PRINCETON PLASMA PHYSICS LABORATORY

WEEKLY highlights

PPPL

U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the week ending February 12, 2016 are as follows:

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

Steady State Electric Network (SSEN):

A Project Change Request (PCR) was submitted to US ITER to authorize the recommended approach for the remaining three SSEN procurements—Uninterruptible Power Supply (UPS) system, DC Distribution, and Low Voltage (LV) Distribution and Sub-distribution Panels. The Low Voltage (LV) Distribution and Sub-distribution Panels procurement will be transferred to the ITER IO, and the UPS and DC Distribution systems (minus the batteries) will be procured by Princeton Plasma Physics Laboratory. Technical specifications for the UPS and DC Distribution systems were submitted to US ITER and ITER IO for approval this week. A Request for Proposal (RFP) for these final procurements will be issued in March.

Diagnostics:

Upper Port Wide Angle View Vis-IR Cameras (UWAVs): UWAVs preliminary design continues with optimization of the in-vacuum optical mechanical design. General Atomics and TNO presented a promising and novel concept for the UWAVs plasma facing shutter. The shutter package also houses a water-cooled aperture, which is critical for the IR measurement. If the aperture to the plasma is not adequately cooled the IR signal “noise” from hot metal surfaces will make the Divertor IR measurements more difficult.

Low Field Side Reflectometer (LFSR): The GA/UCLA have compiled a report outlining the configuration of the Low Field Side Reflectometer front end antenna system for X-mode and Doppler channels. This was the culmination of 18 months of system level design, physics modeling, and testing. The front-end has been configured by PPPL in CATIA accordingly and uploaded to Enovia for Russian Federation DA (port integrator) analysis.

Motional Stark Effect (MSE): MSE preliminary design continues as a joint effort between PPPL and Nova Photonics. The team has been focused on setting up ZEMAX ray-trace software models of the EP1 Core MSE and EP3 Edge MSE views. One difficulty has been accurately modeling the positions of the diagnostic port plugs with respect to the Heating and Diagnostic beams at operating temperature. The team, with help from EP3 integration and the IO, is also accounting for as-built positional tolerances of the installed diagnostic port plugs with respect to the beams.

Electron Cyclotron Emission (ECE): A. Khodak has been compiling reference and contacts in industry and other ITER diagnostic labs on the state-of-the-art for Piezo driven motors. The ECE Hot Calibration source mirrors need to be driven through 45 degrees of motion in the harsh port plug environment. Piezo actuated motion is attractive because the motors are resistant to the magnetic loads and nuclear damage and will also be easier to integrate and mechanically package. One major draw back that needs to be studied is the survival of a Piezo mechanism in the 200C plus vacuum bake.

Diagnostic RGA (DRGA): Progress was made on the Interstage Port Demonstration Test using a borrowed spectrometer. The He:H2 concentration was pushed down another magnitude from previous testing to 0.1:99.9, and the instrumentation could differentiate the mix. This measurement confirmed 1000 ppm resolution. It appears the spectrometer is capable of even better resolution, but there is a question as to whether the gas mixing station can produce 0.01:99.99 mixture. Further testing will be performed to see what the lowest detection threshold is, but the requirements for this test have essentially been met. PCR-708 came before the CCB this week. Ramifications on the RGA are significant, with a potential redesign of the LP12 RGA piping appearing to be likely. Plans to redo the LP12 piping structural integrity analysis have been put on hold until the new cryostat flange design progresses. The structural integrity report was the subject of an FDR-1 cat 1 chit, so it may be some time before the chit (and FDR-1) is closed. Fortunately, the PCR does not affect the design of the analysis chamber, so that work will continue.

Upper Port 11 and 14 Integration: The focus of UPP14 integration engineering is the packaging and stress analysis of all the water supply and return piping inside the port plug. Thermal stresses during bake-out and mechanical stresses during magnetic disruptions require adequate stress relief in the piping. The team is considering the use of various types of vacuum compatible bellows for stress relief.

Equatorial Port 9 Integration: Equatorial Port 9 engineering is focused on re-building DSM-2 and DSM-3 detailed models in CATIA. There were several structural and diagnostic tenant design changes over the past few months. All of these improvements will result in the locked Preliminary Design models for ECE in DSM-2 and TIP in DMS-3. It is important to lock in these designs soon so that neutronics and electromagnetic analysis can commence and feed in to the load specifications for the DSMs and tenants.

Toroidal Interferometer and Polarimeter (TIP): R. Wood has done an initial scoping study of a radiatively cooled Mo retroreflector. Initial results look favorable. If viable, this simplifies the interface with the ITER blankets and removes some of the risks involved in the conductively cooled design.

GA has exercised the prototype real-time alignment system, maintaining alignment through simulated motions corresponding to the growth of the vacuum vessel from room temperature to operating temperature to bake-out temperature. Also determined was the range of compensation for various types of optical distortion from, for example, the nuclear heating of the retroreflectors.

