The PPPL Highlights for the week ending September 20, 2013, are as follows:

FEATURED HIGHLIGHT:

An important theoretical breakthrough in accelerator physics has been reported in two recent publications in Physical Review Letters.

The fundamental theoretical framework of accelerator physics is based on the Courant-Snyder (CS) theory, a theoretical description of charged particle dynamics in an alternating-gradient quadrupole focusing lattice developed by Courant and Snyder in 1958. However, the CS theory can only be applied to the ideal case of an uncoupled quadrupole focusing lattices. In realistic accelerators, there also exist bending magnets, torsion of the design orbit (fiducial orbit), and skew-quadrupole components introduced intentionally or by misalignment. In certain applications, solenoidal magnets are also used. When these realistic components are considered, a new theory in a higher dimension is needed. The generalized Courant-Snyder theory published this month [H. Qin, et al, Phys. Rev Lett. 111, 104801 (2013)] fulfills this much-needed role. The envelope function of the original CS theory is generalized into an envelope matrix, and the phase advance is generalized into a 4D sympletic rotation (also known as the U(2) group). The envelope equation, transfer matrix, and the CS invariant of the original CS theory, all have their counterparts, with remarkably similar expressions, in the generalized theory. Especially, the generalization of the 1D envelope equation (also known as the Ermakov-Milne-Pinney equation in quantum mechanics) to higher dimensions will have broad applications in various branches of physics.

To accelerate and transport high-intensity beams, it is also critical to understand in what modes the beams can propagate quiescently through an alternating-gradient focusing channel. Up to now, the only known class of exactly soluble modes of intense beam propagation including self-electric and self-magnetic field effects is the Kapchinskij-Vladimirskij distribution discovered in 1959. Using the generalized CS theory, and in particular the generalized envelope equation in higher dimension, a new class of propagation modes admitted by the nonlinear Vlasov-Maxwell equations was discovered after applying the Cholesky decomposition technique [H. Qin and R. C. Davidson, Phys. Rev. Lett. 111, 064803 (2013)]. The newly discovered propagation modes enable a large increase in flexibility in the amount of beam control and steering capability. For example, the new modes allow the beam to tumble (rotate) in the transverse plane perpendicular to the propagation direction, which can be utilized as a beam smoothing technique for accelerator applications where smooth illumination is required, such as in the case of accelerators for heavy ion fusion and medical applications.
NSTX (M. ONO):


While in York, United Kingdom, J. Menard (PPPL) participated in the IEA ST executive committee meeting and also chaired a MAST PAC videoconference to discuss preliminary results from the M9 experimental campaign and the status and plans of the MAST Upgrade project. Both meetings were held at the York Plasma Institute.

Joon-Wook Ahn (ORNL) visited KSTAR to participate in H-mode characterization experiments and ran a session MP2013-05-01-123 in the weeks of August 19 and 26. The purpose of this experiment was to create a small ELM H-mode regime with high confinement by controlling plasma shape. Two parameter scans were completed to investigate impact on the small ELM regime. Each of triangularity (d = 0.7 -> 0.95) and drsep (-1 cm -> 0.5 cm) was independently varied with other parameters kept constant. It was found that d alone did not affect the ELM type but drsep close to 0 led to successful creation of a small ELM plasma. Preliminary analysis of ECEI image data showed that fluctuation of emission intensity during the inter ELM period was higher than for standard type-I ELMy plasmas. Work is under way to characterize this small ELM regime and to confirm conditions for its occurrence.

ITER & TOKAMAKS (R. HAWRYLUK):

DIII-D (R. Nazikian):

E. Kolemen participated in experiments this week to suppress NTMs using a real time ray-tracing algorithm to control the microwave beam steering mirrors. The new code, TORBEAM, was developed to rapidly calculate the deposition profile of a microwave beam based on real time electron temperature and density profile measurements from the Thomson scattering diagnostic together with real time MSE equilibrium analysis. The ray tracing enabled the accurate pointing of the EC launcher mirrors for ECCD at the q=3/2 mode rational surface. The experiment proved successful, demonstrating the effective suppression of the 3/2 NTM.

