PRINCETON PLASMA PHYSICS LABORATORY
WEEKLY highlights

PPPL
U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the week ending February 26, 2016 are as follows:

U.S. ITER FABRICATION (C. NEUMEYER):

Steady State Electric Network (SSEN):

Uninterruptible Power Supply (UPS) system, DC Distribution, and Low Voltage (LV) Distribution and Sub-distribution Panels: A Project Change Request (PCR) for a revised plan that optimizes the final three SSEN procurements was approved. Purchasing specifications and Princeton Plasma Physics Laboratory purchase requisitions were submitted to launch the procurement process.

Power Transformers: Factory Acceptance Tests (FAT) were completed for the 10 transformers that comprise the Lot Three shipment from the factory of Schneider Electric, near Istanbul, Turkey. Note that the delivery of this shipment—by June 15—is an important ITER Council and PEMP milestone, and progress is well ahead of schedule.

Diagnostics:

Upper Port Wide Angle View Vis-IR Cameras (UWAVs): Work continues at General Atomics and TNO on the optical-mechanical engineering of the UWAVs in-vacuum optics assembly. This week, PPPL reviewed and approved fabrication drawings and the procurement plan for TNO to start piecing together the Mirror Cleaning Test Stand. Once assembly and commissioning of the device is completed this summer, TNO will verify the effectiveness of the RF driven Argon sputtering mirror-cleaning technique.

Electron Cyclotron Emission (ECE): Work continues at the University of Texas at Austin on the testing and analysis of the ECE Hot Calibration source. The test rig has been moved to a new facility and re-oriented to a vertical position, which represents the implemented installation orientation. Testing is focused on whether the heating element needs to be in direct contact with the back of the silicone carbide emitter disk or whether there can be a small gap. With a small gap, the heating element will need to be driven to a higher temperature, as heat transfer will only occur via radiation. The second meeting of the ECE Real Time Data working group was also held this week. This team is working through the methods by which ECE will be used to measure very fast plasma events like Neoclassical Tearing Modes (NTMs) and how this data can be quickly fed back to the ITER real time control system.

Equatorial Port 9 Integration and DSM Engineering: M. Smith and D. Johnson were at ITER this week participating in an annual meeting of the ITER diagnostic group joined by representatives from all domestic agencies. The meeting is meant to highlight recent progress, describe near-term plans, and discuss common issues and concerns.

Toroidal Interferometer and Polarimeter (TIP): An important preliminary design document, "Applicability of Dispersion Interferometer Approach for ITER Density Measurement (SNHJ9V v1.0)," was released by General Atomics to the ITER Organization (IO) this week. Dispersion Interferometry represents both a potentially viable and perhaps a desirable alternative to the currently planned two-color interferometer-polarimeter system being pursued for ITER. The Dispersion Interferometer (DI) approach has the advantages of (1) common beam path for both beams (no need for a separate reference beam path), (2) effects of path length changes due to vibrations or thermal expansion cancel in the measurement (no postdetection signal processing required), and (3) the total measured phase shift, which is due to the plasma, is typically ~1 to few tens of fringes for ITER (as compared to thousands of fringes for the conventional two-color approach) for source radiation at 10.6 μm, thereby reducing the potential for fringe counting errors. While the DI approach has several appealing features for application to ITER, due to operational inexperience with such a system and lack of development of the polarimetry capability, we recommend that the Dispersion Interferometer-Polarimeter (DIP) approach not replace the currently planned two-color TIP system. However since a DIP system for ITER would likely be built to function around 10.6 μm, all of the front end optics would be common to either the two-color TIP or DIP approach.

Diagnostic I&C Integration Engineering (ORNL, Bill DeVan): Work continues on generating preliminary cable design packages consisting of Piping and Instrumentation Diagrams (P&IDs), Single-Line Diagrams (SLDs), and Cable Collection Lists (CCLs). The IO needs these packages to support cable tray design and definition of other building interfaces. So far, the following packages have been submitted to the IO for review: Diverter DRGA, Equatorial DRGA, LFSR, and CIXS. Diagrams for the other USDA diagnostics are well along at this point. The remaining preliminary cable lists are in various states of progress.

NSTX-U (M. ONO):

A FY 2016 NSTX-U plasma operations update: The department has completed 3.86 run weeks and 388 plasma shots. The total operation targets are to be decided.

