Weekly HIGHLIGHTS

PPPL PRINCETON PLASMA PHYSICS LABORATORY

U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the week ending March 17, 2017 are as follows:

NSTX-U RECOVERY PROJECT (R. HAWRYLUK):

The eighth of the twelve planned Design Verification and Validation Reviews (DVVR's), this one reviewing the NSTX-U test cell construction and safety systems, was held this week. Nick Balshaw, of the Culham Centre for Fusion Energy, took part in the review at PPPL, and Jim Irby, of MIT's Plasma Science and Fusion Center, took part remotely. V. Riccardo, the head of engineering, chaired the review.

Regarding test cell work, engineering has completed initial inspections of the Poloidal-CHERS diagnostic in-vessel passive plate mounting structures, and passive plates/structures have been removed from the vessel for upgrades. Installation and alignment of waveguides for the FIReTIPS diagnostic continues.

Vacuum leak checking of in-vessel neutral beam armor has been completed, and the armor plates will now be removed from the vessel for repairs.

Recommissioning of the coil winding facility also continued with the successful flow testing of the spools of copper conductor to be used for coil winding. The replacement of O-rings and leak checking of a PF1A mandrel continues.

Installation of power components for the PF1 coil test stand in the Field Coil Power Conversion Building also continues.

An engineering review of the motor generator (MG#1) lower guide bearing inspection results was performed by Voith Hydro Inc. and PPPL, and calibrations of MG#1 motor controls were completed.

An assembled neutral beam ion source has been moved to a stand for hydrostatic and electrical insulation testing, and when complete, will be mounted in an ion source enclosure to become the first fresh spare neutral beam source.

ITER & TOKAMAKS (R. NAZIKIAN):

International:

R. Maingi is currently visiting ASIPP to discuss analysis of the December 2016 lithium experiments and to present ideas for future collaborative experiments at the EAST research forum. Maingi is presenting experimental ideas from the US fusion community on lithium research, RF heating and 3D field physics.

F. Poli traveled to JET to participate in an MHD analysis and modeling meeting as part of preparations for a DT campaign in FY19. The focus of the research is to identify discharges suitable for validating a new NTM module in TRANSP and for comparison to related calculations in the European Transport Solver workflow (ETS). Hybrid discharges with a variety of core NTM activity will be selected for model validation.

Poli visited York University in the UK to give a seminar on "the role of integrated modeling in discharge analysis, prediction, and for development of more robust control algorithms". The seminar covered the work funded under the ITER Task Agreement on electron cyclotron suppression of MHD. She also presented results on the analysis of LHCD inn C-Mod and on non-inductive startup on NSTX-U.

DIII-D:

Calculations of the neutral beam injected power for DIII-D has been upgraded to take into account the time evolution of the accelerator voltage. The DIII-D neutral beams can now be operated with time evolving beam voltage for fine-tuning of the input beam ion energy, power and torque. Varying the beam energy continuously during a discharge has advantages over NBI modulation. However, due to the time-evolving voltage, the beam perveance, transmission and neutralization efficiencies, and species mix vary dynamically during a tokamak discharge. The power calculation has been upgraded by B. Grierson, head of neutral beam physics group at DIII-D, to accurately determine the injected power and torque with this new variable beam voltage capability.

The Neutral Beam Local Control System No. 5 has been redesigned to account for the large amount of electrical noise that affected the first system design. The new system uses fiber optic transmission between internal and all external components to minimize pickup. The new design eliminates more than half of the internal wiring in the controller and shrink the system down to 1 tall rack compared to two. A design review will be held next week.

A. Diallo travelled to University of California Davis to meet with Professor Luhmann's group to assess the status of the ECE Imaging upgrade. Progress has been made in the horn antenna assembly and testing. A timeline for the installations of the upgrade on DIII-D was discussed. Installation is now planned for the week of March 27.

ADVANCED PROJECTS (H. NEILSON):

Stellarators (D. Gates):

R. Miller, PPPL Technician, and D. Loesser, Head of Mechanical Engineering at PPPL, traveled to the Institute for Plasma Physics in Greifswald, Germany. The purpose of the trip was to witness and assist in the re-assembly and trial vessel installation of the divertor scraper element components in a W7-X mock up unit. This is the last step before the actual installation of the components into the W7-X device, which is now scheduled for early 2018. The divertor scraper, a high-heat flux component designed to protect the edges of the divertor targets under certain operating conditions, has been a topic of the W7-X collaboration for several years. Currently, a multi-institutional scraper-related physics task force is performing analyses and developing an experimental plan for testing the scraper during OP1.2.

THEORY (A. BHATTACHARJEE):

D. Ruiz and I. Dodin (PPPL) published a paper titled "Ponderomotive dynamics of waves in quasiperiodically modulated media" [Phys. Rev. A 95, 032114 (2017)], where they report how linear waves can experience time-averaged refraction in modulated media. This effect is analogous to the time-averaged ponderomotive effect on charged particles when interacting with high-frequency electromagnetic fields. By using the Weyl calculus, they propose a covariant variational theory of this ponderomotive effect on waves for a general nondissipative linear medium. As an illustration, ponderomotive Hamiltonians of quantum particles and photons are calculated within a number of models. They also explain a fundamental connection between these results and the well-known electrostatic dielectric tensor of quantum plasmas.

D. Ruiz and I. Dodin (PPPL) published a paper titled "Extending geometrical optics: A Lagrangian theory for vector waves" [Phys. Plasmas 24, 055704 (2017)]. They derive general leading-order corrections to the well-known equations of geometrical optics (GO), which are not entirely correct even diffraction effects aside. Traditional GO treats wave rays as classical particles, which are completely described by their coordinates and momenta, but vector-wave rays have another degree of freedom, namely, their polarization. The polarization degree of freedom manifests itself as an effective (classical) "wave spin" that can be assigned to rays and can affect the wave dynamics accordingly. A well-known manifestation of polarization dynamics is mode conversion, which is the linear exchange of quanta between different wave modes and can be interpreted as a rotation of the wave spin. Another, less-known polarization effect is the polarization-driven bending of ray trajectories. This work presents an extension and reformulation of GO as a first-principle Lagrangian theory, whose effective Hamiltonian governs the aforementioned polarization phenomena simultaneously. As an example, the theory is applied to describe the polarization-driven divergence of right-hand and left-hand circularly polarized electromagnetic waves in weakly magnetized plasma.

On March 16, Christopher Smiet (Leiden University, The Netherlands) presented a theory seminar on Self-organizing knots. Magnetic helicity, a measure for the linking and knotting of magnetic field lines, is a conserved quantity in Ideal MHD. In the presence of resistivity, helicity constrains the rate at which magnetic energy can be dissipated. When a localized, helical magnetic field is set to relax in a low resistance high-beta plasma, the magnetic pressure drives

the plasma to expand whilst the helicity is still approximately conserved. Using numerical simulations I show how this interplay gives rise to a novel MHD equilibrium: the initially linked field lines self-organize to form a structure where field lines lie on nested toroidal surfaces of constant pressure. The Lorentz forces are balanced by the gradient in pressure, with a minimum in pressure on the magnetic axis. Interestingly, the rotational transform is nearly constant on all magnetic surfaces, making the structure topologically nearly identical to a famous knotted structure in Topology: the Hopf fibration. I will explore the nature of this equilibrium, and how it relates geometrically to the structure of the Hopf map. Additional dynamics give rise phenomena that are well known from magnetic confinement devices; magnetic islands can occur at rational surfaces, and in certain regimes the equilibrium becomes nonaxisymmetric, triggering a marginal core-interchange mechanism.

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