
**The PPPL Highlights for the week ending December 6, 2013, are as follows:**

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

The Request for Proposal Package for "Physics and Engineering Design Support for ITER Toroidal Interferometer Polarimeter (TIP) Front-End and Provision of TIP Optical Relay and Diagnostic Hall Components" was submitted to DOE for approval.

In a meeting with window experts from the ITER Organization, the PPPL port integration team learned about possible variations in the ITER window configurations aimed at providing flexibility for diagnostic integration. PPPL provided an update on window functional requirements.

Several PPPL engineers participated in an ITER Design Integration Review to review the interfaces with the ITER port plugs. A proposed welded-lip vacuum seal design was presented which requires more space at the back of the plugs. If adopted, this change would have a significant impact on diagnostic integration. A presentation was sent to the ITER Organization summarizing PPPL's experience with large helicoflex vacuum seals on TFTR. A Final Design Review for the large port plug seals is planned in the near future, based on a welded lip approach.

U.S. comments were submitted to the IO drafts of the Procurement Arrangements governing the provision of the Core Imaging X-Ray Spectrometer, equatorial port plug #3 and the Motional Stark Effect Diagnostic.

In an RGA Technical Meeting, a new concept for the divertor RGA sampling pipe was discussed. Modifications to the sensor/pump cart were also proposed to better enable disassembly for replacement of parts.

**NSTX (M. ONO):**

The paper "Measurements and simulations of low wavenumber pedestal turbulence in the National Spherical Torus Experiment" by D. R. Smith (UW-Madison) et al. was published in Nuclear Fusion. The paper 1) reports BES measurements of H-mode pedestal turbulence fluctuation amplitudes, 2) applies an ensemble machine learning algorithm to identify parametric scalings for fluctuation amplitudes, and 3) reports pedestal turbulence simulations with full-pedestal domains. Fluctuations amplitudes at r/a=0.84-0.96 in the steep gradient region are in the range 1.2-4.7%. Modeling results from the machine-learning algorithm indicate fluctuation

amplitudes increase at higher density gradient, collisionality, and beta; fluctuation amplitudes decrease at higher magnetic shear and Ti gradient. Most notably, the scalings are inconsistent with ITG turbulence, but are partially consistent with TEM, KBM, and microtearing. The measurements and scalings are consistent with previous measurements and scalings reported in PoP 20, 055903 (2013). GEM linear gyrokinetic simulations by S. Parker and W. Wan at UC-Boulder with full-pedestal profiles indicate the unstable modes are collisional with mixed-parity mode structure, consistent with observations. In addition, linear growth rates increase at higher density gradient and decrease at higher Ti gradient, in qualitative agreement with observations. Finally, BOUT++ nonlinear Braginskii fluid simulations could not reproduce observed turbulence properties, which is not surprising given the physics contained in Braginskii fluid model. The Braginskii fluid simulations highlight the importance of electron dynamics for pedestal turbulence, and underscore the need for gyrokinetic or gyrofluid simulations of pedestal turbulence.

A paper entitled "Dependence of the L-H transition on X-point geometry and divertor recycling on NSTX" by Devon Battaglia (PPPL) et al., has been published in Nuclear Fusion. The paper describes results from targeted experiments on NSTX to decouple the dependence of the L-H transition on divertor recycling and the X-point radius. It is observed that the L-H power threshold decreases as the X-point is moved to larger major radius (lower triangularity) and as the neutral fueling provided from divertor recycling decreases via lithium condition of the first wall. The significant observation is that the edge temperature at the time of the L-H transition depends on the X-point radius, but is independent of the neutral fueling source and edge density. This result is in agreement with the prediction that the kinetic neoclassical transport, including ion orbit loss, sets the edge radial electric field and the ExB shear available to sustain the H-mode transport barrier. This theory is tested quantitatively using full-f self-consistent XGC0 simulations of the kinetic neoclassical transport in the L-mode edge, which shows excellent agreement with the observed trends with X-point radius and divertor recycling.