NSTX-U and Princeton University researchers recently published articles in the journal of Nuclear Fusion linking quantum mechanical, atomistic modeling of liquid lithium with macroscopic plasma experiments conducted on the Magnum-PSI linear plasma device located at FOM-DIFFER in The Netherlands. The paired papers, published by Tyler Abrams (former PhD student advised by M. Jaworski of PPPL, now at General Atomics), Nuclear Fusion (v56—2016—016020) and Mohan Chen (post-doctoral researcher in Emily Carter's research group at Princeton University), in the January issue of Nuclear Fusion (v56—2016—016022) sought to explain anomalously low erosion rates from high-temperature lithium experiments when subjected to high fluxes of deuterium plasma. The Princeton University group applied novel Density-Functional-Theory methods to demonstrate that LiD compounds were likely to be formed in the temperature ranges and concentration levels expected in the plasma exposures. A

mixed material model developed by Abrams, utilizing D-Li diffusivities derived from the PU quantum modeling, was then able to quantitatively reproduce the suppressed erosion measured in Magnum-PSI after taking into account several changes in erosion due to the LiD surface concentrations. Mixed material erosion experiments will continue with the upcoming High-Z Divertor facility enhancement, which will provide a divertor analogue to the Magnum-PSI experiments and further explore the use of liquid lithium as a high-temperature plasma-facing component.

NSTX-U researcher M. Jaworski (PPPL) gave an outreach talk titled, "Overview of solid and liquid plasma-facing component research for fusion energy at PPPL" on February 18 at the National Energy Technology Laboratory (NETL) in Albany, Oregon. The talk included recent highlights of research on plasma-facing components and the research approach taken to developing and evaluating novel components in the NSTX-U. Additional discussions were held on collaborative development of liquid plasma-facing components.

On February 23, S. Kaye, R. Hawryluk, G. Neilson and M. Zarnstorff of PPPL visited DOE to present the present plans for PPPL implementation of remote collaboration capabilities. In particular, Hawryluk gave the introduction, Neilson discussed plans for PPPL as the national facilitator for the W7-X collaboration, and Kaye discussed the approach that has been taken for NSTX/NSTX-U collaborations, and plans for implementing additional technical capabilities to enhance off-site participation in meetings and directly in experiments. Part of this plan includes establishing a remote participation center, which would be multiple usage, serving NSTX-U and outgoing collaborations on W7-X, EAST, MAST-U, etc.

On February 22 and 23, twenty Ohmic discharges were taken towards XMP-115 (ISOFLUX Commissioning). These shots started from the two "isodnull" discharges developed on February 19; here, "isodnull" refers to the ISOFLUX algorithm used for controlling diverted shapes, while "isoelong" is the algorithm used for controlling inner wall limited shapes. In the initial discharges, control transitioned to the isoelong algorithm at 200 ms, and then to the isodnull algorithm at 400 ms. Over the series of twenty discharges, the two control algorithms were shifted forward, until isoelong was turning on at 100 ms, and then isodnull at 200 ms. The latter was during the current ramp, allowing the single algorithm to be used for the entire 700ms flat-top duration. A number of MHD locked-mode events were observed to cause severe perturbations to the plasma, but the shape controller allowed the plasma to recover from the large disturbances.

On February 24, eighteen shots were taken in support of XMP-115 (ISOFLUX Commissioning) and XMP-137 (Increasing Ip and kappa in L- and H-mode). These discharges produced the first H-mode scenario at 800kA and achieved a kappa ~ 1.95 at li ~ 0.9 (203532) using 3.1 MW of NBI from two beams above 70 kV. This was an improvement from H-mode discharges in January that achieved kappa ~ 1.75 at I_p = 600kA with similar heating from three beams at lower voltage. The higher voltage beams from this day provided initial data for beam spectroscopy diagnostics. Many of the discharges were devoted to developing a ramp-up scenario including the handoff between various shape control algorithms and the timing of heating, diverting and fueling.

Twenty Ohmic shots were taken towards XMP-140 (PF-5 Proportional EFC Test) on February 25. These shots used a new PCS algorithm that applies a 3D field in direct proportion to the field in any of the TF, PF, or OH coils. In this instance, it was used to apply an n=1 field of magnitude proportional to the PF-5 current. Numerous proportionality constants and phases of this n=1 field were applied. The Ohmic target plasma had been selected based on the large MHD modes that it was susceptible to, and an applied field phase and magnitude was found that eliminated nearly all of these MHD modes. This provides a good start towards error field correction in higher-beta plasmas in NSTX-U.

