PRINCETON PLASMA PHYSICS LABORATORY
WEEKLY highlights

PPPL
U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the week ending December 4, 2015 are as follows:

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

The department received a total of 25 inputs from staff in response to solicitation for suggestions for possible PPPL work on ITER, above and beyond the existing scope (in-kind contributions—SSEN and Diagnostics—and the Task Agreement for the Diagnostic First Wall).

Steady State Electric Network (SSEN):

We convened a kick-off meeting for the Reactive Power Compensators with Schneider Electric, including participants from the US office and the factory in Pringy, France.

Diagnostics:

Upper Port Wide Angle View Visable-IR Camera (UPP WAVs): Axel Winter, a principal member of the ITER CODAC team, visited PPPL this week to engage PPPL physics and engineering staff in discussions on ITER data processing and software development. There was a special Town Hall style session on December 2 with members of the US ITER Diagnostics community attending in person or via an open web meeting. As many of the US diagnostic systems progress through Preliminary Design, issues with software engineering and compliance with ITER standards are becoming more important

Motional Stark Effect (MSE): A videoconference was held December 3 to review the status of the project to test the MSE Line Shift (MSE-LS) concept using data from the DIII-D tokamak. The MSE-LS approach has potential advantages for the ITER MSE diagnostic but has not been extensively tested on existing tokamaks. Good progress has been made in performing analysis of six of the nine DIII-D discharges planned for analysis. THE MSE-LS data is shown to be strong constraint on magnetic equilibrium reconstructions but more work is needed to complete analysis and to assess the achievable accuracy. The next status meeting is planned for January. Personnel from General Atomics and PPPL are performing this work.

Diagnostic RGA (DRGA): A revision of the DRGA Load Specification has been developed and is being submitted to the IO.

Equatorial Port 9 Integration: A. Basile attended the Diagnostic Vacuum window PDR at ITER this week. This PDR will review IO standardized port windows, which are critical optical components and primary vacuum boundaries in all USDA diagnostic ports. ITER port window functions are specified by system DAs while the IO bears responsibility for overall design

validation. US attendance of PDR is essential to verify that both parties are meeting their respective technical requirements and schedules for diagnostic window applications.

NSTX (M. ONO):

NSTX-U is in the commissioning phase for the FY16 campaign.

The technical note "Fast Time Response Electromagnetic Disruption Mitigation Concept," by R. Raman (University of Washington), T.R. Jarboe (University of Washington), J.E. Menard (PPPL), et al., was published in Fusion Science and Technology, 68, 797 (2015). It describes a new concept for a disruption mitigation system. The primary advantages of this method are: (1) It can accelerate impurity pellets to the required 1-2 km/s is less than 2ms, (2) the device can be positioned very close to reactor systems, which substantially reduces the overall impurity delivery time to the tokamak plasma, and (3) the external high magnetic fields near a tokamak device significantly improves the system efficiency.

Color contours of NSTX-U magnetic field fluctuations and density fluctuations from microtearing mode turbulence simulated using GYRO that were provided by W. Guttenfelder (PPPL) and Filippo Scotti (LLNL) and were selected as the “Image of the Month” in the November 30 issue of the USBPO Newsletter. The magnetic perturbations cause field lines to become stochastic, enhancing the loss of electron energy. Upcoming experiments in NSTX-U will attempt to exploit the distinct structure of these microtearing mode fluctuations (compared to traditional ballooning mode turbulence) in an effort to determine their existence and effect on confinement in high-beta plasmas across a range of collisionality.

Min-Gu Yoo, a student at Seoul National University, gave a talk at the NSTX-U Monday Physics meeting on November 30 entitled "Distinct ohmic breakdown physics in a tokamak.” The work focused on the time-varying complex field structures during ohmic breakdown. An interesting physical mechanism of the ohmic breakdown, however, has not been clearly revealed due to lack of observations of cold and rarefied initial plasmas. Previous research usually focused on the characteristics of given electromagnetic structures ignoring plasma response in the Townsend avalanche theory. The avalanche phenomena, however, is significantly affected by plasma response such as self-electric fields produced by the space charge. The work showed detailed physics of the ohmic breakdown including the plasma response via establishing a toroidal symmetric plasma model and particle simulations. It is found that the space charge plays a crucial role by decreasing the plasma density growth rate and by enhancing new perpendicular transport. These effects are key ingredients to understand mysterious experimental results which cannot be explained by previous research.

