PRINCETON PLASMA PHYSICS LABORATORY

WEEKLY highlights

PPPL

U.S. DEPARTMENT OF ENERGY

The PPPL Highlights for the week ending April 22, 2016 are as follows:

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

Steady State Electric Network (SSEN):

Uninterruptible Power Supply (UPS) system and DC Distribution: The RFP package for the UPS has been sent to PNNL for review, after which it will be submitted for DOE PSO review. The DC Distribution procurement value falls below the review threshold so it will not been sent to PNNL/DOE and has been held in case comments from the PNNL review seem appropriate for incorporation. Forecast issue date is now May 6.

Power Transformers: Lot 3 is fully ready to ship except that the Release for Shipping (RFS) document package is still a work in progress. Target shipping date is May 3. Factory Acceptance Testing (FAT) of the Lot 1 and Lot 2 transformers has been completed and correction of punch-list items is underway.

Diagnostics:

Upper Port Wide Angle View Vis-IR Cameras (UWAVs): The tolerance analysis, used to evaluate optical performance degradation due to optical elements being out of nominal position, for the Front End Optics Tube (design version 3i) has been performed. The tolerance analysis is based on the Monte Carlo approach, making use of random error distributions. As an indication of the results (spot sizes and Modulation Transfer Function (MTF)), an example of the nominal and a bad-performing case (on 2σ-boundary) are provided. Also, promising results were obtained with the thermal-mechanical-optical performance analysis on the FEOT 3H design.

Low Field Side Reflectometer (LFSR): PPPL held a web-based meeting with the Russian (RFDA EP11) Equatorial Port 11 integration team in Novosibirsk at the Budker Institute. The RFDA EP11 team has been evaluating the latest LFSR in-vacuum design and had feedback and concerns to address with the PPPL LFSR team. The main concern is the nuclear shielding performance of EP11 shield module #1 (DSM-1) that houses LFSR. The RFDA team asked that PPPL consider adding some additional shielding features directly in to the LFSR packaging. Shielding is needed around the LFSR wave-guide piping at the front of the DSM. PPPL was also asked to draft an Assembly and Maintenance Plan to support RFDA preparations for the November 2016 EP11 PDR.

Motional Stark Effect (MSE): This week the MSE team met with IDOM to discuss integration of the Core MSE Viewing system in to Equatorial Port 1 DSM-1. IDOM will be supplying interface

and space reservation models for EPP1 DSM-1 later this month, which will enable the PPPL MSE team to start work on revising the CDR Core MSE optical design.

Work done on the Edge Viewing MSE system in EP03 DSM-1 this week included front-end optical design, shutter concepts, DSM design, and filter wheel concepts. Front-end design is coming along very nicely. Using the concept of an independent module that holds the two first mirrors will hopefully allow for individual mirror isolation while still allowing enough cooling to be done through the module block. The shutter concept being considered is a simple Tungsten slide in which further analysis will determine if the shutter will survive or if a different design must be used. The DSM has been designed to contain all MSE components. Currently, load analysis must be made to decide of the current DSM design is viable.

Upper Port 11 and 14 Integration and DSM Engineering: The UP14 team is working with the Multiphysics Analysis team to finalize the analysis model for EM and structural analysis. The first draft of the Plant Definition Form (PDF) and Task Definition form (TDF) for the UP11 are ready as inputs to the UPP11 Remote Handling Compatibility Assessment report (RHCA). These forms will be sent to IO TRO for review. A request was sent out to the IO to provide an HCF model so that RHCA can be performed and a report can be submitted to IO for review. These documents are part of the primary set of document deliverables for port plug PDRs.

Equatorial Port 9 Integration and DSM Engineering: The IO Port Plug Engineering team sent out an appreciated communication this week that will benefit EP9 and EP3 integration and design optimization. Finding a DSM design solution that meets weight and shielding requirements has been very difficult and costly. The message reads: “During the last IO-DA meeting this year, IO-CT has been asked to look into the issue of the weight (45 tonnes maximum), neutronics and Remote Handling for the integrated Equatorial Port Plug. This is clearly an important area to clear up as soon as possible. We have decided to dedicate some resource to this immediately. As you can imagine this is not a simple task. Our indicative time for the first emission is June. In the meantime, we count on your support and support of your teams.”