Nineteen shots were taken towards the combined efforts of XMP-137 and XMP-115 on February 26. These shots utilized the error field correction strategy determined on the previous day. An attempt at dr-sep control using ISOFLUX revealed a bug in the PCS code, which was corrected later in the day but not yet tested in operations. L-mode scenarios with ~1 MW of NB heating were run at plasma current Ip = 800 kA for a ~1.8 second discharge, and Ip = 1000 kA for a ~1.2 second discharge; these are the longest discharge durations and highest currents yet achieved in NSTX-U.

NSTX-U plasma operations continued this past week with experiments to further develop the use of ISOFLUX control and on H-mode development. Progress was also made on establishing n=1 error field correction on a series of Ohmic shots >700kA. Time was taken this week to complete modifications to the Gas Injection System (GIS) to reconfigure electronics and add higher Voltage protection as needed to address recent failures. GIS operational controls were also updated to address Voltage breakdown failures associated with the low plenum pressures seen on some of our longer pulse plasmas. By the end of the week, high field side GIS injectors were back in service. Time was also taken to replace the NB1A ion source with a fresh spare, which is now being conditioned. The new MAPP diagnostic is successfully taking data.

ITER & TOKAMAKS (R. HAWRYLUK):

DIII-D (R. Nazikian):

S. Haskey visited UC Irvine to give a seminar on his work on beta induced Alfven eigenmodes on the H-1 stellarator and relevance to BAEs in DIII-D. The talk focused on comparisons with modeling that were enabled through unique diagnostic developments. The UC Irvine group and D. Spong discussed prospects for modeling the drive and damping for these modes using the GTC code. Additionally, B. Heidbrink and L. Stagner discussed how recent advancements to the FIDASIM code would significantly improve forward modeling of the DIII-D main ion CER system.

PPPL researchers N. Logan, B. Grierson, and S. Haskey have added a new feature to the OMFIT profiles module that uniformly handles the time base differences between various diagnostics and equilibria. In conjunction, there is a new EFIT time module that better handles running EFIT for many times, and a kinetic EFIT time module that can incorporate constraints from the OMFIT profiles and TRANSP modules in generating EFITs. Grierson, Logan, and Haskey have been added as core developers of OMFIT.

ADVANCED PROJECTS (H. NEILSON):

An important milestone was achieved in the Laboratory's fabrication of two TDU Scraper Elements for Wendelstein 7-X (W7-X), with the award of the last two of the three major industrial contracts. The two contracts were for specialized machining operations for the first-wall subassembly, one of two major subassemblies. Machining of metal components will be performed by Hollis Line Machine Co. of Hollis, New Hampshire. Machining of graphite parts and integration with the metal parts will be performed by MWI, Inc. of Rochester, New York. Material for both fabrication tasks is being furnished by Princeton Plasma Physics Laboratory to ensure compatibility with W7-X's strict material property requirements. A contract for fabrication of the base plate subassembly was awarded previously. With all three major contracts now awarded, the focus of the project is now on vendor management, quality control, and schedule.

D. Gates attended the Exploratory Plasma Research workshop held at Auburn University in Auburn, Alabama where he presented a poster entitled "Recent Advances in Stellarator Optimization." The workshop covers research in the area of Innovative Confinement Concepts.

THEORY (A. BHATTACHARJEE):

On February 25, Wenlu Zhang (Chinese Academy of Science, Beijing) presented a theory seminar on gyrokinetic particle simulation of fast electron driven beta-induced Alfven eigenmodes: "The fast electron driven beta induced Alfven eigenmode (e-BAE) in toroidal plasmas is investigated for the first time using global gyrokinetic particle simulations, where the fast electrons are described by the drift kinetic model. The phase space structure shows that only the processional resonance is responsible for the e-BAE excitations while fast-ion driven BAE can be excited through all the channels such as transit, drift-bounce, and processional resonance. Frequency chirping is observed in nonlinear simulations with both weak and strong drives in the absence of sources and sinks, which provide a complement to the standard 'bump-on-tail' paradigm for the frequency chirping of Alfven eigenmodes. For weakly nonlinear driven case, frequency is observed to be in phase with the particle energy flux, and mode structure is almost the same as linear stage. While in the strongly driven nonlinear case, BAAE is excited along with BAE after the BAE mode saturated. Analysis of nonlinear wave-particle interactions show that the frequency chirping is induced by the nonlinear evolution of the coherent structures in the energetic-particle phase space, where the dynamics of the coherent structure is controlled by the formation and destruction of phrase space islands of energetic particles in the canonical variables. Zonal flow and zonal field are found to affect wave-particle resonance in the nonlinear e-BAE simulations."