Core Imaging X-Ray Spectrometer (CIXS): The department attended a meeting at IO on electronics in a nuclear environment last week. A lot of useful information was presented over

the course of the two-day meeting. Testing strategies and requirements for electronics were outlined.

NSTX-U (M. ONO):

A FY 2016 NSTX-U plasma operations update: The department has completed 2.69 run weeks and 277 plasma shots. The total operation targets are to be decided.

February 8 was spent troubleshooting problems in FCPC and resolving grounding issues on the outer vacuum vessel.

On February 9, six shots were taken towards XMP-137 (Increase I_p and kappa in L- and H-modes). These discharges were used to develop an inner-wall-limited L-mode target discharge with flattop I_p of 0.8 MA. Discharge development was pursued in tandem with XMP-138 on Tuesday and Thursday to realize L-mode discharges with elongation near 1.9 at internal inductance around 1.0 (203209). The improvements in vertical control allowed for repeatable operations close to the present vertical stability limit.

February 10 was largely spent troubleshooting the gas delivery system. A single discharge was taken towards XMP-138 (Vertical Control Checkout).

On February 11, XMP-138 (Vertical Control Checkout) was largely completed. This XMP demonstrated filtering of the voltage and flux differences used in the vertical position observer. The filters successfully removed the pickup of power supply ripple and noise spikes that had triggered vertical instabilities in previous XMPs. A weighted combination of the filtered sensors was also tested, which improved the estimated vertical position. Only some minor steps in XMP-138 are outstanding, and were deferred in order to move forward with other control development. Shots were then taken on XMP-115 (Isoflux Commissioning) for initial testing of ISOFLUX control of the mid-plane outer gap using PF-5.

Operation of February 12 was delayed in order to resolve a problem with the MG cyclo-converter. When this was cleared, further development on ISOFLUX control via XMP-115 was done. These shots resolved a software issue with transitioning into ISOFLUX control and allowed tuning of the PF-5 control of the mid-plane outer gap to be finished. Tuning of ISOFLUX control of PF-3U/L was started before the end of the day.

NSTX-U plasma operations resumed this past week with experiments to evaluate machine conditions after the vacuum vessel boronization over the weekend, and to further test the plasma vertical controls. Earlier in the week, debris was discovered in-vessel on the vessel floor at the lower divertor near Bay L. Further investigation revealed that this material was part of the boron nitride cover on the BES diagnostic shutter. A team has been commissioned to develop the tools and procedures for the recovery of this debris. A procedure to assess the current state and operability of the shutters is also under development. All six NB ion sources were conditioned this week, but the NB2A had to be taken off-line for a telemetry repair. The NB2A system still needs to complete qualification/aiming shots into the in-vessel armor before it can be used to support experiments.

ITER & TOKAMAKS (R. HAWRYLUK):

DIII-D (R. Nazikian):

An article was published in Nuclear Fusion (volume 56) entitled "Dependence of Neoclassical Toroidal Viscosity on the Poloidal Spectrum of Applied Nonaxisymmetric Fields," authored by N. C. Logan, J.-K. Park, C. Paz-Soldan, M. J. Lanctot, S. P. Smith, and K. H. Burrell. The article presents a single mode ideal MHD plasma response model (IPEC) for computing the neoclassical toroidal viscosity (NTV) torque in DIII-D H-mode plasmas. The model provides the physical basis for the ongoing practical application of 3D fields to modify plasma rotation.

N. Logan presented a talk at the DIII-D Friday Science Meeting indicating PPPL and OMFIT user group efforts to develop an alternative time-based profile data analysis system that overcomes many of the limitations of single time slide analysis that has been used at General Atomics for several decades. The new capability will enable much more efficient and consistent analysis of profile data for preparation of time dependent analysis including TRANSP.

C-Mod (S. Zweben):

S. Zweben is a co-author of an Alcator C-Mod paper entitled "Comparison of Velocimetry Techniques for Gas-Puff Imaging Data" by J. M. Sierchio, I. Cziegler, J. L. Terry, A. E. White, and S. J. Zweben—published in Review of Scientific Instruments, 87, 023502 (2016), http://dx.doi.org/10.1063/1.4939672. This paper compares the time delay estimation and Fourier methods of velocity extraction for 2D images taken by the GPI diagnostic in C-Mod. Each method has its advantages and disadvantages. Similar methods are being developed and tested for GPI in NSTX-U.

