PRINCETON PLASMA PHYSICS LABORATORY
WEEKLY highlights

PPPL
U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the weeks ending July 5-12, 2013, are as follows:

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

Feedback was sought from General Atomics diagnostic experts on the present design concept for the 3 Toroidal Interferometer/Polarimeter (TIP) retro-reflectors, which are located in the blankets lining the side-walls of the heating beam ducts. These geometries make full use of the available thickness of these blankets to place these optical elements deep into a penetration through the blanket. The primary issue being investigated is the need for active cooling of these components to avoid optical degradation due to thermal distortion under the volumetric heat load from neutrons and gammas. Preliminary calculations indicate distortion limits are exceeded for retro-reflectors geometries cooled by thermal conduction to the blanket with no active cooling.

A report entitled "Nonlinear Elasto-Plastic Thermal Fatigue Analysis during Normal Operation" was circulated to the IO for comment. This reports documents fatigue analysis of the diagnostic first wall (DFW) with a thickness of 8 mm. The analysis indicates that a DFW design with this thickness cannot be justified through analysis, whereas a 5 mm thickness is justified by similar analysis.

A monthly progress meeting of the upper port plugs 11 and 14 focused on the cooling of the diagnostic shield module (DSM). The volume of the DSM must accommodate features that guide and hold the DSM in place, space to install and support the upper endoscope, the disruption mitigation system, and the glow discharge probe, and channels for water cooling/heating. Designs for all of these elements will have to be closely coordinated to optimize the use of available space.

NSTX (M. ONO):

NSTX-U is in the Upgrade Project outage in FY 2013. NSTX Upgrade construction activities continued this week and are highlighted in the Engineering section below.

S. Gerhardt (PPPL) submitted to DOE the third quarter report for the 2013 Joint Research Target (JRT) on June 28. This JRT is designed to examine high-performance, stationary regimes without large ELMs. The report described various experiments on DIII-D designed to study I-mode or different aspects of QH-mode. The report also described ongoing analysis of previously collected C-Mod and NSTX data.

Members of NSTX-U participation at the RF Conference held in Sorrento, Italy during June 25-28 consisted of one engineer and four physicists. R. Ellis presented his design of the compliant center conductors needed on NSTX-U to reduce disruption forces on the center feed conductors of the HHFW antenna. N. Bertelli presented full wave modeling results for the NSTX-Upgrade H-mode plasma scenario obtained with the AORSA code, which importantly show that a collision term can be used as a proxy for the complex wave damping processes occurring in the scrape off layer (SOL) to determine the magnitude of damping required to match the experimental RF power deposition results. J. Hosea examined the effect of the choice of the magnetic equilibrium for NSTX on the SPIRAL calculation for power flow along the magnetic field lines passing in front of the HHFW antenna in the SOL. LRDFIT04 gave the best matches between SPIRAL strike points and IR heat deposition measurements, and between the predicted outer vessel strike radius (OVSR) and the location of a Langmuir probe detecting the crossing of the OVSR. This supports the conclusion that RF power flow to the divertor in the SOL is essentially along magnetic field lines. G. Taylor presented RF modeling results for EC heating of low-density CHI start-up discharges in NSTX-U and for EBW heating and current drive in NSTX-U H-mode plasma scenarios. He found that ~500 kW of 28 GHz EC heating should be sufficient to support the goal of heating a CHI discharge to 200-400 eV in 20 ms, and it should be possible to drive ~ 25 kA/MW with EBW current drive in a typical high-density NSTX-U H-mode plasma. The conference was well attended by RF physicists and engineers from all the major fusion facilities worldwide. It covered many areas of RF of interest for heating and current drive, as well as for RF machine conditioning during magnetic field operation, and RF spectra in space.

S. Jardin (PPPL) made a presentation at the June 24 NSTX-U Physics Meeting entitled "The Nonlinear M3D-C1 Code with Application to the Disruptive Beta Limit in NSTX". The motivation for developing this code was to assess the non-linear and fully 3D aspects leading to both hard and soft disruptive scenarios. M3D-C1 has high accuracy, flexible geometry that can handle a separatrix, it can run long-time simulations, encompassing both transport and stability time scales. It can be run in 2D nonlinear or 3D linear or nonlinear modes. It uses an unstructured mesh with high resolution near the plasma edge (developed by collaborators at RPI), and uses a unique implicit PDE solver that enables large time steps and quick convergence (e.g., 10s to 100s iterations). The code is inherently numerically stable even if the toroidal mode number of the mode being studied is the same order as the number of toroidal elements being used (i.e., underresolved). The code was used to examine pressure driven modes in NSTX with q0>=1 in OH and NBI heated plasmas. In the OH case, with relatively low and decreasing beta, the 3D mode effect was found to be important for redistributing Te by comparing to 2D simulations. 3D asymmetries are found to develop during the initial phase of the calculation, but the plasma becomes more axisymmetric in time, most likely due to fast parallel transport. With NBI heating to keep beta constant near the beta limit, the surfaces remain distorted with toroidal asymmetries, but the plasma retains confinement, suggesting a mechanism for a soft (non-disruptive) beta limit. As q0 decreases towards 1, the simulations show a thermal collapse, indicating more violent behavior that might reflect a hard (disruptive) limit.