Toroidal Interferometer and Polarimeter (TIP): Two meetings were held with the ITER vacuum group regarding the interface between the blanket shield modules and the TIP retroreflectors. In order to complete the design of the retroreflectors—imbedded in the blanket modules—a better understanding of the temperature range at this location is needed. This requires neutronics and thermohydraulic analysis, and the meeting addressed the strategy for this effort.

Core Imaging X-Ray Spectrometer (CIXS): Magnetic Field Testing—Ocilloscope setup is underway, network bridge installed for remote access to ocilloscope and detector computers. Power supply testing near completion, expected to be ready by end of the week. Drawings for cutout and mounting brackets are completed and currently being moved through checking process. Hardware for mounting brackets, and components has been ordered and received. Health Physics prepared to assist with testing. Procedure revision is underway. Software for power supply control has been written and is ready for testing.

NSTX (M. ONO):

A FY2016 NSTX-U plasma operations update: The department has completed 7.23 run weeks and 748 plasma shots. The total operation target is 18 run weeks.

A paper entitled "Phase space effects on fast ion distribution function modeling in tokamaks" by M. Podestà et al. was published online in Physics of Plasmas. The full paper is available to view at http://scitation.aip.org/content/aip/journal/pop/23/5/10.1063/1.4946027. The paper discusses the modeling of energetic particle dynamics in tokamaks when EP transport departs from "classical." Examples include transport by plasma instabilities. New approaches based on physics-based reduced models are being developed to address those issues in a simplified way, while retaining a more correct treatment of resonant wave-particle interactions. The kick model implemented in the tokamak transport code TRANSP is an example of such reduced models. It includes modifications of the EP distribution by instabilities in real and velocity space, retaining correlations between transport in energy and space typical of resonant EP transport. The relevance of EP phase space modifications by instabilities is first discussed in terms of predicted fast ion distribution. Results are compared with those from a simple, ad-hoc diffusive model. It is then shown that the phase-space resolved model would also provide additional insight into important issues such as internal consistency of the simulations and mode stability through the analysis of the power exchanged between energetic particles and the instabilities.

A paper "Observation of quasi-coherent edge fluctuations in Ohmic plasmas on National Spherical Torus Experiment" by S. Banerjee (Institute of Plasma Research, India), A. Diallo (PPPL), and S. J. Zweben (PPPL) was published in Phys. Plasmas 23, 044502 (2016) and is available to view at http://scitation.aip.org/content/aip/journal/pop/23/4/10.1063/1.4946871. This paper describes the recent work on the quasi-coherent edge density mode observed in Ohmic plasmas in NSTX using the gas puff imaging diagnostic (GPI). This mode is located predominantly just inside the separatrix, with a maximum fluctuation amplitude significantly higher than that of the broadband turbulence in the same frequency range. The quasicoherent mode has a poloidal wavelength ~ 16 cm and a poloidal phase velocity of about 4.9±0.3 km s-1 in the electron diamagnetic direction, which are similar to the characteristics expected from a linear drift-wave like mode in the edge. This is the first observation of a quasi-coherent edge mode in an Ohmic diverted tokamak, and so may be useful for validating tokamak edge turbulence codes.

D. Brunner, A. Kuang, B. Labombard, and R. Mumgaard from MIT visited PPPL on April 19 with R. Kaita (PPPL) as a host. Installation details for the advanced scanning mirror Langmuir probe (MLP) were discussed. They included the feasibility of mounting both the MLP and a Langmuir probe for high harmonic fast wave (HHFW) studies on a new port cover with behind the HHFW antenna array. Port possibilities where divertor multispectral imaging could use existing optical fiber bundles were also identified.

R. Kaita (PPPL) gave a seminar entitled "Measurement Challenges in Fusion Research: Plasma Diagnostics on the National Spherical Torus Experiment-Upgrade" at the Johns Hopkins University Applied Physics Laboratory (JHU-APL) in Laurel, Maryland on April 20. The talk included diagnostics covering detection energies from eV in the edge plasma to MeV for fusion products, and the utility of tokamak plasmas for calibrating spectrometers used on spacecraft.