NSTX-U research on liquid lithium plasma-facing components was featured in an APS press release, http://www.aps.org/units/dpp/meetings/vpr/2013/index.cfm. The research, led by M. Jaworski (PPPL), was carried out in collaboration with the Dutch Institute for Fundamental Energy Research (FOM-DIFFER) in the Netherlands. Experiments were conducted on the linear plasma device Magnum-PSI that mimics divertor densities and temperatures and produces heat-fluxes similar to those expected in the NSTX-U divertor. A candidate material for the NSTX-U high-Z divertor upgrade, the molybdenum alloy TZM, was tested with and without thin lithium coatings (1 micron thick) applied in-vacuum during these experiments. Lithium was applied via evaporation using a prototype evaporator developed for use on the NSTX. In these experiments, the samples tested reached temperatures of approximately 1300C during 7s exposures to the Magnum-PSI plasma - a temperature range similar to that expected in the NSTX-U divertor. Initial estimates of the lifetime of the lithium coatings indicated that as little as 0.5s might be expected in the absence of redeposition of the eroded material onto the TZM substrate. During the course of the tests, however, the coating was found to persist for 3-4s indicating significant redeposition. These exposures resulted in the production of a cloud of lithium vapor directly in front of the TZM target that remained stable during the 3-4 seconds that macroscopic layers of lithium were present. The experiments already indicate that usage of evaporated layers of only 1 micron thickness of lithium in the NSTX-U may have similar lifetimes allowing early research on vapor-shielded targets in advance of the deployment of fully flowing liquid lithium systems in the NSTX-U.

The APS Invited Talk, “Physics of fast flux closure in Coaxial Helicity Injection (CHI) experiments in NSTX,” by Fatima Ebrahimi (PPPL/Princeton University) was highlighted in a APS DPP Press Release “Building a Better Tokamak by Blowing Giant Plasma Bubbles” – http://www.aps.org/units/dpp/meetings/vpr/2013/upload/ebrahimi.pdf. These studies carried out using the 3-D NIMROD code, describe the mechanisms for the generation of closed flux surfaces in NSTX transient CHI discharges. Although CHI is believed to be a 3-D process, the simulations show that the NSTX CHI experiments could be described by 2-D Sweet-Parker type reconnection and have some universal aspects such as the process that produces solar flares. These experiments also represent the first-ever occurrence of *forced* magnetic reconnection during transient CHI discharges on a large-scale fusion facility.

"Fusion foe lends a helping hand" was featured in an APS press-release: http://www.aps.org/units/dpp/meetings/vpr/2013/upload/taylor.pdf. The talk and paper corresponding to this press release were, "Differentiating the role of lithium and oxygen in retaining deuterium in lithiated graphite plasma-facing components" by Chase Taylor (INL) and JP Allain (UIUC). In this paper, surface oxygen was shown to contribute more strongly to deuterium retention than lithium. However, the graphite tiles cannot maintain high enough oxygen concentration needed to retain deuterium without lithium. Accordingly, lithium is a necessary ingredient that getters the oxygen required to retain deuterium.

High-resolution vacuum field divertor footprint structures, produced by n = 3 perturbation fields from the ex-vessel RWM/EF coil with a current of 1 kA, have been calculated for NSTX discharge 127317. The internal structure and total wetter area of the upper outer and lower outer footprints in this slightly unbalanced DN discharge are found to be significantly different. The total area covered by the lower outer footprint is 352.3 cm^2 while the upper outer area is 431.7 cm^2. A comparison with an image of the lower outer divertor recycling emission in a similar DN discharge shows footprint features that are very similar to those found in the vacuum field modeling but indicate toroidal variations that do not appear in the vacuum modeling results. These differences are being investigated. (Todd Evans, General Atomics).

Preparations for plasma operations in the NSTX-U configuration also continued with the completion of a second Stand Alone Digitizer (SADII) module to be used for plasma diagnostics. Re-commissioning of neutral beam power systems also continued with the replacement of a Autotransformer/Tap Changer assembly with an operational spare.

**ITER & TOKAMAKS (R. HAWRYLUK):**

This week the U.S. Patent office approved a patent for "Systems and Methods for the Magnetic Insulation of Accelerator Electrodes in Electrostatic Accelerators," invented by L. Grisham. This is a method to improve the voltage holding and performance of electrostatic accelerators, which was conceived under funding from the ITER and Tokamaks Department at PPPL.

The ITER and Tokamaks Department hosted a delegation from the Chinese Academy of Science headed by Professor Ding Li, Director General, Bureau of Supervision and Auditing.

