China is a medium-sized conventional tokamak with a range of auxiliary heating systems, and profile and fluctuation diagnostics. The HL-2A team is interested in establishing a strong collaborative relationship with NSTX-U and is offering run time in 2017 to the NSTX-U team.

Ian Waters (PhD student at UW Madison) completed a two week visit to Oxfordshire, United Kingdom to initiate a collaboration on 3-D modeling of RMP pump out physics with the MAST team at CCFE. The goal is to gain insight into the mechanism behind the observed RMP induced density pump out at MAST, and compare it to ongoing studies of neutral fueling and exhaust for NSTX-U. This on-site collaboration identified three MAST shots for detailed study, integrated MARS-F plasma response results into a 3D computational grid generator, and yielded initial EMC3-EIRENE modeling for axisymmetric MAST plasmas.

Members of the University of Washington CHI team traveled to the QUEST ST from December 5 to 16 to commission the newly installed Transient CHI system on QUEST (R. Raman and J. Rogers to December 13). The first week was spent commissioning the CHI capacitor bank and the two fast CHI gas injection systems, both of which were attached to the QUEST machine. During these non-plasma tests remote control operation of both systems was tested, and the QUEST vessel was subjected to the CHI voltage potential of 600V for the first time. During the second week, reliable plasma breakdown was demonstrated for the first time in the new ST-FNSF relevant CHI electrode configuration used on QUEST. During these tests, the QUEST vessel was subjected to the full 2kV CHI voltage potential. This was followed by operation with increased capacitor bank energy using two switching ignitrons to generate at least 18 kA of toroidal current (possibly as high as 30kA - to be determined after additional data analysis). A slow visible camera showed plasmas detaching from the CHI electrode and drifting up. The magnitude of the toroidal current is similar to that achieved on NSTX during first CHI commissioning tests on NSTX. With the successful completion of these tests, the QUEST CHI system is now ready for CHI physics studies. These tests represent the effort of over three years of activities by the University of Washington, PPPL and Kyushu University groups to design, implement and test a new-design (much more reactor relevant) CHI configuration on QUEST. Successful gas breakdown and toroidal current generation, in this configuration, are major accomplishments for the Transient CHI effort to test solenoid-free plasma current generation in an electrode configuration in which the CHI insulator is not part of the vessel vacuum boundary and the injector current needs to be fed to the electrodes using a custom-designed vacuum feedthrough that can withstand large J x B forces. During over 150 CHI pulses on QUEST; the CHI engineering systems operated with 100% reliability with no issues. The CHI capacitor bank and the large primary CHI insulators are in-kind USA contributions to CHI effort on QUEST. Members of the QUEST Team and from Himeji University participated and provided dedicated support during the plasma initiation tests.

M. Ono (PPPL) visited the QUEST group at the Kyushu University on December 12 – 16. The primary purpose of his trip was to participate in the first experimental run of the coaxial helicity injection (CHI) experiment on the QUEST facility with the University of the Washington group led by Roger Raman (see the detail of the initial CHI operation by R. Raman above). M. Ono

also discussed during his visit possible QUEST Electron Cyclotron Heating (ECH) and Hot Wall physics collaboration areas with Profs. K. Hanada and H. Idei.

C. Myers led a meeting on December 14 summarizing NSTX-U error field metrology results and preliminary analysis, and outlined next steps for analysis and plans for reducing NSTX-U intrinsic error fields.

S. Gerhardt attended the Fusion Power Associates Annual Meeting and Symposium in Washington, DC on December 13 to receive his Fusion Power Associates 2016 Excellence in Fusion Engineering Award. J. Menard also attended the Fusion Power Associates meeting and presented "Progress and Plans on NSTX-U" on behalf of the NSTX-U research team.

ITER & TOKAMAKS (R. NAZIKIAN):

International (R. Maingi):

A team of people from the US-China PMI collaboration, A. Diallo (PPPL), R. Lunsford (PPPL), R. Maingi (PPPL), D. Mansfield (PPPL), T. Osborne (GA), K. Tritz (JHU), continued experiments on EAST, focused on ELM control with the lithium dropper, the lithium granule injector, and also a flowing liquid lithium limiter. Preliminary results include (1) the ability to pace ELMs in EAST with the granule injector, (2) achievement of windows of ELM suppression with the lithium dropper, and (3) reliable operation of the second generation flowing liquid lithium limiter, including compatibility with ELMy H-mode. Many thanks go to our ASIPP colleagues, J.S. Hu, S. Zhen, G.Z. Zuo, W. Xu, G.S. Xu, and X.Z. Gong, to enable these visits.

