PRINCETON PLASMA PHYSICS LABORATORY
WEEKLY highlights

PPPL
U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the week ending November 27, 2015 are as follows:

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

Steady State Electric Network (SSEN):

Release for Manufacturing (RFM) was issued to Schneider Electric to begin manufacturing of the SSEN Power Transformers.

Diagnostics:

Low Field Side Reflectometer (LFSR): N. Allen spent last week at the IO, Cadarache, France meeting a number of individuals to review and discuss the status and plans for the LFSR diagnostic. Integration strategies were agreed upon with the RF DA and the US DA members in association with the integration of EPP#11. The dates were clarified for early delivery and final delivery of waveguide components to ITER. Also, the status of SIC1 windows for LFSR was discussed and information was provided on moving the SIC2 window development.

Diagnostic RGA (DRGA): B-field axial and radial profiles were made from the Helmholtz coil pairs, along with a B-field magnitude scan. The purpose is to document the achievable B-field values and uniformity for gauge susceptibility testing. The Gas-mixing manifold (cart) is nearly complete, especially with the arrival onsite of a D2 bottle. Assembly is expected to be completed next week, with use commencing immediately. A calibrated He-leak was installed on the prototype DRGA and a back-fill of N2 confirmed the ITMS is measuring the approximately correct ratio of He in N2 in the main chamber. A preliminary check of the OPG on the interstage port showed measurable response time periods as the main chamber N2 pressure is varied, which is a concern for "stagnancy" of the interstage volume.

Upper Port 11 and 14 Integration: The UP 11 and 14 integration team participated in the ITER Port Integrator Coordination Team (PICT) event held November 16. In addition, the first draft of the Upper Port PCR planning was submitted for review.

Equatorial Port 9 Integration: Y. Zhai, W. Wang, A. Basile, and R. Feder met this week to discuss the status of the equatorial port diagnostic shield module design (DSM). Electromagnetic and Structural analysis has advanced rapidly now that the interface between the DSM and Generic Port Plug has been defined and reviewed by the IO. The results of this analysis show that the EPP DSMs should be split horizontally and welded versus the previous design that had three vertical forging sections bolted together.

Toroidal Interferometer and Polarimeter (TIP): Drawings are being prepared for a corner cube reflector that is prototypical of that designed for the ITER TIP diagnostic for its outermost chord. This second prototype is much smaller than the original, will be made from copper rather than aluminum, and will feature revisions based on the testing of the first prototype. The copper prototype will be utilized in a single channel interferometer/polarimeter on DIII-D, hopefully next summer.

Core Imaging X-ray Spectrometer (CIXS): N. Allen spent last week at IO in Cadarache, France in multiple meetings conducted on the viability of using Xenon gas for the CIXS diagnostics. All parties met with agreed that Xenon could be used in the reactor. The purchase order for shipping the magnetic field testing detector was completed with the shipping of the loaned detector expected very soon. Also completed was the purchase order for adding John Rice (MIT) to physics team on the CIXS.

Equatorial Port 3 Integration: The EP03 integration team participated in the PICT meeting on November 16. The team is assessing the impact of new vacuum window assemblies on the E3 closure plate. The next E3 monthly progress meeting is scheduled for November 30 at 8 AM EST.

Post Plug Test Facility (PPTF) and D-Site Operations: A meeting was held this week at PPPL to discuss the PPPL institutional position on hosting the Diagnostics Port Plug Assembly and Environmental Testing Facility. R. Feder presented the latest technical, budget, and schedule aspects of this sub-project to PPPL management. There is a concern that if the TFTR Test Cell is used for the ITER work then some future fusion experiment will not be able to use the space. Alternative building areas at PPPL with adequate crane capacity were identified that could be utilized in case a conflict develops.

NSTX (M. ONO):

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

The paper "Design description for a Coaxial Helicity Injection plasma start-up system for a ST-FNSF," by R. Raman (University of Washington), T. Brown (PPPL), L.A. El-Guebaly University of Wisconsin), et al., was published in Fusion Science and Technology 68, 674 (2015). The paper describes two possible configurations for CHI implementation in a fusion reactor. In the first concept, referred to as "NSTX-like," the entire blanket structure is insulated from the vessel using insulating supports. In the second configuration, referred to as "DIII-D – like," a toroidal insulated electrode is placed on top of the blanket structure to shield the insulator from neutrons, allowing more than six years of full power operations before insulator replacement. The second concept is planned to undergo a test on the QUEST ST in Japan.

Two doctoral students from the United Kingdom—Jakob Brunner (Durham University) and Dave Thomas (University of York)—visited PPPL from November 10-25 to install an innovative Synthetic Aperture Microwave Imaging (SAMI) diagnostic on NSTX-U. The SAMI diagnostic can both measure plasma emission over a broad frequency range (10--34.5 GHz) and can actively probe the plasma edge to study Doppler Back Scattering (DBS). SAMI measured the magnetic pitch angle in the edge for the first time using DBS on MAST. This is possible with

simultaneous 2D DBS because the maximum backscattered power is perpendicular to the turbulence and turbulence is elongated along the magnetic field. SAMI has also studied the effect of NBI and the L--H transition on turbulent velocity, and turbulence suppression in the edge during H−mode plasmas in MAST. The diagnostic has been significantly upgraded for operation on NSTX-U. Brunner and Thomas made presentations on SAMI technology and physics results at an NSTX-U seminar on November 24.