**DIII-D (R. Nazikian)**

This week A. Nagy continued work on confirming the location of the short for the I-coil in DIII-D. The shorted coil is on the upper (R+1) vessel location at toroidal angle of 60 degrees (the IU60 coil). A 32 kHz electrical signal across the coil was used to detect the short location. This week a DC power supply, 8 volts, 10 amps, was used to heat the short for 5 sec while being viewed by an IR camera. The shorted zone was conclusively identified to within .25" and found to be 1" long. A repair plan is underway. Both measurements are consistent in the position of the short. The nest step is to begin removal and replacement of the damaged coil

PPPL researchers submitted 51 research proposals to the DIII-D Research Opportunities forum in the areas of pedestal physics, ELM suppression by the application of RMP fields, advanced scenario development, burning plasma physics including energetic particles, MHD stability and transport physics.

**ADVANCED PROJECTS (H. NEILSON):**

In the Laboratory's collaboration with Japan's Large Helical Device (LHD) stellarator program, PPPL physicist N. Pablant continues to lead an experimental investigation of transition dynamics and heat transport of high electron-temperature, electron cyclotron-heated (ECH) discharges. The goal in the most recent phase of this experiment was to repeat an ECH power scan at higher densities than previous scans in order to investigate the transition in the confinement regime from the ion-root to the electron-root. As in the earlier experiment the injected ECH power was scanned between 2.0MW and 3.4MW in steps of 0.2 MW. During the experiment the team was able to obtain a fine density scan at constant power near the transition. The data shows a clear dependence of poloidal rotation velocity on density during the electron-root phase. Scans of ECH power at constant density show a much smaller dependence of the rotation velocity on the ECH power. This data set will allow us to separate the dependence on density and ECH power of the poloidal rotation and other plasma parameters. Additionally, shots with similar final densities, but different density evolutions show significant temperature and rotation differences. Finally a ECH power scan at higher density, ne0=2x1019, provided a measurement of the plasma response in the ion root, which is a complement to an earlier scan made in the electron root.

The Laboratory and the Institute of Plasma Physics of the Chinese Academy of Sciences (ASIPP) this week launched a new collaboration on a range of engineering topics. The topics include engineering analysis, detailed design, and manufacturing study for PPPL's new magnetic reconnection facility, currently under design; engineering analysis and design review preparation for the ITER in-vessel coils (continuing an ongoing collaboration); and fusion blanket analysis and simulation. Concerning blanket analysis, while the effort in that area is currently very small in the U.S., it is believed that contributions via the ASIPP collaboration may benefit the FES Systems Studies program, with its new focus on fusion nuclear science facilities (FNSF). Four members of the ASIPP Engineering Department will visit the Laboratory for short (2-3 weeks) visits over the next few months to exchange detailed information and plan collaborative tasks in each of these topics. It is planned that most of the work will be performed by staff at their home institutions, with periodic videoconference meetings to maintain contact on the technical progress.

Physicist D. Mikkelsen has completed a study using comprehensive gyrokinetic linear stability calculations for ion-scale microinstabilities in a Large Helical Device (LHD) plasma with a so-called "impurity hole," i.e., the impurity ions flow out of the core. The calculations are used to explore whether microturbulence can explain the observed outward carbon fluxes that, surprisingly, flow "up" the impurity density gradient, causing the core carbon density to decrease continually with time. To fully sample these varying conditions the calculations are carried out at three radial locations and four times. The plasma parameters are based on experimentally measured profiles of electron and ion temperature, as well as electron and carbon density. The calculations show that the most unstable modes have ion temperature-gradient (ITG) characteristics at all radial locations and times sampled. As the carbon density gradient is scanned in the simulation between the measured value and zero, the quasilinear carbon flux is invariably inward when the carbon density profile is hollow. Therefore, it is concluded that turbulent transport cannot explain the observed outward flux of impurities in impurity hole plasmas. A manuscript on this work is being prepared for publication.

**THEORY (A. BHATTACHARJEE):**

Paper by W. Fox, A. Bhattacharjee, *et al*, "Filamentation Instability of Counterstreaming Laser-Driven Plasmas" was published in Physical Review Letters on November 27.

P. Porazik and J. R. Johnson's paper entitled "Gyrokinetic particle simulation of nonlinear evolution of mirror instability" has been published in Journal of Geophysical Research at the end of last month. The paper describes gyrokinetic particle simulations of the mirror instability, and discusses simulation results on saturation levels, and nonlinear structure formation.

