Weekly HIGHLIGHTS

PPPL PRINCETON PLASMA PHYSICS LABORATORY

U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the week ending June 9, 2017 are as follows:

U.S. ITER FABRICATION (H. NEILSON):

The Laboratory's ITER Diagnostics Activities were well represented in contributions to the IEEE Symposium on Fusion Engineering, held June 4 to 8 in Shanghai, China. Team leader R. Feder gave an oral presentation, "Managing ITER Diagnostics and Port Plug Engineering Project Risks," while analysis leader Y. Zhai spoke on "Design and Analysis Progress of US ITER Integrated Diagnostic Upper Port 14." Zhai addressed the Equatorial Port 9 progress in a poster. Port integration analysis work was also reported in posters by W. Wang, H. Zhang, and J. Chen, while a poster by J. Teodoro reported on progress in hard core components for ITER diagnostics. Posters by F. Cai and A. Ouroua reported on prototype design and testing for ITER diagnostics systems. Due to budget constraints, which precluded travel by several of these authors, many of the papers were presented by co-authors.

NSTX-U RESEARCH (J. MENARD):

FY 2017 status: NSTX-U is in a maintenance and repair outage.

J. Hosea, E. Kim, N. Bertelli, R. Perkins and G. Taylor attended the Topical Conference on Radiofrequency Power in Plasmas that was held in Aix en Provence, France, May 30 - June 2. Hosea presented an invited talk, "An Overview of Some of the Main Experimental Results and Challenges in the Development of Slow and Fast Wave Heating from the C-Stellarator to NSTX-U," and Kim presented an invited talk entitled "2D Full-wave Simulations of Waves in Space and Tokamak Plasmas." Perkins presented a poster paper entitled "ICRF-Induced Changes in Floating Potential in the EAST Divertor and Implications for Impurity Production," Bertelli presented a poster paper entitled "Self-Consistent Calculation of the Effects of RF Injection in the ICRF/HHFW Heating Regimes on the Evolution of Fast Ions in Toroidal Plasmas," and Taylor presented a poster paper entitled "Time-Dependent Simulations of Fast-Wave Heated High-Non-Inductive-Fraction H-Mode Plasmas in the National Spherical Torus Experiment Upgrade."

N. Bertelli attended the Workshop on ICRH scenarios for ITER that was held at ITER headquarters (France, June 6 to 8) organized by the ITER team. The workshop covered the following topics: (i) ICRF scenarios (including RF wave, Fokker-Planck and possibly transport) for the ITER non-active and active phases; (ii) Coupling and PWI (including sheath effects), and (iii) Brief review of ITER antenna design. Bertelli presented a talk entitled "Self-consistent simulations of ITER plasmas using the TORIC-CQL3D coupling."

R. Maingi presented an invited talk at the SOFE meeting in Shanghai entitled “Overview of NSTX-U progress.” In addition, Maingi presented a 1-hour lecture at the mini-course on plasma-material interactions: "PMI and the divertor," and chaired one of the plenary sessions.

R. Perkins participated in a three-week campaign at the Large Plasma Device (LAPD) at the University of California - Los Angeles (UCLA) focused on ICRF physics and sheaths together with UCLA staff B. von Compernolle and Oak Ridge National Laboratory staff J. Caughman, C. Lau, and E. Martin. The LAPD is a long (16.5 m) device that is part of a user-facility dedicated to basic plasma physics. A high-power RF source, recently built by M. Martin, has enabled high-power experiments at frequencies up to several times the cyclotron frequency. This experiment focused on RF rectification, near- and far-field sheaths, DC current circuits across the vessel, and antenna-coupling studies. Substantial DC currents were observed both at the antenna and also at limiters several meters away. Wave response to the so-called sheath boundary condition was tested by subjecting the limiter to various electrical terminations.The floating condition of probes was tested at various densities, RF powers, capacitive loads, and probe-emission levels. The effect of rotating the antenna relative to the field line was studied as well as density changes at various levels of RF power.

A paper titled “M3D-C1 simulations of the plasma response to RMPs in NSTX-U single-null and snowflake divertor configurations” has been published in *Nuclear Fusion* by G. Canal et al. In this paper, linear M3D-C1 single- and two-fluid resistive MHD calculations of the plasma response to n = 3 magnetic perturbations in single-null (SN) and snowflake (SF) divertor configurations are compared. Differences between the single- and two-fluid responses were found to be caused by different screening mechanisms intrinsic to each model. No significant differences between the M3D-C1 responses were found in the SN and SF configurations. However, the n=3 fields caused the SF configuration to develop additional and longer separatrix lobes than the SN, regardless of the plasma model used. The intersection of the additional SF lobes with the divertor plates are expected to cause more striations in the particle and heat flux target profiles. In addition, the size of the magnetic lobes in both SN and SF configurations are found to be more sensitive to resonant rather than to non-resonant magnetic perturbations.