The X-ray photoelectron spectroscopy (XPS) system on the Materials Analysis and Particle Probe (MAPP) was used to provide a baseline characterization of samples prior to their insertion into the NSTX-U vacuum vessel. The samples have been positioned so that their faces are flush with the divertor plasma-facing surface, and will be subject to wall conditioning techniques that include glow discharge cleaning and boronization. (J. P. Allain and F. Bedoya, University of Illinois at Urbana-Champaign, and C. Skinner, PPPL)

ITER & TOKAMAKS (R. HAWRYLUK):

DIII-D (R. Nazikian):

R. Nazikian led an experiment this week with Andrew Kirk (Culham), Wolfgang Suttrop (IPP Garching), Carlos Paz-Soldan (GA), and Al Hyatt (GA) to explore the accessibility of RMP ELM suppression in the ASDEX-U shape. While DIII-D observed ELM suppression in the ITER shape with strong pumping on the outer strike point, AUG does not observe complete ELM suppression but rather ELM mitigation in ITER relevant collisionality. A long-standing question was whether the lower triangularity of the ASDEX shape contributed to the lack of complete suppression. In a joint experiment with ASDEX, low triangularity plasmas were generated with low collisionality and with the outer strike point on the lower shelf well away from the inlet to the cro pump. After a number of conditioning discharges, ELM suppression was obtained in the ASDEX shape and in the usual ELM suppression window $q95 \approx 3.4$ for DIII-D. These experiments will now continue on ASDEX-U to match the conditions in DIII-D and explore the window of suppression.

In a paper accepted for publication this week, Samuel Zemedkun (University of Colorado, PPPL co-authors) shows the first ever images of 2D electron temperature fluctuations associated with trapped electron mode (TEM) turbulence obtained with the ECE-Imaging diagnostic. By applying 2D correlation techniques to ECE-Imaging data from DIII-D, researchers obtained agreement with the dispersion relationship obtained by the GEM gyrokinetic particle-in-cell code at finite beta. Including experimentally estimated electron-ion collision rates in these simulations, modes with $n<20$ become marginally stable, suggesting the influence of inverse cascade or turbulence spreading processes. These mechanisms may prove important for describing the presence of a so-called “transport shortfall” region observed in DIII-D L-mode plasmas. The manuscript entitled “Spatially resolved measurement of two-dimensional turbulent structures in DIII-D plasmas” is scheduled to appear in the December 2015 Issue of Physics of Plasmas.

C-Mod (S. Zweben):

F. Halpern (EPFL) presented an invited talk at the 2015 APS-DPP conference explaining the origin of the narrow heat-flux feature in the scrape-off layer of inner-wall limited tokamaks. The work, carried out in close collaboration with PPPL, MIT, ITER I/O, and IPP Prague, argues that turbulent transport plays a very important role in setting the near SOL width. Indeed, this is consistent with GPI measurements of C-Mod discharges carried out specifically for this study, which show a large fluctuation level around the LCFS. A detailed comparison of the C-Mod SOL turbulent characteristics, also presented at APS, shows very good agreement between GPI measurements and the GBS turbulence code.

ITER (F. Poli):

F. Poli traveled to Barcelona, Spain, to participate into a meeting to report on progress in an ITER agreement on heating and current drive power management. The meeting was held in conjunction with an engineering meeting on the development of the Upper Launcher, where half a day was dedicated to physics analysis. During the joint session, Poli gave a short presentation

on the use of the EC in scenario development, with focus on simulation of NTM control and stabilization using TRANSP expert files.

ADVANCED PROJECTS (H. NEILSON):

The Laboratory is working with the Institute of Plasma Physics of the Chinese Academy of Sciences (ASIPP) on a concept study for a proposed China Fusion Engineering Test Reactor (CFETR). A benefit of the collaboration is the opportunity it provides to develop multi-physics simulation capabilities for complex, multi-material fusion environments. In a joint ASIPP-PPPL project meeting, PPPL's A. Khodak reported on 3D fluid dynamics and heat transfer analysis of a water-cooled ceramic breeder blanket module for CFETR. A computer-aided design (CAD) model of the module, furnished by ASIPP, was imported into the ANSYS simulation suite that was used for the analysis. The model features a complex network of coolant flow channels and manifolds, multiple layers of breeder and multiplier, and a structural casing. Analysis of the coolant flow and heat transfer in this model was performed using ANSYS CFX and included 3D coolant flow and external volumetric and surface heating. Results showed the ability of the model to simulate two-phase boiling flow in a complex configuration, and they also provided temperature and pressure distributions. Professor Songlin Liu reported progress in the water-cooled breeding blanket design effort at ASIPP.