ADVANCED PROJECTS (H. NEILSON):

The Fusion Energy Systems Studies group has completed its 2015 Year End report on the Fusion Nuclear Science Facility (FNSF), a study that is continuing until the end of 2016. Progress is briefly reported in nuclear analysis, CAD facility layout, maintenance and remote handling, tritium systems, thermo-mechanics of the first wall and blanket, magnet assessment and stress analysis, LiPb breeder thermofluids, transients and disruptions, plasma ideal MHD, and SOL/divertor. In addition, the operating point and operating space around this point are determined, giving a major radius of 4.8 m, plasma current of 7.9 MA, toroidal field of 7.5 T, total normalized beta of 2.5, q95 of 6, bootstrap fraction of 52%, IPB98(y,2) confinement multiplier of 1.0, and density to Greenwald ratio of 0.9. The evolution to this operating point is described. The program on the FNSF is described and supported in terms of its mission. A plasma strategy is pursued to support the basis for the operating point and the unique features of the FNSF. This will appear as a PPPL report.

D. Gates participated in the annual Competition Week of Physics Review Board for the Canadian National Science and Engineering Research Council (NSERC) in Ottawa, Canada, from February 8-10. Gates has a three-year appointment to the international panel and is tasked with reviewing and rating several hundred "Discovery Grant" proposals made to the NSERC. At this review, Gates assessed proposals in several areas of physics in which he has expertise.

THEORY (A. BHATTACHARJEE):

W. Fox attended and presented an invited talk, "Magnetic Reconnection in Low-Dissipation, Large-System Size Regimes on the NIF" at the National Ignition Facility (NIF) Users Group meeting, at Lawrence Livermore National Laboratory (LLNL), from February 1-3. Fox and collaborators from Princeton Plasma Physics Laboratory—A. Bhattacharjee, Y. Huang, L. Gao, K. Hill, and H. Ji—have been awarded upcoming experiment time at the NIF in FY 2017-18, through the NIF Discovery Science program. The experiments will focus on magnetic reconnection in laser-produced plasmas.

On February 11, F. Wang (PPPL) presented a theory seminar on nonlinear fishbone dynamics in spherical tokamaks with toroidal rotation: "Fishbone is one of the most important energetic particles driven modes in tokamaks. A numerical study of the nonlinear dynamics of fishbone has been carried out in this work. Realistic parameters with finite toroidal plasma rotation are used to understand nonlinear frequency chirping in NSTX. We have carried out a systematic study of nonlinear frequency chirping and energetic particle dynamics. It is found that, linearly, the mode is driven by both trapped particles and passing particles, with resonance condition $\omega_d \simeq \omega$ for trapped particles and $\omega_\phi + \omega_\theta \simeq \omega$ for passing particles, where ω_d is trapped particle toroidal precession frequency, and ω_ϕ, ω_θ are passing particle transit frequency in toroidal and poloidal direction. As the mode grows, trapped resonant particles oscillate and move outward radially, which reduces particle precessional frequency. We believe this is the main reason for the mode frequency chirping down. Finally, by way of the mode frequency chirping down, initially non-resonant particles with lower precessional frequencies become resonant particles in the nonlinear regime. This effect can sustain a quasi-steady state mode amplitude observed in the simulation."

PLASMA SCIENCE & TECHNOLOGY (P. EFTHIMION):

Aaron Scheinberg presented a Plasma Science and Technology seminar on the lunar dynamo: a basal magma ocean as the missing piece of the puzzle. The abstract reads: "The surprising strength and longevity of the magnetic field recorded in the lunar crust remains an unresolved problem in planetary science. Apollo samples indicate a surface field of ~77 μT that was active between 4.2 and 3.56 Ga and likely continued at a lower magnitude for billions of years. Previous models suggest that thermally driven convection in the core would have produced a dynamo two orders of magnitude weaker than the observed field, and last only ~100 m.y. First, we present a coupled core-mantle thermal evolution model of the Moon and show that core solidification could explain the extended longevity but not the high magnitude. We then test the hypothesis that convection in a basal magma ocean composed of radioactive, electrically conducting material drove the early dynamo. We adapt our model to estimate the longevity and heat flow of such a basal magma ocean and show that, if sufficiently conductive, it could have produced an early dynamo with surface fields consistent with the paleomagnetic observations."

COMMUNICATIONS & MEDIA RELATIONS (L. BERNARD):

L. Bernard and C. Cane visited the Department of Energy (DOE) in Washington, DC, for a communications summit and a meeting of the National Laboratories Chief Communications Officers. The summit, on National Lab-University collaboration, featured talks by C. Murray and L. Orr, as well as several panel discussions with representatives from DOE's Office of Science and other federal agencies, universities, and national laboratories.

BEST PRACTICES & OUTREACH (J. DELOOPER):

Science Education (A. Zwicker):

A. Dominguez participated in the DOE Lab Day at Howard University on February 4. Dominguez spoke in a plasma physics class that he helped establish at Howard and strengthened collaboration with the physics department.

More than 250 individuals participated in the Science on Saturday lecture, "Music and 3D Audio," given by Professor Edgar Choueiri of Princeton University.

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