International Collaborations (R. Hawryluk):

R. Hawryluk participated in the EAST International Advisory Committee meeting in Hefei, China and had other discussions regarding potential collaborations between ASIPP and H. Neilson.
ADVANCED PROJECTS (H. NEILSON):

C. Kessel participated in the ARIES Project Meeting in Germantown, Maryland, where progress was reported on the ARIES-ACT2 tokamak power plant study. This configuration targets conservative physics and conservative technology. Kessel reported progress on the physics. Ideal MHD stability indicates the maximum betaN with no stabilizing wall for low-n kink modes is about 2.6, while taking credit for a wall behind the shield or behind the blanket resulted in values up to 2.85 and 3.2 respectively. P. Snyder of General Atomics supplied the maximum pedestal pressure at about 220 kPa, resulting in a high pedestal temperature of about 8.5 keV. Simple ELM analysis indicated that the energy released in an ELM would be about 150-180 MJ, which appears would result in melting even with footprint expansion observed for large ELMs. TSC time-dependent free-boundary simulations of the plasma from startup are converging to the target configuration identified in the systems analysis. Neutral beam, ion cyclotron, and electron cyclotron will be examined as heating and current drive sources, since the lower hybrid is cutoff very close to the plasma edge with the high pedestal temperature.

The Laboratory's stellarator research activities were well represented at the International Stellarator Heliotron Workshop, held September 16-20 in Padova, Italy. S. Lazerson presented "3D Equilibrium Diagnostic Response for W7-X and ITER," which generated interest in divertor scenario development for W7-X. N. Pablant presented "Investigation of ion and electron heat transport of high-Te ECH heated discharges in the Large Helical Device," reporting work performed in collaboration with Japan's National Institute for Fusion Science. D. Gates presented "The QUASAR facility," while M. Zarnstorff presented an invited talk, "Path to a Stellarator Demo." H. Mynick presented a talk, "Designing stellarators & tokamaks for reduced turbulent transport". S. Prager also attended this workshop.

In the Laboratory's collaboration with the Wendelstein 7-X project at Germany's Max Planck Institute for Plasma Physics, it was reported that the fourth of five U.S.-supplied trim coils was installed on the device.

N. Pablant attended the International Conference on Fusion Reactor Diagnostics, held September 9-13 in Varenna, Italy, and presented "Recent Advances in X-ray Imaging Spectroscopy and Implementation on ITER."

H. Neilson attended the meeting of the EAST International Advisory Committee at the Chinese Academy of Sciences' Institute for Plasma Physics (ASIPP) in Hefei, China.

THEORY (A. BHATTACHARJEE):

Dr. W. Tang presented an invited talk on "Supercomputing Grand Challenges & Advances in Fusion Energy Simulations" at the International Conference on Numerical Simulation of Plasmas (ICNSP-2013) in Beijing, China, September 14-16. Other invited oral presentations from Princeton included talks by Xujin Li (PPPL) on "Adaptive Grids in Simulations of Toroidal Plasma Starting from MHD Equilibrium" and by Dr. Bei Wang (Princeton U.) on "Gyrokinetic PIC Method with Phase-Space Remapping for Long-Duration Simulations of Plasma Turbulence. Dr. Tang, as a member of the International Advisory Committee for the new "Large
Scale Fusion Simulation Project" that was recently funded by ITER/China and hosted by the Fusion Simulation Center (FSC) at Peking University, also participated in strategic planning discussions at the FSC on September 12-13.

W. W. Lee attended the International Conference on Numerical Simulation of Plasmas (ICNSP) in Beijing, China (as a member of the Program Committee and the Chairman of the Awards Committee) and gave a poster presentation entitled "Finite-Beta Simulation of Micrturbulence in Sheared Geometry." He also gave a short talk on the "Development of Finite-Beta Simulation Model and Recent Controversy on Nonlinear Gyrokinetics" at the Institute of Plasma Physics and Fusion, Peking University, describing the use of the double split-weight scheme for electromagnetic PIC simulations and questioning the relevancy of the nonlinear terms in the gyrokinetic Vlasov and Poisson's equations.