The Laboratory is continuing its study, begun in FY2015, to identify a range of missions and associated program elements for a world-leading U.S. stellarator initiative. For more than twenty years, U.S. stellarator researchers have focused on the quasi-symmetric family of stellarator concepts, studying both quasi-helical (QH) and quasi-axisymmetric (QA) concepts. The first study meeting of FY2016 featured a pair of presentations laying out a scientific case for each led by A. Boozer of Columbia University (QH) and M. Zarnstorff (QA). The presentations and discussion help to clarify the benefits of each option, as well as the scientific arguments that will underpin future decisions on the direction for U.S. stellarator research.

THEORY (A. BHATTACHARJEE):

On November 30, Hua-Sheng Xie (Fusion Simulation Center, Peking University) presented a theory seminar on a gyrokinetic study of the L-H transition: "First principle gyro-kinetic study of the edge turbulent transport suggests a completed new possible mechanism, without invoking shear flow or zonal flow, for the the low (L) to high (H) confinement modes transition. At H-mode strong gradient the most unstable micro-instabilities are non-ground eigenstates with unconventional mode structures which significantly reduce the effective correlation length and thus reverse the transport trend. Both linear and nonlinear critical gradients exist, which lead discontinuous jump as required to explain the L-H transition."

On December 3, Gianluca Spizzo (Consorzio RFX, Italy) presented a theory seminar on the electrostatic response to edge islands induced by Resonant Magnetic Perturbations: "Measurements of plasma potential have been experimentally determined in great detail in the edge of the RFX reversed-field pinch (RFP), and of the TEXTOR tokamak, with applied magnetic perturbations (MP's). Generally speaking, the potential has the form $\Phi(r, \theta, \varphi) = \Phi 0 \sin u$, with u the helical angle: this fact implies a strong correlation between the magnetic field

topology and the poloidal/toroidal modulation of the measured plasma potential. In a chaotic tokamak edge, the ion and electron drifts yield a predominantly electron driven radial diffusion when approaching the island X-point, while ion diffusivities are generally an order of magnitude smaller. In the RFP the picture is more complicated, since X-points can act both as drivers of electron diffusion, or dynamical traps (reduced electron diffusion), depending on the helicity of the dominant island. In both devices, this differential electron-to-ion diffusion, causes a strong radial electric field structure pointing outward (inward) from the island O-point. An analytical model for the plasma potential is implemented in the code Orbit, and analyses of the ambipolar flow shows that both ion- and electron-dominated transport regimes can exist, which are known as ion and electron roots in stellarators. Moreover, the good agreement found between measured and modeled plasma potential supports that a magnetic island in the plasma edge can act as convective cell. These findings and comparison with stellarator literature, suggests that the role of magnetic islands as convective cells and hence as major radial particle transport drivers could be a generic mechanism in 3D plasma boundary layers."

On December 4, Igor Kaganovich and Ken Hara gave a Theory Department Research and Review Seminar titled "Acceleration of plasma electrons by intense nonrelativistic ion beams propagating in background plasma due to two-stream instability." The abstract reads: "In this paper we study the effects of the two-stream instability on the propagation of intense nonrelativistic ion and electron beams in background plasma. Development of the two-stream instability between the beam ions and plasma electrons leads to beam breakup, a slowing down of the beam particles, acceleration of the plasma particles, and transfer of the beam energy to the plasma particles and wave excitation. Because of the two-stream instability the plasma electrons can be accelerated to velocities as high as twice the beam velocity. The resulting return current of the accelerated electrons may completely change the structure of the beam self - magnetic field, thereby changing its effect on the beam from focusing to defocusing. Therefore, previous theories of beam self-electromagnetic fields that did not take into account the effects of the two-stream instability must be significantly modified. We show through simulations and analytical estimates that a beamlet produced from an ion beam that has passed through an aperture can be used as a diagnostic tool to identify the presence of the two-stream instability and quantify its defocusing effects. This effect can be observed on the National Drift Compression Experiment-II (NDCX-II) facility by measuring the spot size of the extracted beamlet propagating through several meters of plasma."