These topics were of interest to researchers at the JHU-APL because their work on spacecraft instrumentation.

On April 22, S. Sabbagh (Columbia University) presented the talk "Initial results from NSTX-U and the Disruption Prediction, Avoidance, and Mitigation Working Group" at the DIII-D Science Meeting. The presentation covered NSTX-U results from the first seven weeks of NSTX-U operation, initial analysis using the Disruption Event Characterization and Forecasting (DECAF) code on NSTX and NSTX-U data, and the present status of the disruption mitigation system presently being installed on NSTX-U.

The reinstallation of the UCLA 16-channel reflectometer system continued this week. Waveguide runs, microwave source/receiver boxes, and power supplies were successfully installed. Lab testing of the sources/mixers, digitizer, and data acquisition software were successfully completed prior to this installation. This work was performed by UCLA engineer R. Lantsov (on travel to NSTX-U) and S. Kubota (UCLA). Completion of this work awaits installation of cable runs and an additional isolation transformer.

A. Diallo and B. LeBlanc of PPPL travelled to Physical Science Laboratory in Madison to continue the integration of the pulse burst laser system under A. Diallo's early career research proposal. Progress has been made in terms of testing the response of NSTX-U Thomson detection system to double-hump pulses. In addition, the system has been tested for 30 Hz operations for 5 seconds with success. The slow burst (1 kHz rep rate) was achieved. The fast burst (10 kHz rep rate) is still under development. Once the fast burst is achieved, the beam will be propagated to the amplifier stage in the upcoming weeks.

Installation of the Lithium Granule Injector (LGI) was completed with a successful leak check. Installation of the variable angle flange for SPRED was completed. Installation of lower Massive Gas Injection (MGI) valve continues.

NSTX-U is in a maintenance period. Maintenance on the Motor Generator set has been completed, and the set is ready to support full power operations. Installation activities in support of the UCLA Reflectometer, MSE-LIF, the Massive Gas Injector, a variable angle flange for the SPRED diagnostic, the Bay H Top Camera, and the fast Voltage measuring system needed for CHI operations continued this week. All six of the RF sources are being prepared for operation and conditioning of the HHFW antennas.

After it was determined that the LHe Refrigerator Cold Box had a Helium leak into its vacuum, several tests were performed to ascertain the extent and location. It was determined that the Helium leak required entry into the Cold Box so the shell was lowered. Leak checking identified one large leak in a thermocouple well. This well is no longer used in favor of more modern measurements already in place so it was removed and capped. A similar well was also removed and capped as a precaution. Another small leak was found and also capped. After leak checking was successful, the shell was raised into place and the Cold Box pumped down to rough vacuum. Once the Cold box pumpdown is complete, Helium process startup will continue to support NBI operations.

ITER & TOKAMAKS (R. HAWRYLUK):

DIII-D (R. Nazikian):

S. Haskey has implemented a python wrapper for the XGC0 code allowing the parameters of the ad-hoc diffusion model to be optimized between XGC0 runs without needing to resubmit the job to the NERSC queue. This should allow analysis to be completed in days instead of weeks. The wrapper allows the user to guide the diffusion model between XGC0 runs, or alternatively use an optimizer to determine the coefficients. Additionally, work is ongoing with D. Battaglia, R. Hager, and D. Stotler on optimizing D. Battaglia's branch of the XGC0 code on the Edison computer at NERSC. S. Haskey and B. Grierson are planning on using XGC0 to study the extent to which non-local neoclassical transport can account for observed differences between carbon (impurity) and deuterium (main ion) properties in the pedestal, which have been measured on DIII-D using the recently completed edge main ion CER system.

D. Eldon led a development session on divertor detachment control in helium. The detachment controller successfully reduced and then stabilized the divertor electron temperature to the requested value. Demonstrating control of the divertor electron temperature in Helium is valuable for ITER startup where detachment control will be needed.

