

PRINCETON PLASMA PHYSICS LABORATORY

WEEKLY highlights



The PPPL Highlights for the week ending April 25, 2014, are as follows:

U.S. ITER FABRICATION (D. JOHNSON):

U.S. presentations on the current designs for the Residual Gas Analyzer and the Low-Field-Side Reflectometer were made at a meeting between the integrator of port E11 (RF) and representatives of all the tenant diagnostics. This is the first of several planned meetings over the next year, prior to freezing of interfaces in this port and the subsequent preliminary design review for the port.

The RGA design team met twice with the IO TRO to discuss the location of a second isolation valve for the divertor RGA sampling tube, to discuss scoping studies to evaluate moments on ITER flanges, and to plan dates for the Readiness Review and Final Design Review for this sampling tube.

A new version of the Annex B covering the Motional Stark Effect diagnostic was sent by the IO for US comment.

NSTX (M. ONO):

The NSTX-U Team Meeting was held on April 25. The presentations are available on http://nstx.pppl.gov/DragNDrop/NSTX_Meetings/Team_Meetings/2014/04_25_2014/. One important note is that the schedule for the in-vessel work continues through mid-June 2014, so please plan accordingly (see the Engineering Operation Update). Please also note that since we are not planning any vacuum vessel entry after the CD-4 in December, this period before mid-June maybe the only chance you have for the in-vessel access until the end of the FY15 research run (~ September 2015). If you are expecting any in-vessel activities, which are not already on the NSTX-U work planning list, please contact M. Ono or other NSTX-U managers immediately.

Several PPPL/NSTX-U scientists made presentations at the TTF meeting in San Antonio, Texas from April 21-25. S. Gerhardt presented a plenary talk "Recent research on high confinement, stationary ELM free operating scenarios for ITER and beyond", including highlights of the NSTX contributions on Enhanced Pedestal H-mode scenarios. Y. Ren presented an oral "Experimental observation of high-k turbulence evolution across the L-H transition in NSTX". M. Podesta presented an oral "Development of a new reduced fast ion transport model in TRANSP". W. Wang presented an oral "Roles of low-k turbulence in spherical tokamak plasma transport." D. Russell (Lodestar) presented an oral "Modeling the effect of lithium on SOL

dynamics and the SOL heat flux width observed in NSTX." NSTX posters were present by D. Battaglia, J. Chowdury (University of Colorado), W. Guttenfelder, R. Maingi, Y. Sechrest (University of Colorado), and D. Smith (University of Wisconsin).

Dr. Yeong-Kook Oh, Director of the Fusion Engineering Research Center at NFRI, and a team of electrical and mechanical engineers from the KSTAR superconducting tokamak device met with S. Sabbagh and Y-S Park of Columbia University and R. Ramakrishnan, J. Menard, and M. Ono of PPPL at PPPL on April 22-23 to discuss final details of a new high-bandwidth power supply and circuitry to be used to support research in several 3D physics topical areas on KSTAR as part of an ongoing NSTX-U/KSTAR collaboration.

R. Kaita (PPPL) gave a seminar entitled "Addressing the First Wall Challenge for Magnetic Confinement Fusion in the National Spherical Torus-Upgrade" at the Institute for Research in Electronics and Applied Physics at the University of Maryland at College Park. The presentation included a summary of lithium behavior in the NSTX Liquid Lithium Divertor, and the implications of recent high heat flux experiments with thin lithium films on candidate NSTX-U plasma-facing components. These results were also discussed with collaborators during a visit to Johns Hopkins University.

ITER & TOKAMAKS (R. HAWRYLUK):

DIII-D (R. Nazikian)

B. Tobias participated in DIII-D steady state fast ion transport experiments where extensive data was obtained on the 2D structure of Alfvén eigenmodes using the ECE-I and MIR diagnostics. Many other coherent edge-localized fluctuations were imaged in the experiment. Analysis will be performed to determine the relevance of these modes to fast ion transport. The ECE-I and MIR diagnostic is a joint collaboration between PPPL and UC Davis.

W. Solomon participated in QH-mode experiments aimed at addressing critical issues related to the extrapolation of the scenario to ITER, including improving the understanding of the rotation shear requirements for generating an edge harmonic oscillation (EHO), and mapping out the path to high normalized fusion performance at low input torque.

R. Nazikian participated in experiments on DIII-D aimed at addressing the dependence of the width of q95 resonant windows for ELM suppression on mixed harmonics of the applied 3D magnetic field. Toroidal mode numbers $n=1,2,3$ were applied using a reduced coil set (7) instead of the full compliment of 12 I-coils.