COMPUTATIONAL PLASMA PHYSICS GROUP (S. JARDIN):

E. Feibush presented a seminar on scientific visualization to the Princeton Neuroscience Institute and a visualization mini-course for the Princeton Institute for Computational Science and Engineering. The seminar on November 17 emphasized techniques for looking at image data acquired by MRI machines and how to portray the shape of three-dimensional neural structures. The mini-course on December 2 gave attendees the opportunity to work with the VisIt visualization software and learn about a variety of techniques for exploring data from various fields. Both presentations described the Princeton remote visualization capability where data is stored on a centralized server and displayed on the researcher's wireless laptop computer. Joon Lee and Zachary Stier served as Teaching Assistants for the PICSciE mini-course.

PLASMA SCIENCE AND TECHNOLOGY (P. EFTHIMION):

Snezhana I. Abarzhi from Carnegie Mellon University presented this week's PS&T Department seminar. The title of her talk was "Rayleigh-Taylor instability and interfacial mixing," and the abstract read as follows: "Rayleigh-Taylor instability (RTI) develops when fluids of different densities are accelerated against their density gradient. Extensive interfacial mixing of the fluids ensues with time. Rayleigh-Taylor (RT) mixing controls a broad variety of processes in fluids, plasmas and materials, in high and low energy density regimes, at astrophysical and atomistic scales. Examples include formation of hot spot in inertial confinement, radial compression of imploding Z-pinches, supernova explosion, stellar convection, flows in atmosphere and ocean, reactive and supercritical fluids, material transformation under impact and light-material interaction. In some of these cases (e.g. inertial confinement fusion) RT mixing should be mitigated; in some others (e.g. turbulent combustion) it should be enhanced. Understanding the fundamentals of RTI is crucial for achieving a better control of non-equilibrium processes in nature and technology. Traditionally, it was presumed that RTI leads to uncontrolled growth of small-scale imperfections, single-scale nonlinear dynamics, and extensive mixing that is similar to canonical turbulence. The recent success of the theory and experiments in fluids and plasmas suggests an alternative scenario of RTI evolution. It finds that the interface is necessary for RT mixing to accelerate, the acceleration effects are strong enough to suppress turbulence even on the large scales, and the RT dynamics is multi-scale and well correlated. This talk presents a physics-based consideration of fundamentals of RTI and RT mixing, and summarizes what is certain and what is not so certain in our knowledge of RTI. The focus question — Is RT interfacial mixing a disordered process indeed? We also discuss new opportunities for improvements of predictive modeling capabilities, physical description, and control of RT mixing in fluids, plasmas and materials."

BUSINESS OPERATIONS (K. FISCHER):

Budget Office:

DOE approved a new Laboratory Directed Research and Development (LDRD) project titled "Stellarator Core Designs for a Net-Energy Breakeven (Qeng = 1) Fusion Plant." The total budget allocated to LDRD projects in FY16 is $2.9M against the $3.0M LDRD funding ceiling approved by DOE.

BEST PRACTICES & EXTERNAL AFFAIRS (J. DELOOPER):

Education (A. Zwicker):

During the week of November 16, the Science Education Department participated at the annual APS-DPP meeting in Savannah, Georgia. All members of the department presented posters on their ongoing work/projects. The APS-DPP Teacher's Day workshop was held on November 17 with about 75 middle and high school science teachers in attendance, and A. Dominguez presented the Plasma 101 to them. The Plasma Science Expo was held on November 19 and 20 with about 1200 middle and high school students (with a couple of elementary grades mixed in) in attendance on Thursday and approximately 2000 middle and high school students on Friday.

About 20 graduate student and staff volunteers from PPPL were on hand to run the Science Education booth.

A. Dominguez participated in a panel at Columbia University about Science Communication on December 3.

DIRECTOR'S OFFICE (C. AUSTIN):

On December 2, Professor Robert Hazen, Carnegie Institute of Washington & George Mason University presented a colloquium entitled "Chance, Necessity, and the Origins of Life".

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