Michael Fox, a graduate student from the University of Oxford, working at CCFE on the BES diagnostics on MAST, visited PPPL from November 23-25. Fox gave a seminar on November 25 entitled "Extracting physical quantities from BES data." The talk focused on a method to extract the underlying physical properties of turbulence from measurements, thereby facilitating quantitative comparisons between theory and experiment. Beam Emission Spectroscopy (BES) diagnostics record fluctuating intensity time series, which are related to the density field in the plasma through Point-Spread Functions (PSFs). Assuming a suitable form for the correlation function of the underlying turbulence, analytical expressions are derived that relate the correlation parameters of the intensity field: the radial and poloidal correlation lengths and wavenumbers, the correlation time and the fluctuation amplitude, to the equivalent correlation properties of the density field. In many cases, the modification caused by the PSFs is substantial enough to change conclusions about physics. The method is tested by applying PSFs to the "real" density field, generated by non-linear gyrokinetic simulations of MAST, to create synthetic turbulence data, from which the method successfully recovers the correlation function of the "real" density field. This method is applied to BES data from MAST to determine the scaling of the 2D structure of the ion-scale turbulence with equilibrium parameters, including the ExB flow shear. A correlation between the poloidal correlation length and the ExB shearing rate was found, with higher correlation lengths and eddy tilting the stronger the shearing. The shearing rate is probably below the threshold required for actual shearing of the eddies and resulting suppression of turbulence.

Field Coil power testing on individual coils per the Integrated System Test Procedure continued this past week in preparation for combined field test shots scheduled for this coming week. The Preoperational Test Procedure (PTP) for the deuterated Trimethyl Borane (dTMB) system was successfully completed. The initial wall conditioning technique in preparation for NSTX-U plasma operations uses dTMB, and the system is ready for its application. The MPTS laser delivery optics was tweaked on the night of November 25. A previously seen "seasonal" displacement was observed and corrected. This motion is consistent with a breathing in of the test wall during the colder season of the year; previous laser operation had been done in August. A mirror which is attached to the test-cell east wall was adjusted. A set of laser burns and camera videos was obtained to document the alignment.

The NSTX-U Test Cell will be in restricted access this coming week for field coil testing. Access will be available on the second shifts for approved work.

ITER & TOKAMAKS (R. HAWRYLUK):

DIII-D (R. Nazikian):

R. Nazikian presented an invited talk at the MHD workshop at PPPL on transport bifurcation at

the threshold of edge localized mode suppression with magnetic perturbations. N. Logan presented a contributed talk on the use of the reluctance concept for representing the plasma response. M. Okabayashi presented a contributed talk on torque feedback on NTMs.

A successful CDR was held on a new concept for a sliding interface between the 210 neutral beam line and the DIII-D torus; A. Nagy is leading the design team. The sliding interface will enable the beam box to be oriented in both a co and counter direction for beam injection. A sliding seal is being proposed that contains three seals (differentially pumped), two inner Viton O-rings, and one outer Silicone inflatable seal coated with Parylene for friction reduction, located on cylindrical surfaces. The O-ring grooves contain a new cross section developed to hold the O-ring seals in place and enable easy manufacture on a five axis milling machine. A full-scale prototype was approved for fabrication and testing. If this design works, it will enable two-to-three day movement of the 210 NB, which can be switched over a weekend.

Boron granules were received and plans are in place to reduce the granule irregularity by use of a simple rock tumbler for a week or two. The granules will then be inspected tested in the LGI. Installation of the LGI is expected in December after the drop tube is calibrated for lithium and boron granules.

THEORY (A. BHATTACHARJEE):

On November 23, Julien Dominski (EPFL, Switzerland) presented a theory seminar on studying the effect on turbulent transport of non-adiabatic passing electron dynamics near mode rational surfaces using gyrokinetic simulations: “The non-adiabatic response of passing electrons in ITG and TEM dominated microturbulence is studied in tokamak geometry by making use of the gyrokinetic codes GENE and ORB5. Results obtained with the flux-tube version of GENE show that fine radial structures on linear eigenmodes, located at low order mode rational surfaces and resulting from the non-adiabatic passing electron response, persist in the non-linear turbulent regime and affect transport levels [Dominski, PoP, 2015]. The presence of these fine structures are confirmed in global ORB5 simulations for conditions relevant to the Tokamak á Configuration Variable (TCV). To study short scale physics in ORB5, a new field solver valid for arbitrary wavelengths, $k_\perp \rho_i \sim 1$, has been implemented by accounting for the full integral form of the linearized polarization drift contribution, following a variation of the approach in Ref. [Mishchenko, PoP 2005].”