ITER & TOKAMAKS (R. NAZIKIAN):

JET: F. Poli attended a conference on Radiofrequency waves in plasmas, in Aix-en-Provence, from May 29 to June 1, where she presented a poster summarizing her work on the control of NTMs in ITER. She visited the ITER Organization to discuss final details of her NTM control work on ITER and to discuss plans for the integration of a reduced edge transport model in TRANSP for ITER simulation.

KSTAR: D. Mueller completed a two-week visit to KSTAR where he conducted experiments with the K-STAR team aimed at improving vertical control. The results were very positive, including for the first time stable control of the plasma with elongation around 2.15 with high li of 1.15. The improvements were achieved with the use of 1) analog differencing of a pair of flux loops on the centerstack to provide a low noise vertical control (Z) signal and its derivative from the loop voltage, 2) the use “fast-Z” digital filter that eliminate slow plasma motion controlled by the superconducting PF coils and 3) use of the analog loop voltage to provide the derivative term in the controller. It is note-worthy that there was no loss of vertical control after the proper gains

were chosen; the upper limit on elongation was from the inability of the shape control system to produce higher kappa without saturating one of the superconducting PF coils.

DIII-D: W. Guttenfelder visited General Atomics May 22 to 26 to prepare for the NSTX-U/DIII-D collaborative campaign experiment to "Validate electromagnetic effects on transport in high performance plasmas" and to discuss potential longer-range DIII-D engagement during the NSTX-U outage.

B. Grierson and N. Logan attend the IAEA Technical Meeting on Fusion Data Processing, Validation and Analysis at the Massachusetts Institute of Technology. Grierson first presented the use of TRANSP in OMFIT for interpretive tokamak analysis including verifying plasma diagnostics, profile and neutron rate self-consistency by assessing systematic uncertainties in measured quantities such as Zeff. By using OMFIT, common procedures for verification and simulation fidelity are easily implemented and visualized across tokamaks. Predictive simulation workflow, and post-processing validation metrics are provided by OMFIT for transport model validation. Logan presented the OMFIT profile analysis workflow, which uses a new technique of time convolution to processes, the inherently time-dependent tokamak equilibrium profile evolution and tokamak diagnostics. Pre-processing of discontinuous events such as ELMs removes measurement outliers, creating a profile dataset that can be fit with the wide range of fitting function provided by OMFIT with much less user-intervention.

The nomination for an APS-DPP Invited Talk by A. Ashourvan has been selected by the program committee for presentation at the meeting in Milwaukee, Wisconsin. The work by Ashourvan with T. Stoltzfus-Dueck (Princeton University), B. Grierson, S. Haskey and D. Battaglia of PPPL advances the predictive capability of main-ion toroidal rotation by comparing a reduced rotation model by Stoltzfus-Dueck to main-ion rotation measurements on DIII-D.

THEORY (A. BHATTACHARJEE):

A paper titled "A model of energetic ion effects on pressure driven tearing modes in tokamaks" by M.R. Halfmoon & D.P. Brennan was published in Physics of Plasmas. The abstract reads "The effects that energetic trapped ions have on linear resistive magnetohydrodynamic (MHD) instabilities are studied in a reduced model that captures the essential physics driving or damping the modes through variations in the magnetic shear. The drift-kinetic orbital interaction of a slowing down distribution of trapped energetic ions with a resistive MHD instability is integrated to a scalar contribution to the perturbed pressure, and entered into an asymptotic matching formalism for the resistive MHD dispersion relation. Toroidal magnetic field line curvature is included to model trapping in the particle distribution, in an otherwise cylindrical model. The focus is on a configuration that is driven unstable to the $m/n = 2/1$ mode by increasing pressure, where m is the poloidal mode number and n is the toroidal. The particles and pressure can affect the mode both in the core region where there can be low and reversed shear and outside the resonant surface in significant positive shear. The results show that the energetic ions damp and stabilize the mode when orbiting in significant positive shear, increasing the marginal stability boundary. However, the inner core region contribution with low and reversed shear can drive the mode unstable. This effect of shear on the energetic ion pressure contribution is found to be consistent with the literature. These results explain the observation that the 2/1 mode was found to be damped and stabilized by energetic ions in δf-MHD simulations of tokamak experiments with positive shear throughout, while the 2/1 mode was found to be driven unstable in

simulations of experiments with weakly reversed shear in the core. This is also found to be consistent with related experimental observations of the stability of the 2/1 mode changing significantly with core shear."