PLASMA SCIENCE & TECHNOLOGY (P. EFTHIMION):

This week there were two Plasma Science and Technology seminars. On February 24, Zhenyu Wang from Auburn University presented a seminar on Gyrokinetic Electron and Fully Kinetic Ion Particle Simulation of Current Sheet. The abstract reads: "Current sheet instabilities have attracted great attention for their potential roles in collisionless fast reconnection as a source of anomalous resistivity. Previously, the current sheet instabilities were investigated mainly in the

2-D geometries corresponding to lower-hybrid drift instability and the tearing mode instability. Besides, an artificial ion-to-electron mass ratio has often been used in fully kinetic particle simulations of reconnection. In this work, instabilities of a Harris current sheet are investigated using a 3-D linearized (δ{f}) electromagnetic gyrokinetic electron and fully kinetic ion (GeFi) simulation model. By removing the rapid electron cyclotron motion while retaining the finite Larmor radius effects, the instabilities under a finite guide field can be simulated for a realistic mass ratio. First, details of the GeFi scheme are introduced. Then, the complete profile of 3-D electrostatic instabilities are illustrated. The properties of 3-D electromagnetic instabilities are also presented. The simulation is performed for cases with a broad range of mass ratio m_i/m_e, current sheet half-width L, and the guide field B_G. The simulation results are benchmark against the GeFi analytical eigen theory and fully kinetic simulation in both the electrostatic limit and electromagnetic regime."

On February 26, Alex Khabry from St. Petersburg Polytechic University presented a talk on numerical simulation of flows governed by extended Navier-Stokes. The abstract reads: "Numerical simulations of fluid flow accompanied by additional physical phenomena go beyond Navier-Stokes formulation. They require specific tests for validation of models and for investigation of applicability and performance of computational tools. The present work covers the results of several studies, which include the following: 1) physical model elaboration, 2) testing and implementation of computational techniques, 3) performing of numerical simulations of various types of phenomena, including free-surface flows, heat and mass transfer and arc discharge. One of the topics included is a numerical study of Taylor-Couette flow (being a model of accretion disk flow) under conditions of Princeton Hydrodynamic Turbulence Experiment conducted in PPPL. Effects of various turbulence models on the computed flow field are investigated, and computational results are compared with experimental data. Also included is the development of algorithms for simulation of free surface flows (using Volume-of-Fluid method) and heat and mass transfer in a condenser tube attached to a radiator plate. Developed algorithms were incorporated into an in-house CFD-solver. Original computational techniques aimed at improvement of the Volume-of-Fluid method robustness and solution accuracy are presented."

Y. Raitses visited University of Madison Wisconsin (UWM) on February 21 and gave a Plasma Seminar entitled "Hall Thruster for Space Applications: Research Challenges and Advanced Concepts." He was invited by Professor Cary Forrest of UWM.

BUSINESS OPERATIONS (K. FISCHER):

Budget Office:

A Strategic Partnership Project proposal was submitted to NASA titled "Heavy Ion Effects on Low Frequency Waves in Planetary Magnetospheres." The Principle Investigator for this project is J. Johnson and the proposed budget is $415,797.

BEST PRACTICES & OUTREACH (J. DELOOPER):

Science Education (A. Zwicker):

On February 19 and 20, the New Jersey Regional Science Bowls took place at PPPL. Basking Ridge's William Anin Middle School, won the middle school regional and West Windsor-Plainsboro, South won the high school regional for the second consecutive year.

DIRECTOR'S OFFICE (C. AUSTIN):

On February 24, Dr. Andy Cheng, Johns Hopkins University Applied Physics Laboratory, presented a colloquium entitled, "New Horizons at Pluto."

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