Preparations for plasma operations in the NSTX-U configuration also continued with the refurbishment and maintenance of the transformers and fast vacuum interrupters for the neutral beam power system.

ITER & TOKAMAKS (R. WILSON):

DIII-D (R. Nazikian):

M. Podestà (PPPL) and the DIII-D Energetic Particles group run an experiment to explore the impact of external magnetic perturbations on TAE modes. Good progress was made toward a suitable L-mode target featuring robust TAE activity and plasma rotation close to zero, to which n=1 perturbations at f=500Hz from the I-coils were added. Scenario development required a fine tuning of the NBI waveforms, with partial success in achieving the required conditions (TAEs, zero rotation, L-mode) simultaneously. Analysis is under way to define the path forward for further studies.

ADVANCED PROJECTS (H. NEILSON):

As part of PPPL's collaboration with Japan's Large Helical Device (LHD) stellarator program, N. Pablant traveled to the National Institute for Fusion Science to continue work on the investigation of ion and electron heat transport of high electron-temperature electron cyclotron-heated LHD discharges. The transport analysis is being done using the TASK-3D transport suite in collaboration with NIFS scientists. During this trip development has continued on the PPPL developed pyTask3d front end for the TASK-3D transport suite. Newly completed is the integration of ion temperature profiles from the XICS system, equilibrium reconstructions from STELLOPT, and ECH deposition profiles as calculated by the ray-tracing codes TRAVIS and LHDGauss. This integration allows for the first time an experimental transport analysis of both ions and electrons to be completed in a pure ECH heated discharge (without neutral beam injection). In addition, progress was made on making predictions of the neo-classical transport expected in these High-Te shots using the codes GSRAKE and FORTEC-3D. This work will be presented at the International Stellarator Heliotron Workshop in September.

PPPL engineer M. Mardenfeld visited the Max Planck Institute for Plasma Physics (IPP) in Greifswald, Germany, this week and Stellarator Physics Leader D. Gates arrived at IPP to begin a three-week visit. Both visits are in support of U.S. planning for the next phase of our collaboration with the Wendelstein 7-X (W7-X) program, which will see the completion of construction, first plasma, and the first research campaign. Mardenfeld explored opportunities for on-site collaboration in engineering tasks critical to the U.S. research agenda, such as interfacing of U.S.-supplied equipment to the W7-X facility. Gates will work with the W7-X research team to explain the menu of options being considered the in the U.S. and agree on priorities and scheduling.

THEORY (A. BHATTACHARJEE):

W. Tang participated in the invitation-only DOE ASCR Workshop on "Accelerating Scientific Knowledge Discovery (ASKD) in Washington, DC on July 11-12. The workshop agenda is located at http://www.orau.gov/ASKD2013/agenda.htm with reference documents posted at http://www.orau.gov/ASKD2013/reference.htm . The vision for this proposed program is to "significantly shorten the time needed to transform scientific data into actionable knowledge by enabling the dynamic creation of advanced discovery ecosystems."

ENGINEERING AND INFRASTRUCTURE (M. WILLIAMS):

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

Construction: The assembly and testing of TF coil #13 has been completed and it has been installed in position K. All TF outer legs are now in place, so the upper cable tray can be completed and the re-installation of cables can begin. All umbrella stiffeners are now in place and welding of these stiffeners to the umbrellas continues. PF4/5 support modifications continue as well. The new vessel penetration between Bays F and G was cut this week and the port plug for the MPTS diagnostic should be installed in a few days. In addition, the electrical items moved on the south side of the machine for TF work have now been re-installed and similar re-installations are now in progress on the east and west sides of the machine. This includes the re-installation of rack 419 on the 109' platform at bay J. The installation of five new gas injection ports is just getting underway, as is the set-up for aligning the outer TF support structure weldments.

CS Upgrade: The TF bundle full mold from Reno has been measured using the laser tracker and was found to be in tolerance and of high quality. The mold is now being prepped to accept the quadrants for the VPI of the full TF Bundle. The OH conductor samples have been made for test and are now in the Material Test Lab awaiting test. Also ready for test are the e-beam weld test samples. The CS casing stud welding has commenced and the studs have been installed on 75% of the divertor area. The grapfoil gaskets for the remaining tiles have been received from Carolina. Also completed at Carolina Fabricators this week were the OH G-10 Insulators and Lower Umbrella Lid sections. The only remaining structural part at Carolina is the pedestal for the centerstack which is on track to ship near the end of August. A decision was made to not install the CHERS passive plates in their current condition. The drawings are being prepared to go out for procurement of new plates using the Cu-Cr-Zr material in the warehouse.