N. Ferraro presented a Research and Review Seminar titled "Disruption modeling with M3D-C1." The abstract of the presentation is: "A successful tokamak reactor will require robust methods for avoiding and withstanding disruptions. Achieving this will require considerable progress in understanding both the causes and dynamics of disruptions. Here we describe present research and future directions in extended-MHD modeling, in particular with the M3D-C1 code, to address these issues. Nonlinear MHD modeling is necessary to understand how some linearly unstable modes develop into disruptions while others saturate or cycle without causing disruptions. For example, the nonlinear evolution of the tearing mode may result in locking—one of the most common causes of disruptions—or may saturate benignly, as in "hybrid" operation. Macroscopic linear instability is therefore not a sufficient condition for disruption prediction and avoidance schemes. We present results of M3D-C1 modeling of mode locking and Resistive Wall Tearing Mode stability as a step towards understanding how linearly unstable modes may develop into disruptions. In order to characterize the dynamics of a disruption, we also present M3D-C1 simulations of vertically unstable plasmas in toroidal geometry. In these simulations, the plasma drifts toward the wall and the plasma current quenches, leading to large halo currents and eddy currents in the surrounding conducting structures. We consider the effect of breaks in the resistive wall on the evolution of the current quench and the wall currents."

Computational Plasma Physics Group (S. Jardin):

As an on-going effort to optimize the GTS turbulence code on the Cori Intel Xeon Phi computer at NERSC, J. Chen greatly sped up a section of the code that could account for up to 45% of the run time on the Cori KNL nodes depending on the simulation parameters. By rearranging the memory access in critical loops, Chen was able to speed up this routine by 87% by taking advantage of more efficient vectorization and improved data access.

PLASMA SCIENCE & TECHNOLOGY (P. EFTHIMION):

Several members of the PST Department attended ICOPS 2017 in Atlantic City last week. Four invited talks were given: I. D. Kaganovich, "Amplification due to the two-stream instability of self-electric and magnetic fields of an ion or electron beam propagating in background plasma;" A. V. Khrabrov, "Paschen curve for helium in 100-1000 kv range;" A. D. Stepanov, "Dynamics of ion beam charge neutralization by ferroelectric plasma sources;" V. Vekselman, "Complex structure of the carbon arc discharge for nanomaterial synthesis." J. Carlsson presented two oral talks: "Particle-in-cell simulation of anomalous transport in a penning discharge," and "Validation and benchmarking of two particle-in-cell codes for a glow discharge." A. Khrabry, "Self-consistent numerical simulation of carbon arc for nanoparticle synthesis;" S. Gershman, "Microplasma source of high energy electrons;" C. Jin, "Secondary electron emission from carbon velvet." Other talks and posters presented by PPPL collaborators were: "Three-dimensional and sheath boundary effects on the instabilities in ExB plasma discharges;" "Irradiation of materials using short, intense ion beams from an induction accelerator;" "Nonlinear electron cyclotron oscillations and cross-field transport in ExB discharges;" "Improvement in the flat probe diagnostics for arbitrary degree of anisotropy;" "The two-stream instability in a finite length plasma;" "Electron acceleration due to the interaction between a

neutralized ion beam and background plasma;" and "Experimental study of time dependence ablation rate in atmospheric pressure dc carbon arc discharges."

ENGINEERING & INFRASTRUCTURE (V. RICCARDO):

Coil Winding: The new fire rated soft wall cleanrooms for the winding area was delivered this week. Coil winding trials started.

IEEE Symposium on Fusion Engineering (SOFE): Several engineers attended and presented posters and orals, as well as a number of NSTX-U and ITER ones, these also included collaborative ones.

B. Ellis gave an oral presentation on the conceptual design of a 2-channel steady state ECH launcher for KSTAR. D. Loesser presented a poster on the Test Divertor Unit (TDU) Scraper Element for Wendelstein7-X. A. Nagy presented a poster on a quasi-periodic linear feeder for the Impurity Granular Injector (IGI) in operation at DIII-D. In order to study the beryllium-steam reaction in a Water Cooled Ceramic Breeder (WCCB) blanket, A. Khodak wrote user routines in ANSYS to model the multi-component flow and the chemical reactions and replaced the granular beds with porous material to reduce the size of the model, still thirty-five million elements. The work presented in Khodak's oral was carried out in collaboration with the Institute of Plasma Physics Chinese Academy of Sciences (ASIPP). Two engineers from the institute are visiting PPPL, X. Cheng and Li Liu. Also Cheng presented a poster on the WCCB analysis.

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