On November 26, R. Kulsrud presented seminar on his memories of Lyman Spitzer prepared in celebration of Spitzer's 100$^{th}$ birthday. This historic talk was videotaped and the video is available online.

This week's regular theory seminar was presented by Dr. Greg Bewley from Max Planck Institute, Germany, entitled "The decay of turbulence: experimental scrutiny". Abstract: "Fluid turbulence is fascinating in part because it is disordered and therefore seems naturally resistant to organization. Underlying a wide range of natural phenomena like mixing is the as-yet unanswered question of how turbulence dissipates mechanical energy. The practical implication is that turbulence often cannot accurately be modeled, despite a long history of study. Freely decaying laboratory turbulence, a representative for both transient and wake flows, provides a rich environment in which to generate and to test ideas. Descriptions will be provided about systematic experiments that reveal the interplay between large and small scale characteristics of turbulent flow."

**COMPUTATIONAL PLASMA PHYSICS GROUP (S. JARDIN):**

The PPPL UNIX "mccune cluster" with 256 cores has been brought online for dedicated use by TRANSP runs. In addition, 80 cores in the fielder cluster are also being made available for use by TRANSP. These additional compute resources are needed due to the increasingly heavy use

of the NUBEAM, TORIC and PT_SOLVER mpi components in TRANSP.

S. Ethier gave a tutorial on mixed parallel programming at Princeton University's Institute for Computational Science and Engineering. The event was attended by over 20 researchers and students from several departments at the University, such as physics, engineering, chemistry, economics, political science, and others. Participants learned to exploit the power of parallel computing on distributed memory systems using message passing (MPI) combined with shared memory multi-threaded parallelism using OpenMP directives on multicore processors. GPU programming with recently-developed OpenACC directives was also presented. Mixed parallel programming with all of these methods together allows for very high scalability on the largest computers currently available, such as the hybrid CPU-GPU Cray XK7 "Titan" at the Oak Ridge Leadership Class Facility.

**ENGINEERING AND INFRASTRUCTURE (M. WILLIAMS):**

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

Construction: Installation of the TF outer leg supports has been completed and temporary platforms have been removed so the re-installation of cabling around the machine can begin. Re-enforcement of the vacuum vessel feet is about 75% done. The electricians have finished cabling for the new bakeout power supplies so they can be tested. They are now completing the flux loops on the outside of the vacuum vessel and will then move on to the installation of the category 4 cables. In-vessel measurements and preparations for the installation of mirnov coils, TAE antennas and langmuir probes are nearly complete. The window for these installations is next week.

CS Upgrade: The taping heads for the OH winder have been programmed and setup by the local PLC controller representative. Initial taping runs have produced acceptable results, however, there are a couple of mechanical problems that need to be corrected before actual winding can be started on the OH coil. The successful OH Conductor brazing qualification tests were completed on test samples for four technicians. Everson is making good progress on the first magnet (the PF-1B Lower). They have completed winding the copper and are setting up for the brazing of the second lead flag. Expect to VPI this month. The PF1B upper will be placed into the winding station as soon as the PF1B lower is removed. Machining of the remaining mandrels at Precision Boring is proceeding smoothly. The FDR for the modified CHERs passive plates has been scheduled for December 17.

NBI Upgrade: Progress on services includes BL2 DI water manifold welding and valve installations. The four DI water pumps have been received and inspected. Armor quadrant fit-up, assembly, and installation took place on three quadrants. Rework for water line interferences has been completed. Six additional tiles for the fourth quadrant were baked and are scheduled to return next week. Work continues on subcontract cable tray and conduit installations. Ground cable installation continues. Cable pulleys are being installed in strategic locations. Cable spools have been moved from the warehouse and will be positioned in the TTC for the cable pulls through the tray network. NB and TVPS duct component assembly continued in the NB shop including installation of bakeout lines and ceramic break pieces. The Armor thermocouple scanner rack was installed and prepared. Management conducted the monthly CAM status

meeting with active jobs reporting EVMS data and plans.

**BUSINESS OPERATIONS (K. FISCHER):**

PPPL executed a Work for Others agreement with the Pohang University of Science and Technology (POSTECH). PPPL will design upgraded mirrors on existing KSTAR ECH launchers and will complete a conceptual design of a new, 2MW, 2-beam steady-state ECH launcher. The PPPL Principal Investigator for this project is Robert Ellis. The total funding to be provided by POSTECH to PPPL, under this agreement, is $200,000 for the 20-month period of performance.