A second team from the US-China RMP collaboration, R. Nazikian (PPPL), N. Logan (PPPL), Z. Wang (PPPL), L. Cui (PPPL) and C. Paz-Soldan (General Atomics) visited EAST to explore the effect of resonant magnetic perturbations on pedestal stability and confinement. Experiments were for formed with n=1 and n=2 fields and ELM mitigation was observed at the peak of the plasma noaxisymmetric magnetic perturbation. Plasma response was studies for a range of RMP frequencies and phases in order to extract the plasma transfer function for future stability detection and plasma control.

G. Taylor visited EAST to run an experiment titled "Interactions of Fast Waves with the Scrape Off Layer Plasma". The experiment was run for about five hours with over 20 good plasma shots. Shots were completed for all phases of the experiment at ICRF power levels ~ 1 MW from. Notable differences between the performance of the Bay-B and Bay-I ICRF antennas were observed. Analysis of visible and IR camera images and divertor probe data is currently under way.

L. Cui visited the South West Institute of Plasma Physics in Chengdu and the HL-2A Tokamak . She gave a seminar titled "Energy Confinement Recovery Observed in DIII-D Plasmas with Resonant Magnetic Perturbations" . Lang gave a follow up presentation on TRANSP + OMFIT based on strong interest from the researchers in transport modeling for HL-2A.

DIII-D (R. Nazikian):

An article entitled "Main-ion intrinsic toroidal rotation profile driven by residual stress torque from ion temperature gradient turbulence in the DIII-D tokamak" by B.A. Grierson, W.X. Wang, S. Ethier, G.M. Staebler, D.J. Battaglia, J.A. Boedo, J.S. deGrassie and W.M. Solomon has been accepted for publication in Physical Review Letters. In the article, the main ion charge exchange system measures a hollowing of the core ion (deuterium) toroidal velocity profile above a critical power threshold in the applied ECH. Global gyrokinetic simulations with the GTS code reproduce quantitatively the hollow rotation profile in both shape and absolute magnitude, and indicate that residual stress is the dominant mechanisms producing the hollow rotation profile.

T. Stoltzfus-Dueck visited DIII-D this week to present his work on "Parasitic Momentum Flux in the Tokamak Core" at the DIII-D Friday Science Meeting, and worked with A. Ashourvan, B. Grierson and the DIII-D Rotation Thrust experimental team on plasma rotation modeling.

A comprehensive set of tests has been completed on the new granule feeder prototype developed by A.Nagy, A.Bortolon and D. Mauzey (student intern) for improving the impurity granule injector performance. The prototype was able to achieve granule feed rates up to 160 Hz. The feed rate was calibrated against applied voltage and observed to be highly reproducible. The reliability and robustness of the concept were demonstrated with an extended continuous run, during which the feed rate was maintained approximately constant at 90 Hz for more than 120 seconds. In addition to carbon and lithium granules, the prototype was also successfully operated with boron carbide hollow spheres 0.80-1.1 mm, which is of interest for ELM pacing and mitigation research.

ADVANCED PROJECTS (H. NEILSON):

Stellarators (D. Gates):

A project to develop a new style of a lost ion detector (LID) for W7-X has cleared a critical design milestone. These detectors use thin-film deposition technology to create Faraday cup style detectors which are only micros thick. This low aspect ratio design will allow them to be installed inside armor tiles on W7-X. Being mounted inside of armor tiles, greatly improves the device coverage necessary for experiments in stellarators. The design team led by Samuel Lazerson has been cleared to begin talks with thin-film deposition companies, detailed designs of a test holder, and electronics back-ends. These detectors will be tested on the 140keV accelerator at the Texas A&M Radiation Material Science and Characterization Facility before integration on W7-X.

S. Lazerson has been awarded one million hours of computational time to study energetic particle losses in W7-X at NERSC in 2017. This allocation continues 2016 project to prepare and demonstrate the BEAMS3D code on the Edison supercomputer. The BEAMS3D code is a energetic particle code which uses Monte Carlo methods to simulation both neutral beam deposition in stellarators and energetic particle loss to the wall. Currently the code is undergoing upgrades to treat a more detailed wall model of the W7-X experiment.