The paper "High frequency pacing of edge localized modes by injection of lithium granules in DIII-D H-mode discharges" by A. S. Bortolon et al., was published in Nucl. Fusion 56 (2016) 056008. The paper demonstrates that ELM pacing efficiency was close to 100% obtained with 0.9 mm diameter granules and lower with smaller sizes. Robust ELM pacing was demonstrated in ITER-like plasmas at ELM frequencies 3–5 times the "natural" ELM frequency. Overall, high frequency ELM pacing using the lithium granule injection appears to be compatible with both H-mode energy confinement and attractive H-mode pedestal characteristics, but further assessment is needed to determine whether the projected heat flux reduction required for ITER can be met.

A synthetic diagnostic to forward model the response of ECE-Imaging to plasma simulation codes such as XGC-1 and GTC has been developed by L. Shi, a Princeton University student collaborating with B Tobias, E. Valeo, G. Kramer, and W. Tang of PPPL. Forward modeling is critical for the comparison of simulation to imaging data obtained in experiment, and this synthetic diagnostic is the first of its kind, using a reciprocal method to self-consistently model the refraction and diffraction of a quasi-optical beam alongside the emission and transport of cyclotron radiation. Initial results reveal a mixing of temperature and density effects in the diagnostic signal that may lead to techniques for obtaining the fluctuation cross-phase from a single instrument. The synthetic ECE-Imaging module has been incorporated into a fusion plasma synthetic diagnostics platform (FPSDP) that now includes the response of beam emission spectroscopy (BES) and microwave imaging reflectometry (MIR) systems. Applications of the FPSDP for the study of Alfvén eigenmodes and fluctuations in the plasma edge will be presented during an invited talk at the upcoming HTPD in Madison, Wisconsin.

A manuscript entitled "Rotation profile flattening and toroidal flow shear reversal due to the coupling of magnetic islands in tokamaks" by B. Tobias appeared online in Physics of Plasmas this week. This work, presented as an invited talk at the APS-DPP in Savannah, Georgia, describes the phenomenon of non-local momentum transport observed in hybrid and ITER

baseline scenario discharges on DIII-D when multi-helicity modes are present—a ubiquitous nonlinear feedback mechanism impacting tokamak disruptivity. Phase-locking, or the toroidal co-rotation of multi-helicity structures, is compared to a nonlinear theory of 3-wave mode coupling developed by R. Fitzpatrick (UT Austin). Discharges that develop hollow rotation profiles are also analyzed in this paper. The surprising dynamics of these discharges do not conform to a simple phase-locking model and help to motivate ongoing investigations into other island-induced effects, such as NTV and stochastic particle transport, for a more complete and predictive model of the evolution of tearing instabilities toward locking and disruption.

International (F. Poli):

F. Poli traveled to the ITER Headquarters to work with the Heating and Diagnostics Department. The topics of discussion covered details of the power management during the various phases of operation, from the first plasma to the demonstration baseline, as they change with the plasma composition, to satisfy the requirements and the objectives of the ITER research plan.

ADVANCED PROJECTS (H. NEILSON):

A sample tile assembly that will be tested by the Max Plank Institute for Plasma Physics (IPP) in their GLADIS high heat flux facility was shipped to IPP this week. The sample, consisting of a graphite tile and Langmuir probe mounted on a steel backplate, is the first hardware deliverable of Wendelstein 7-X TDU Scraper project to be completed. The planned testing is expected to confirm the thermal performance of the scraper design.

H. Neilson chaired the 2016 meeting of the DIII-D Program Advisory Committee, held April 19-21 at General Atomics in San Diego. The committee responded to charges related to DIII-D research programs in the areas of transients and boundary/plasma-material interactions. A debrief of the committee's conclusions was presented to the DIII-D and DOE Fusion Energy Sciences staff on April 21. A written report is in preparation.

THEORY (A. BHATTACHARJEE):