B. Grierson attended the Transport Task Force Meeting in San Antonio, TX and presented a talk titled "Time Dependent Predictive Modeling of Torque Rampdown Plasmas in DIII-D". Gerrit Kramer also attended the TTF meeting in San Antonio, Texas and presented a poster on the "Physics of Alfvén eigenmode induced transport in DIII-D plasmas".

G. Kramer visited DIII-D from April 14-18 and participated in TBM and fast ion physics experiment. The ORNL IR camera that is normally used on NSTX has been installed on DIII-D to measure localized heat loads on the TBM surface for fast-ion loss studies. It was successfully

tested in a series of piggyback experiments and is ready for the upcoming fast-ion loss TBM experiment in May.

The Lithium Granular Injector MOU has been signed off following a successful Physics Validation Review. The injector fabrication is presently underway at PPPL and will be delivered to DIII-D in July with installation scheduled for the next vent.

C-Mod (R. Hawryluk)

Robert T. Mumgaard (MIT), S. Scott (PPPL), and Jinseok Ko (MIT) will publish in Review of Scientific Instruments an article entitled “ Robotic calibration of the motional Stark effect diagnostic on Alcator C-Mod. The abstract states “The capability to calibrate diagnostics, such as the Motional Stark Effect (MSE) diagnostic, without using plasma or beam-into-gas discharges will become increasingly important on next step fusion facilities due to machine availability and operational constraints. A robotic calibration system consisting of a motorized three axis positioning system and a polarization light source capable of generating arbitrary polarization states with a linear polarization angle accuracy of $<0.05^\circ$ has been constructed and has been used to calibrate the MSE diagnostic deployed on Alcator C-Mod. The polarization response of the complex diagnostic is shown to be fully captured using a Fourier expansion of the detector signals in terms of even harmonics of the input polarization angle. The system’s high precision robotic control of position and orientation allow it to be used also to calibrate the geometry of the instrument’s view. Combined with careful measurements of the narrow bandpass spectral filters, this system fully calibrates the diagnostic without any plasma discharges. The system’s high repeatability, flexibility, and speed has been exploited to quantify several systematics in the MSE diagnostic response, providing a more complete understanding of the diagnostic performance.”

International

The article, "External heating and current drive source requirements towards steady-state operation in ITER", by F.M. Poli et al. has been published in *Nucl. Fusion* 54 (2014) 073007. This study indicates that a combination of electron cyclotron (EC) heating and lower hybrid (LH) current drive is compatible with the ITER goals of $Q=5$, H-factor of 1.6, and bootstrap current fraction above 50%. The LH is needed to form expanded ITBs, while the EC is needed to freeze the bootstrap current profiles with the maximum at mid-radius.

H.Q. Wang and G.S. Xu presented an oral at the TTF meeting in San Antonio, Texas from April 21-25; "Stationary H-mode regimes with edge coherent modes achieved by RF heating with lithium wall conditioning in the EAST superconducting tokamak." In the talk the role of edge coherent modes in driving quasi-steady regimes was identified. Furthermore it was concluded that the lithium powder injection using a device invented by D. Mansfield from PPPL facilitates access to this ELM-free, quasi-steady H-mode regime.

ADVANCED PROJECTS (H. NEILSON):

A manuscript entitled "Quasilinear Carbon Transport in an Impurity Hole Plasma in LHD," by D. Mikkelsen, K. Tanaka, and fourteen co-authors, was submitted to Physics of Plasmas. The

paper reports research carried out in collaboration with Japan's National Institute for Fusion Science. The characteristics of a Large Helical Device (LHD) plasma with an "impurity hole" are described, and the linear stability of ion-temperature-gradient modes is discussed. Quasilinear estimates of the radial flux of carbon are made for the experimental conditions as well as for a wide range of carbon density gradients. The carbon flux is always inward when the carbon density profile is hollow, so turbulent transport due to electrostatic long wavelength modes cannot explain the observed outward flux of carbon that creates the "impurity hole".

Several extensions of the STELLOPT optimization code have been made by S. Lazerson and H. Mynick of PPPL, in collaboration with J. Proll, visiting PPPL from Germany's Max Planck Institute for Plasma Physics. The improvements will greatly enhance STELLOPT's capability to optimize stellarator shapes for turbulent transport. New "proxy" measures for the expected levels of turbulence have been developed, permitting STELLOPT to address for the first time turbulence from trapped-electron modes as well as ion-temperature gradient (ITG) modes. An earlier "GENE-in-STELLOPT" proxy, which uses the GENE gyrokinetic code in STELLOPT's optimization cycle, has been extended in the new version to permit GENE to run in parallel mode, reducing the execution time of initial linear GENE runs by an order of magnitude on the PPPL cluster. Setup scripts have been developed so that STELLOPT may now be run on the Hopper cluster at NERSC, which will produce another major speedup. This added speed will make practical optimizing for an extended range of modes and physical effects than previously. Additionally, the ability to add parallelized codes to STELLOPT has been modularized allowing future parallel codes to be implemented with increased ease.