Laboratory staff, with colleagues from Oak Ridge National Laboratory and the University of Wisconsin, have developed a new plan for collaboration with Japan's National Institute of Fusion Sciences (NIFS), consisting of several joint tasks to be accomplished within the next several months. The plan was developed in response to an invitation from NIFS for the U.S. to re-engage with Japanese scientists in joint research on stellarators, including the Large Helical Device (LHD) facility at NIFS. With the start of deuterium operation for the first time next Spring, the LHD offers opportunities for new physics discoveries through comparisons with data from over 15 years of operation in hydrogen. Moreover LHD and Germany's Wendelstein 7-X (W7-X) stellarator offer contrasting plasma core and divertor configuration designs, and therefore the potential for new insights via LHD – W7-X comparisons. Topics for near-term collaborations include core heat transport, divertor optimization, pellet fueling, and energetic particle physics.

THEORY (A. BHATTACHARJEE):

A Research Letter by Dr. Fatima Ebrahimi was published in *Physics of Plasmas* titled "*Dynamo-driven plasmoid formation from a current-sheet instability*". Dr. Ebrahimi shows, for the first time, that axisymmetric current-carrying "plasmoids", coherent structures of plasma and magnetic fields, can form in the presence of *non*-axisymmetric magnetic perturbations. These three-dimensional (3D) effects are shown to be an important factor in the onset of reconnection, the so called "trigger" problem. To examine the 3D effects on the axisymmetric plasmoids, complete 3D resistive MHD simulations were carefully compared with two-dimensional (2D) calculations during coaxial helicity injection in spherical tokamaks. The driven current structure at the edge of the injected flux is unstable to peeling-like 3D instabilities, and these amplify the magnetic field that is driving the plasmoid reconnection. The field amplification enhances the local Lundquist number to trigger plasmoid instability. The proposed mechanism for local flux amplification is a dynamo action. This mechanism could play a role in the dynamics of solar flares, as well as the fast reconnection events in laboratory plasmas.

Dr. J. Carlsson, Dr. A. Khrabrov and Dr. I. Kaganovich, with external collaborators Dr. T. Sommerer (General Electric Global Research) and Dr. D. Keating (former Science Undergraduate Laboratory Internship student from U. California Berkeley) published the paper "*Validation and benchmarking of two particle-in-cell codes for a glow discharge*" in a special issue on kinetic methods in technological plasmas of *Plasma Sources Sci. Technol.* 26, 014003 (2017). The paper demonstrates the importance of code *validation*, *benchmarking* and *uncertainty quantification* to correctly simulate plasma devices with gas pressures of as little as a few Torr and strong electric fields (kilovolts/centimeter). The author's define a set of benchmark problems to test various anisotropic-collision models for these types of plasmas. The work was done as part of an effort to simulate a gas switch with power-electronics applications and was funded by the Advanced Research Projects Agency-Energy.

ENVIRONMENT, SAFETY, & HEALTH (J. LEVINE):

Keith Rule hosted three visitors from the University of Tokyo and the Japanese National Institute for Fusion Science (NIFS) as part of the DOE-FES sponsored Joint Working Group for Fusion Safety (Keith is the United States Team Leader for this Group). The program was established in

the late 1990s to improve the safety standards and communications for collaborative research activities between the two countries. The respective country representatives rotate visits to fusion research facilities on a periodic basis. The visitors toured Laboratory experiments, made several presentations to our staff, and shared safety practices and experiences.

COMMUNICATIONS & PUBLIC OUTREACH (A. ZWICKER):

Communications (L. Bernard):

J. Greenwald reported, wrote and posted a feature story on a paper by H. Qin and others *t*hat produced a new theoretical framework for particle accelerators; *Physical Review Letters* published the paper. Greenwald also arranged an interview by *American Scientist* magazine with Y. Raitses for a column on images of plasma nanosynthesis. Stefan Gerhardt won the 2016 Excellence in Fusion Engineering Award from Fusion Power Associates on December 13, and R. Rosen posted a press release on December 15.

DIRECTOR'S OFFICE (C. AUSTIN):

IOI (L. Hill)

Contractor mobilization continues to progress well. The first wave of Whiting Turner's primary subcontractors (demolition, electrical and mechanical) has been mobilized. The processing of RFIs and submittals is ramping up. Construction areas have been posted in the LSB Annex and C-Site MG Building and spaces are now under access control. The mechanical and electrical isolation of the Annex is nearing completion and full demolition will commence this week. Walk-downs in the C-Site MG Building continue to support demolition in early January. Laboratory support of IOI throughout mobilization has been excellent.

This report is also available on the following web site:
http://www.pppl.gov/publication-type/weekly-highlights