NBI Upgrade: BL2 handrail installation on the Source platform continues. TTC HVAC duct reinstallation continues and nears completion. Some decon of the TTC SE side was performed and more is planned. Fabrication and leakchecking of LHe and LN cryo line continues in the NB shop. Installation of LN supply line in the NTC continues and nears completion. Fabrication and welding on the NB/TVPS duct and bellows shield components in the Tech Shop nears completion. Evaluation and analysis of the VV leg modification required for NB duct and TMP installation concluded that the proposed change in leg angle and other minor adjustments will be adequate for the upgrade loads. SFLIP VV modification analysis concluded successfully. The calculation is being formally approved. The DI water system subcontract continues with pipe fitting, welding, and installations in the Pump Room. Planning for MER work is in progress. Pipe was lowered to the MER mezzanine. MER scaffold set up is planned. The power system cable and tray procurement is in progress. The IP is in review. The JK VV reinforcements and SFLIP pieces are on order and delivery is expected next week. LCC Controls work continues. NBI Armor ATJ tile machining is complete and tiles have been delivered. The NSTX Safety Assessment document NBI section was reviewed and updated for the NSTX Upgrade in preparation for Activity Certification Committee use.

Facilities and Site Services (M. Viola):

Material Services Highlights: Property Management participated in the ITER Project training held on-site at PPPL on July 9 with ITER and ORNL folks. The meeting was provided to give PPPL training and guidance concerning procurements, transactions and exports associated with ITER related Personal Property and deviations employed.

INVITED TALKS:

M. Jaworski (PPPL) delivered an invited presentation, "Liquid metal plasma-facing component research on the NSTX" at the European Physical Society Conference on Plasma Physics in Espoo, Finland. Three critical issues which face liquid-metal plasma-facing component development were described: liquid-metal stability, mass-transport and inventory control, and the development of integrated scenarios. In this talk, results of the Liquid Lithium Divertor experiments conducted in NSTX during the FY2010 run campaign which demonstrates stable operation of a liquid metal target in the NSTX divertor. The research also indicates that vacuum residual gases rapidly contaminate lithium surfaces in the NSTX and motivate development of flowing systems for future experiments in the NSTX-U. The talk also described design studies conducted with Laboratory Directed Research and Development funding aimed at developing a self-consistent divertor target appropriate to a power reactor. In these studies that focus on state-of-the-art cooling technologies, it was found that surface temperatures above 700C are likely to be found when the surface is subjected to typical divertor heat-loads expected for next-step devices. This result motivates research on continuously vapor-shielded divertor targets on the NSTX-U and the impact of such a regime on mass-transport and core performance. [NSTX]

R. Perkins presented an invited talk on the magnetic field-aligned edge-loss of HHFW RF power on NSTX at the RF Conference held in Sorrento, Italy during June 25-28. A very crude initial estimate of the power loss to the divertor plates for a given case was that up to ~ 50% of the edge power loss was in the RF heat spirals on the divertor plates. There was considerable interest in the components of the total edge power loss and further experiments will need to be conducted on NSTX-U to quantify these using a broad array of IR camera coverage. [NSTX]

Dr. I. Kaganovich gave a plenary talk at European Physical Society Conference on Plasma Physics titled "Nonlocal Kinetic Theory of Plasma Discharges". The purpose of the talk was to describe recent advances in nonlocal electron kinetics in low-pressure plasmas. Low-pressure discharges are widely used in industry as the main plasma sources for many applications including plasma processing, discharge lighting, plasma propulsion, particle beam sources and nanotechnology. Being partially-ionized, bounded, and weakly-collisional, the plasmas in these discharges demonstrate nonlocal electron kinetic effects, nonlinear processes in the sheaths, beam-plasma interaction, collisionless electron heating, etc. Such plasmas often have a non-Maxwellian electron velocity distribution function. The plethora of kinetic processes supporting the non-equilibrium plasma state is an invaluable tool, which can be used to adjust plasma parameters to the specific needs of a particular plasma application. The talk reports on recent advances in nonlocal electron kinetics in low-pressure plasmas where a non-Maxwellian electron velocity distribution function was “designed” for a specific purpose: in dc discharges with auxiliary biased electrodes for plasma control, hybrid DC/RF magnetized and unmagnetized plasma sources, and Hall thruster discharges. It was shown using specific examples that this

progress was made possible by synergy between full-scale particle-in-cell simulations, analytical models, and experiments. U.S. Department of Energy and Air Force Office of Scientific Research supported this research. [Theory]

PUBLICATIONS:

The article “Mitigation of Alfvén Activity in a Tokamak by Externally Applied Static 3D Fields” by A. Bortolon (UTK/UCI), W.W. Heidbrink (UCI), et al., has been published on Physical Rev. Letters (Vol. 110, p 265008). The article reports NSTX observations demonstrating that externally applied 3D fields can be used to alter the dynamic of high-frequency bursting and chirping Alfvén modes, driven by energetic beam ions. Using static n=3 pulses with field amplitude close to the threshold for ELM trigger, the amplitude of the bursting modes (GAE, 400-700 kHz) could be reduced, the bursting frequency increased, with a smaller frequency chirp. For modes of weaker bursting character, the magnetic perturbation induced a temporary transition to a saturated continuous mode. The article reports calculations of the perturbed fast-ion distribution function made with the SPIRAL code, indicating that the 3D perturbation affects the orbits of fast ions that resonate with the bursting modes. Although these NSTX high-frequency modes were not particularly detrimental to performance, the results represent an early demonstration of the possibility of controlling fast-ion instabilities by “phase-space engineering” of the fast-ion distribution function. [NSTX]

The paper "Electron-scale Turbulence Spectra and Plasma Thermal Transport Responding to Continuous E × B Shear Ramp-up in a Spherical Tokamak" by Y. Ren (PPPL), et al., has been published in Nuclear Fusion (53 (2013) 083007). It presents the first observation of the change in electron-scale turbulence wavenumber spectrum (measured by a high-k scattering system) and thermal transport responding to continuous ExB shear ramping-up in an NSTX center-stack limited and NBI-heated L-mode plasma. It is observed that as the ExB rate is continuously ramped up in the high-k measurement region, the ratio between the ExB shearing rate and maximum ITG mode growth rate continuously increases (from about 0.2 to 0.7) and the maximum power of the measured electron-scale turbulence wavenumber spectra decreases. Meanwhile, electron and ion thermal transport is also reduced in the outer half of the plasmas as long as MHD activities are not important and the L-mode plasmas eventually reach H-mode-like confinement. Linear and nonlinear gyrokinetic simulations are presented to address the experimental observations. [NSTX]

The paper "Comparison of Gas Puff Imaging Data in NSTX with DEGAS 2 Simulations" by B. Cao (Chinese Academy of Science, China), D. P. Stotler (PPPL), et al., was published in Fusion Science and Technology 64, 29 (2013). It describes a validation test of the DEGAS 2 Monte Carlo neutral transport code using deuterium light emission data obtained with the Gas Puff Imaging (GPI) diagnostic on NSTX. The radial widths and peak locations of the simulated and measured light emission profiles agree to within the estimated uncertainties, similar to previous validation efforts. An important new aspect of this validation is a comparison of the absolute magnitude of the light emission. The experimental result for a particular shot is 1/89 +/- 34% photons per atom, while the DEGAS 2 simulation yields 1/75 +/- 18% photons per atom, again agreeing to within the estimated uncertainties. This result provides confidence that similar techniques can be used to interpret passive light emission in NSTX. [NSTX]

A paper titled "Boundary perturbations coupled to core 3/2 tearing modes on the DIII-D tokamak" by B. Tobias et al. has been published online in Plasma Physics and Controlled Fusion. [ITER and Tokamaks]

The following PPPL Reports were posted to the web:

Axisymmetric Simulations of the ITER Vertical Stability Coil PPPL-4925
Authors: Peter H. Titus, Han Zhang, Michael Kalish, Edward Daly
Submitted to: SOFE 2013 Proceedings (June 0213) 25th Symposium on Fusion Engineering, San Francisco, CA (June 10-14, 2013)

Upward-facing Lithium Flash Evaporator for NSTX-U PPPL-4926
Authors: A.L. Roquemore, et. al.
Submitted to: SOFE 2013 Proceedings (June 0213) 25th Symposium on Fusion Engineering, San Francisco, CA (June 10-14, 2013)

Development of a Process to Build Polyimide Insulated Magnets For Operation at 350C PPPL-4927
Authors: I.J. Zatz and S. Jurczynski
Submitted to: SOFE 2013 Proceedings (June 0213) 25th Symposium on Fusion Engineering, San Francisco, CA (June 10-14, 2013)

Physics Design of a 28 GHz Electron Heating System for the National Spherical Torus Experiment Upgrade PPPL-4928
Authors: Gary Taylor, et. al.
20th Topical Conference on Radio Frequency Power in Plasmas, Sorrento, Italy, June 25-28, 2013)

Comparison of Measurement And Modeling Of Current Profile Changes Due To Neutral Bean Ion Redistribution During TAE Avalanches in NSTX PPPL-4929
Authors: Douglas S. Darrow, et. al.
Submitted to: Plasma and Fusion Research (July 2013)

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