In the Laboratory's collaboration with Germany's Wendelstein 7-X (W7-X) project, D. Gates and N. Pablant visited the project site in Greifswald this week to prepare for the upcoming preliminary design review of the x-ray imaging crystal spectrometer (XICS) diagnostic being prepared for W7-X. Several meetings were held with key staff to discuss future activities in the U.S. collaboration with a focus on opportunities for U.S. university engagement in anticipation of an expected Funding Opportunity Announcement from the Department of Energy. Plans for the upcoming inaugural run of W7-X were also discussed.

THEORY (A. BHATTACHARJEE):

The theory seminar on April 24 was presented by Dr. Eun-Hwa Kim from PPPL entitled "Role of the ion-ion hybrid resonance in the planetary magnetospheres". The abstract is "Ion cyclotron frequency range waves (or electromagnetic ion cyclotron wave, EMIC) have been often observed at Earth and Mercury's magnetospheres. Because the presence of different ion species has an influence on the plasma's dispersion characteristics near the ion gyrofrequencies, new multi-ion resonances, such as Buchsbaum and ion-ion hybrid (IIH) resonances, are added with each additional ion species. When the frequency of incoming fast compressional waves matches the ion-ion hybrid resonance condition in an increasing (or decreasing) heavy ion concentration or inhomogeneous magnetic field strength, wave energy from incoming compressional waves concentrates and mode converts to electromagnetic ion cyclotron (EMIC) waves. Mode conversion at this resonance has been simulated using a multi-fluid code showing that the resulting EMIC waves are strongly guided by the ambient magnetic field (B_0) and have linear polarization, therefore, the IIH resonance has been suggested to be the field-line resonance at Mercury and linearly polarized EMIC waves at Earth. In addition, because the IIH resonance

frequency depends on B_0 and the ratio of the ion densities, the ratio of the ion densities can be estimated using the IHH resonance frequency of the observed linearly polarized EMIC waves. Using 1D and 2D full wave codes, time-dependent multi-ion wave model, we discuss how such IHH resonance occurs in the Earth and Mercury's magnetosphere and how to infer heavy ion density using the IHH resonances."

A paper entitled "Analytical methods for describing charged particle dynamics in general focusing lattices using generalized Courant-Snyder theory" by H. Qin, R. C. Davidson, J. W. Burby, and M. Chung published this month in the Physical Review Special Topics – Accelerators and Beams was selected by the Editor as a highlight article for the journal. This paper analyzed the gauge group structure of the generalized Courant-Snyder (CS) theory for coupled beam dynamics. By fixing the gauge freedom with a desired symmetry, the generalized CS parametrization assumes the form of the modified Iwasawa decomposition, whose importance in phase space optics and phase space quantum mechanics has been recently realized. This gauge fixing also symmetrizes the generalized envelope equation and expresses the theory using only the generalized Twiss function beta. The generalized phase advance completely determines the spectral and structural stability properties of a general focusing lattice. For structural stability, the theory enables application of the Krein-Moser theory to greatly simplify the stability analysis. This new theoretical development provides an effective tool to study coupled dynamics and to discover more optimized lattice designs in the larger parameter space of general focusing lattices.

W. Fox attended the annual OMEGA Laser User Group conference at the University of Rochester Laboratory for Laser Energetics and presented a poster, "Colliding Magnetized and Unmagnetized Laser-produced Plasma Plumes for Laboratory Astrophysics."

COMPUTATIONAL PLASMA PHYSICS GROUP (S. JARDIN):

E. Feibush presented a hands-on programming workshop at Princeton University on April 24 about scientific computing in Python. The session was a mini-course organized by PICSciE, the Princeton Institute for Computational Science and Engineering. The primary topic was Python's N-dimensional array software "numpy." Topics and programming exercises included the creation and use of computationally efficient arrays, applying Python's numerical functions, and plotting data in Python. There was also a demonstration of how to embed LaTeX commands into Python graph functions to format equations and high quality labels. Matthew Lotocki was the Teaching Assistant for the class. Researchers from ten different departments attended.

J. Chen implemented a new diagnostic in the nonlinear M3D-C1 extended MHD code to calculate and display the toroidal harmonics of the magnetic energy. This complements a similar diagnostic implemented earlier that calculates and displays the toroidal harmonics of the kinetic energy. This capability greatly assists the interpretation of the results of a 3D calculation and provides a consistency check when comparing weakly nonlinear runs with linear runs. Setting `ibh_harmonics=nmax` in the namelist file will calculate and plot the first nmax harmonics as a function of time.