On November 24, Alexis Tuen (ANU, Australia) presented a theory seminar on the stability of a two-volume MRxMHD model in slab geometry: “Ideal MHD models are inadequate to describe various physical attributes of toroidal plasmas with no continuous symmetry, such as magnetic islands and stochastic regions. A new MHD formulation, MRxMHD, uses only a finite number of ideal-MHD flux surface interfaces, with relaxed plasma regions in between, thus allowing a stepped-pressure profile, magnetic islands, and stochastic regions. In toroidally asymmetric plasma, the existence of interfaces in MRxMHD is contingent on the field pitch, or rotational transform, of flux surfaces being irrational; a KAM argument shows that some good equilibrium flux surfaces continue to exist for small perturbations to an integrable system (foliated by flux surfaces), provided that the rotational transforms on both sides of each interface are sufficiently irrational. Building upon the MRxMHD stability model by Hole, we study the effects of irrationality of the rotational transform at interfaces in MRxMHD on plasma stability.

Investigating the plasma stability of a two-volume MRxMHD periodic-slab, we find that the 2D system stability conditions are dependent on the interface and resonance layer magnetic field pitch at minimised energy states. While tearing instabilities exist at low order rational resonances, investigating instability of high-order rationals requires study of pressure-driven instabilities."

M. Sengupta (IPR, India) also presented a theory seminar on November 24 on the dynamical properties of trapped nonneutral clouds using particle-in-cell simulations: "An efficiently manoeuvrable 2D Electrostatic Particle-in-Cell (PIC) code has been developed to simulate cross-sections of plasma magnetized in a linear trap of arbitrary cross-sections with perfectly conducting boundaries. With minimal adjustments to its internal structure, the code can be modified to introduce slight toroidicity to the trap cross-section (up to aspect ratios > 9) as well. Further a 2D3v version of the same code with additional facility for Monte-Carlo-Collisions (MCC) of the plasma with background neutrals has also been developed because such collisions can often play an important role in the plasma dynamics inside the trap. For fundamental studies a 1D version of the code has been developed. The first set of numerical experiments performed with the 2D PIC code was an investigation of the nonlinear growth and relaxation of excited radial breathing modes (Bernstein modes) in cylindrically confined electron plasmas of high Brillouin fractions. The nonlinear relaxation process associated with these breathing modes, include formation of density voids, triggering of surface azimuthal modes on the electron plasma, and reorganization of the radial density profile of the electron plasma. The next set of numerical experiments involved loading an electron cloud in a cylindrical trap with an embedded fractional population of uniformly distributed ions and studying the linear and nonlinear evolution of the ion resonance instability in the two-component nonneutral cloud. Presently the 2D3v plus MCC version of the 2D PIC code is being used to study how dynamically introduced ions from ionizing collisions of the electrons with background neutrals, and electron-neutral elastic collisions influence the stability and dynamics of a cylindrically trapped electron cloud. Simulations of mechanical compression and relaxation of quasineutral plasmas performed with the 1D version of code qualitatively mimic a similar electrostatic compression and relaxation process that can be externally generated along the magnetic field lines in linear traps for single species plasmas as well as the magnetic compression and relaxation of tokamak plasmas. These numerical experiments reveal a fundamental result that substantial collisionless heating of a plasma can be achieved by taking it through an adiabatic cycle of quasistatic compression and non-quasistatic relaxation. Several interesting results and related significant aspects of the above numerical investigations will be presented."

On November 25, A. K. Swamy (IPR, India) presented a theory seminar on collisionless microtearing modes in large aspect ratio tokamaks with weak reversed shear configurations: "Gyrokinetic simulations have found Collisionless Microtearing Modes (MTM) to be linearly unstable in sharp temperature gradient regions of tokamaks, typically with high magnetic shear. The collisionless MTM is driven by the magnetic drift resonance of passing electrons, aided by the closeness of Mode Rational Surfaces (MRS) arising due to the high shear. Here, the role of global safety factor profile variation on the MTM instability and global mode structure is studied, in particular in weak reverse shear (WRS) configurations in large aspect ratio tokamaks. At lower shear profiles, multiple MTM branches are found with tearing parity as well as mixed parity. The linear growth rates of MTM is found to be weakened and linearly unstable modes are found whose global mode structures of $\tilde{\varphi}$ and Ã|| exhibit Mixed Parity. For the same equilibrium profiles and parameters, AITG instability is also studied and global mode structures are

compared with MTM. The growth rate spectrum is found to extend to shorter/mesoscale wavelengths in WRS. Several other characteristics of MTMs and AITG are recovered in the WRS configuration, such as the dependency on free energy source and on plasma β."

DIRECTOR'S OFFICE (C. AUSTIN):

On November 24, two colloquia were presented at PPPL: Dr. Richard Buttery, General Atomics presented a colloquium entitled, "DIII-D Recent Results and Future Direction," and James Morris, Rutgers University presented a colloquium entitled "Sustainability Economics."

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