D. Brennan gave a Theory Department Research Review Seminar on April 22 entitled "Modeling Stability and Control of Tokamaks with Resistive Walls." The abstract reads: "In a collaborative effort covering several areas within MHD stability theory, we employ a theoretical and computational framework to analyze and understand experimental discharge stability. Reduced MHD modeling is developed to interpret simulations and computational analyses, where we alternately include several essential ingredients to study global mode stability: toroidal field line curvature to couple modes in a cylindrical model, trapped energetic ions, differential flow between surfaces, a resistive wall, and a model for feedback control from external coils. Asymptotic matching methods are used to determine the non-ideal MHD stability, where toroidal effects can also enter into the resistive layers, causing finite frequency responses and altering the stability. We briefly review a few research projects where extended MHD simulations and computational analyses of experiments including some of these ingredients are interpreted using reduced models. We then further focus on one of these projects, the effects of trapped energetic ions on resistive MHD instabilities. In simulation analyses modeling the DIII-D tokamak, the 2/1

tearing mode was found to be damped or stabilized by energetic ions with monotonic safety factor profile extending to the core, while the mode was found to be driven unstable with weakly sheared or reversed core safety factor profile. Using a reduced analytic model, we add in the effect of a slowing down distribution of energetic ions integrated to a scalar modification to the perturbed pressure. We find that with positive magnetic shear (s = 1/q dq/dr) and a pressure gradient, the particles contribute a stabilizing effect to the 2/1 tearing mode, while for s <= 0, the particles drive the mode unstable. This finding agrees with the drift-kinetic PIC / extended MHD simulations, and indicates that the core shear and pressure gradient combination can determine if energetic ions stabilize or drive the 2/1 mode unstable."

BUSINESS OPERATIONS (K. FISCHER):

Budget Office:

PPPL submitted a proposal to the DOE Office of Basic Energy Sciences in response to Funding Opportunity #DE-FOA-0001514—Energy Frontier Research Centers (EFRC). PPPL is the lead institution for this collaborative proposal titled "Center for Plasma-Based Remediation of Nuclear Waste." PPPL's collaborators on this proposal are Savannah River National Laboratory (SRNL), the University of Michigan and Northwestern University. The total requested budget for the four-year period of performance is $8.0 million with approximately $4.2M allocated to PPPL. The Principal Investigator is N. Fisch.

A proposal was submitted to NASA entitled "On the Relationship Between EMIC Wave Polarization and Plasma Conditions." The proposal is requesting funding for three years in the amount of $410,299. The Principle Investigator for this proposal is E. Kim.

A proposal was submitted to NASA entitled "An Information-Dynamical Approach to the Coupled Inner-Magnetosphere Environment." The proposal is requesting funding for three years in the amount of $457,120. The Principle Investigator for this proposal is J. Johnson.

INFORMATION TECHNOLOGY (S. ZELICK):

A new transport analysis capability has been deployed for NSTX-U. A modified version of the TRANSP input namelist has been created to enable TRANSP runs to complete automatically between NSTX-U discharges. This version, called BEAST (BEtween and Among Shots Transp) takes only 165 seconds from start to finish, including saving an output file for plotting. It runs on a new compute node with 64 GB of memory and solid-state disks to optimize performance. Running TRANSP in parallel on all 16 cores of one chip minimizes interprocess communication time.

The BEAST run starts automatically after it receives MDSplus events indicating that the acquired and processed input data is available. Similarly, it signals an event when the TRANSP run is complete so other programs can utilize the analyzed data. The output data is graphed according to a plotting script and saved to a web page. A new set of graphs can be plotted for a different time of interest within the shot. The graphs can be viewed in any browser and on the

Control Room Display Wall. Typical results show time-based neutron emission, plasma currents, confinement enhancement factor, beam power losses, and electron and ion temperature.

The BEAST system was developed by P. Henderson, S. Kaye, M. Gorelenkova, R. Andre, T. Carroll, I. Johnson, and E. Feibush.

DIRECTOR'S OFFICE (C. AUSTIN):

On April 20, S. Prager served as a witness at a Congressional hearing on fusion energy research held by the House Committee on Science, Space and Technology. The two-hour hearing covered many aspects of fusion research, including ITER, the PPPL program, outstanding challenges, exploratory fusion concepts, and opportunities for new US initiatives. A video of the hearing is at: https://science.house.gov/legislation/hearings/energy-subcommittee-hearing-overview-fusion-energy-science

Professor Dale Jamieson from New York University presented a colloquium on April 20 entitled, "Living with Climate Change: The Road from Paris."

On April 20-21, M. Zarnstorff attended the DOE Big Ideas Summit in Crystal City, Virginia.

On April 22, U. S. Representative Rodney Frelinghuysen and Princeton University President Christopher Eisgruber toured NSTX-U.

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