On September 15, X. Li gave a talk on "Adaptive grids in simulations of toroidal plasma starting from MHD equilibrium" to the International Conference on Numerical Simulations of Plasmas in Beijing, China. In the talk, she described specifics of macroscopic plasma dynamics in tokamaks and presented a special set of equations, which she called Tokamak MHD (TMHD) describing the disruptions. One specific of TMHD simulations is the necessity of using the adaptive numerical grids aligned with magnetic field lines. As a step in this direction, she outlined the recently developed ESC-EEC code system and showed examples of plasma equilibrium of different tokamak configurations calculated by ESC-EEC. She introduced the Reference Magnetic Coordinates (RMC), which resolves the problem of creating toroidal coordinates for 3-D ergodic magnetic fields. The RMC provides the algorithm for generation of adaptive grids in TMHD with a fast Newton scheme.

This week's theory seminar was presented by M. Campanell, PPPL graduate student working with Dr. Kaganovich, on "Effects of Electron Emission on Plasma-Surface Interaction". The importance of electron emission through plasma surface interaction for different applications was discussed. The concept of inverse sheath model (positive inverse sheath potential) and a simulation thereof was presented. The implication of inverse sheath was discussed and compared to the classical sheaths. For example, in tokamaks, ion acceleration to the wall by classical sheaths can be eliminated by exploiting emission to generate inverse sheaths. There is only one indirect experimental evidence of inverse sheath. The simulations of (a) wall coupling when the emitted electrons can travel to the other wall in a low collisional plasma and (b) sheath instabilities driven by secondary electrons were also shown. Here is the abstract of the talk.

"Secondary, thermionic and photon-induced electron emission from surfaces are important in many plasma applications. Most theoretical models of PSI with emission invoke assumptions that the sheath is time-independent, the wall potential is negative, ions enter the sheath at the Bohm velocity, the presheath is negligibly affected, and one wall is present [1]. It can be shown with basic theory and PIC simulations that these assumptions break down in a variety of situations. When emission is strong, the sheath potential can become positive, repelling ions from the wall and eliminating ion sputtering [2,3]. Emitted electrons entering the plasma can drastically affect the presheath structure too. If the electron mean free path is large, emitted electrons can transit the plasma and impact other walls; hence in low collisionality systems wall charging becomes a complex global flux balance problem [4]. Secondary emission can trigger sheath instabilities preventing plasma-wall systems from reaching steady state [5,6]. Implications of these effects are discussed for tokamak divertors, Hall thrusters, dusty plasmas, hot cathodes, RF discharges and spacecraft. [1] G.D. Hobbs and J.A. Wesson, Plasma Phys. 9, 85 (1967). [2]
ENGINEERING AND INFRASTRUCTURE (M. WILLIAMS):

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

Construction: Permanent shims are being custom made for the upper TF supports and are now 80% complete. The upper TF support splice plates have been fully torqued. Custom fabrication and installation of shims for the upper TF turnbuckles is in progress. Electricians are working on restoring normal AC power to the racks in the NTC (everything in the Test Cell has been on construction power since the start of the outage). Electricians are installing cable trays under the beamlines. The tFIDA tube welded to the vessel has passed leak check. Welding inside the vacuum vessel has been completed so in-vessel cleanup is underway.

NBI Upgrade: Decon of the TTC wall for cable tray installation continues. Work on cryo valves on the south wall and BL continues. The DI water system subcontract continues with hydrostatic testing. The Ion Source and Ion Dump DI H2O Pump procurement continues. Vacuum system installation detailed drawings are in progress and a package is being developed for installation. BL2 alignment of 90-inch flange and source platform rails has started. The power system cable and tray subcontract received notice to proceed for fieldwork. Mobilization is in progress. Cable tray supports have been delivered. A template fabrication is in progress in the Tech Shop. The rectangular spool piece duct shields were completed. Thermocouple installation on armor tiles continues. Final welding of t-bar studs is imminent. Management preparations and dry run reviews continue for the upcoming Office of Science review scheduled for early October 2013.