An amendment to the Work for Others Agreement with UCLA for the project titled "Micro-Engineered Material Surfaces for Electric Propulsion and Pulsed Power" was executed for the third year work scope and funding. Third year funding is $135,000; the cumulative funding to date is $405,000. The Principal Investigator for this project is Yevgeny Raitses.

An amendment to the Work for Others Agreement with Lockheed Martin Corporation Space Systems Company titled "Solar Array and Hall Effect Thruster Plume Interaction Studies" was executed for additional work scope and associated funding of $15,000. The Principal Investigator for this project is Y. Raitses.

DOE approved an additional new Laboratory Directed Research & Development (LDRD) project for FY14 titled "Development of a Suite of Atomistic Codes for Fusion, Advanced Materials and Warm Dense Matter Applications". With the approval of this project, the total LDRD budget allocated to date for FY14 is $1.9 million.

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

PPPL was notified that it was selected by the DOE-HQ Sustainability Performance Office (SPO) to receive a special DOE Sustainability Award as the DOE site with the Most Improved Performance. This award is one of several new awards presented in 2013 specifically selected by SPO staff to recognize DOE sites with outstanding sustainability commitment and progress.

**INFORMATION TECHNOLOGY (S. BAUMGARTNER):**

Bill Davis' manuscript "Fast 2-D camera control, data acquisition, and database techniques for edge studies on NSTX" has been accepted for publication in the Journal of Fusion Engineering and Design.

A new cluster for the exclusive use of the TRANSP facility has been created from systems gleaned from the retired kruskal cluster. A total of 32 systems, which had not suffered any degradation while working in the kruskal cluster were racked and connected, and renamed mccune001-032. The cluster name "mccune" was chosen in memory of Doug McCune, who led the work on the TRANSP application for many years.

**BEST PRACTICES & EXTERNAL AFFAIRS (J. DELOOPER):**

A. Zwicker was a guest scientist at the Rider University Bristol-Myers Squibb Center for Science Teaching & Learning's Consortium for New Explorations in Coherent Teacher Education workshop.

**DIRECTOR'S OFFICE (C. AUSTIN):**

On November 26, A. Cohen was interviewed by Chris Good (a reporter at ABC's national bureau) for information about nuclear energy.

M. Zarnstorff gave an invited talk titled "Stellarator / Heliotron - Complementary Path to Fusion", at the Monaco ITER International Fusion Days Energy Conference, held December 2-4, in Monaco.

On December 4, Dr. G. Hammett and Professor R. Kulsrud of Princeton University presented a colloquium entitled, "Spitzer's 100th: Founding PPPL & Pioneering Work in Fusion Energy".

S. Prager traveled to Washington, DC on December 5-6 to meet with DOE management on various topics, and also provided an update on the NSTX Upgrade project.

**PUBLICATIONS:**

Smith, D.R. (UW-Madison); Parker, S.E.; Wan, W.; Chen, Y.; Diallo, A.; Dudson, B.D.; Fonck, R.J.; Guttenfelder, W.; McKee, G.R.; Kaye, S.M.; Thompson, D.S.; Bell, R.E.; LeBlanc, B.P.; and Podesta, M., "Measurements and simulations of low wavenumber pedestal turbulence in the National Spherical Torus Experiment," Nuclear Fusion 53, 113029 (2013).

Battaglia, D.J.; Chang, C.S.; Kaye, S.M.; Kim, K.; Ku, S.; Maingi, R.; Bell, R.E.; Diallo, A.; Gerhardt, S.; LeBlanc, B.P.; Menard, J.; Podesta, M.; and the NSTX Team, "Dependence of the L-H transition on X-point geometry and divertor recycling on NSTX," Nuclear Fusion vol 53, page 1130132.

Fox, W.; Fiksel, G.; Bhattacharjee, A.; Chang, P.-Y.; Germaschewski, K.; Hu, S.X.; and Nilson, P.M., "Filamentation Instability of Counterstreaming Laser-Driven Plasmas," Physical Review Letters 111, 225002 (2013)

Porazik, P.; and Johnson, J. R.; "Gyrokinetic particle simulation of nonlinear evolution of mirror instability," Journal of Geophysical Research, Volume 118, Issue 11, pages 7211–7218, November 2013, DOI: 10.1002/2013JA019308

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