ENGINEERING AND INFRASTRUCTURE (M. WILLIAMS):

NSTX Upgrade (R. Strykowski, E. Perry, L. Dudek, T. Stevenson)

Construction: Lower outboard diverter tiles have been installed and the upper diverters will be installed the week of April 28. The Langmuir probe tiles have been installed. The centerstack casing has been stood up in the south high bay so the lower PF1B coil can be installed once it has passed testing. The gas injection valves have been installed. The bay I port cover is being machined to accept a shutter that will be installed the week of April 28. The stainless rings for the ceramic breaks are being re-tapped. The cabling for the vacuum/RGA/GIS systems is being installed and new fibers at bay G have been installed for MSE. The bus bar fabrication and trial fits continue. The final metrology procedure is in progress and it will be completed by May 9. The potting of the TF outer leg aluminum blocks will start the week of April 28. The MAPP probe needs to be trial fitted to assure that it clears the new CHI bus.

CS Upgrade: The winding on layer 4 continued smoothly this week with approximately 50% of the layer completed along with four inline brazes and a conductor spool changeout. The PF1B coil cover was refitted and welded on, the only item remaining is to rerun the coil ring test before delivering the coil to D-site for installation on the CS Casing. One of the cracked lead extensions was delivered from Martinez. The extension was dissected into three pieces, one piece was subjected to solution anneal and age hardening, and one piece a short stress relieving cycle and the third was left as received. The pieces have been shipped to Laboratory Testing for specimen preparation and testing for UTS, fracture toughness and grain structure analysis. Results are expected the week of April 28. The remaining pieces at Martinez are being UT inspected for hidden cracks. At this time, only one additional piece failed to pass tests and approximately 24 remain to be tested. The hoses for the water system upgrades were received from the supplier, but three reels were received damaged and are being returned. Personnel from PPPL visited a new machine shop in northern New Jersey, Imperial Machine Shop. The Shop appeared to be well suited to provide PPPL with quality machining services. Two contracts were awarded to Imperial, the high strength studs for the ceramic break and the G10 Crown Pieces.

NBI Upgrade: The Armor installation is complete. Transmission line assembly and preparation for relocation continues in the TTC. One transmission line is complete and ready to move to NTC. Mod/Reg controls work and preparation continues. Calorimeter water manifold installation is in progress. VV RWM coil fabrication continues for the Bay JK area. Vacuum system fabrication and installation continues in the NTC. A BL2 entry is being performed to remove alignment gear and clean out the box prior to pumpdown. NB Controls work on rack wiring continued in NTC and gallery. Additional NB installation procedures are in development and review.

Digital Coil Protection System: DCPS stage I testing continued this week using the Autotester (AT) and waveform input files. The test procedure can be performed in its entirety. Work continued on the DCPS GUI. DCPS code development included some clean up of known loose ends. Hardware and I/O layout and design continues and work on hardware drawings continues. PCB design and procurement is in progress. The DCPS Data Dictionary has been updated to include latest information from interface discussions. A status meeting was held to review progress. Progress continues on the FCPC Level 1 fault circuitry drawings and plans.

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

PPPL celebrated Earth Day with a campus-wide grounds cleanup on April 22 and special events of April 23. A special Earth Day colloquium was presented by John Lee of the New York City Mayor's Office of Long Term Planning and Sustainability. Mr. Lee discussed New York City's long-range efforts to reduce greenhouse gas emissions, promote energy and water efficiency, reduce waste and develop sustainable communities while accommodating over one million new residents and adapting to the impacts of global climate change.

BEST PRACTICES & EXTERNAL AFFAIRS (J. DELOOPER):

PPPL hosted the New Jersey Technology Council on April 24 for its first "Energy Storage" work group meeting and a technology tour. More than 35 individuals participated in the event.

DIRECTOR'S OFFICE (C. AUSTIN):

On April 24, the quarterly Laboratory Management Review (LMR) was presented to the Laboratory. At this meeting, departmental managers provided a six-month review of the various departments at PPPL.

PUBLICATIONS:

Poli, F.M., "External heating and current drive source requirements towards steady-state operation in ITER," *Nuclear Fusion* 54 (2014) 073007

Qin, H.; Davidson, R.C.; Burby, J.W.; and Chung, M., "Analytical methods for describing charged particle dynamics in general focusing lattices using generalized Courant-Snyder theory," *Physical Review Special Topics – Accelerators and Beams* 17, 044001 – Published 8 April 2014

This report is also available on the following web site:

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