BUSINESS OPERATIONS (K. FISCHER):

PPPL received $100,000 from the National Science Foundation (NSF) for continued work on the research project entitled "GEM: Modeling How Substorm Induced Waves Power Broadband Aurora." The total expected budget is $400,000 and the Principal Investigator is J. Johnson.

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

The DOE Office of Emergency Management conducted a Laboratory-wide No Notice Emergency Exercise (NNX) at PPPL on September 18. The exercise focused on command, control and communications functions normally executed in response to an operational emergency. The scenario included a simulated glove box seal failure, leading to an explosion and potential lithium contamination of personnel on scene. The simulated explosion occurred before an ESU emergency response, simulated off-site mutual aid response, and actual activation of the PPPL Emergency Operations Center and Emergency Response Organization. The emergency exercise was executed very well, and much was learned about the readiness of our response,
communications, intervention and business recovery activities.

PUBLICATIONS:

F. Ebrahimi and her coauthors' paper on "Magnetic reconnection process in transient coaxial helicity injection," Physics of Plasmas 20, 090702 (2013) was published online (URL: http://link.aip.org/link/?PHP/20/090702&aemail=author). Non-inductive current formation is a critical issue in NSTX and in future ST-based fusion devices. Coaxial Helicity Injection (CHI) is a leading candidate for plasma start-up and current formation. Understanding the dynamics and the mechanism of closed flux surface formation during transient CHI is of great importance and has been an outstanding problem for a long time. In a systematic and detailed approach, this is the first paper that explains the fundamental reconnection mechanism that leads to the generation of closed flux surfaces in a transient CHI discharge. The minimum conditions required for generating closed flux are also obtained. It is found that at sufficiently low magnetic diffusivity (high Lundquist number), and with a sufficiently narrow injector flux footprint width, the oppositely directed field lines have sufficient time to reconnect (before dissipating), leading to the formation of closed flux surfaces. Simulations show that an X point is formed in the injector region, followed by formation of closed flux surfaces within 0.5 ms after the driven injector voltage and injector current begin to rapidly decrease. As the injector voltage is turned off, the fields lines tend to untwist in the toroidal direction and magnetic field compression exerts a radial J × B force and generates a bi-directional radial Etoroidal × Bpoloidal pinch flow to bring oppositely directed field lines closer together to reconnect. The reconnection process is shown to have transient Sweet-Parker characteristics. Numerical simulations hint that transient CHI experiments in NSTX may be the first to demonstrate a forced magnetic reconnection process in a large-scale fusion device. (NSTX)

E. B. Hooper (LLNL) and his coauthors' paper on "Flux surface closure in helicity injected startup plasmas for NSTX," Physics of Plasmas 20, 092510 (2013) was published online. The paper report a study of the generation of helicity-injected startup plasmas in NSTX using resistive-MHD (NIMROD) simulations with plasma flows, currents, ohmic heating and anisotropic thermal conduction. Results include buildup of the plasma, formation of an X-point above the injection slot following the end of injection, and the following evolution of the plasma. Non-axisymmetric effects are not important in the plasma evolution. Simulations demonstrate the injection of toroidal flux below the bias poloidal flux and extraction of toroidal flux by the absorber slot. The difference between the two is small but causes sufficient magnetic pressure across the bias flux to expand it into the NSTX volume. X-point formation is triggered as the injector voltage drops to zero; magnetic pressure due to toroidal field entrained in the ExB plasma flow from the injection gap drops, allowing resistive magnetic reconnection even though the total injected current is almost constant. Although, these simulations demonstrate flux closure, an important difference between the simulations and the experiment is that the amount of initially closed flux and the rate at which the toroidal current is incorporated into the closed flux region in the simulations are much less than in the experiment. However, these results provide a physics basis for extending simulations to obtain quantitative agreement. (NSTX)

A paper entitled "Access to high beta advanced inductive plasmas at low injected torque" by Wayne Solomon et al. was recently published in Nuclear Fusion. (DIII-D)
This report is also available on the following web site:
http://www.pppl.gov/publication-type/weekly-highlights