NSTX-U Weekly Report (April 8, 2016)

FY 2016 NSTX plasma operations
Operation Targets: Total – 18 run weeks
Completed: 7.23 run weeks and 748 plasma shots

A research highlight on the Materials Analysis Particle Probe (MAPP) appeared in the March 31, 2016 Monthly Newsletter of the U.S. Burning Plasma Organization (USBPO). Understanding plasma-wall interactions is critical to the development of controlled thermonuclear fusion. The MAPP diagnostic provides unique data toward this goal through exposing first-wall materials to tokamak discharges, and analyzing them without compromising any time-sensitive chemistry-dependent surface information. This is accomplished by withdrawing samples into a separate chamber under vacuum, where their surfaces can be probed with X-rays and low energy ions to characterize them. The MAPP system was installed on NSTX-U as a collaborative effort by the University of Illinois at Urbana-Champaign (UIUC) and PPPL, and has already been used to study the effects of surface conditioning techniques on plasma-facing components. (R. Kaita, PPPL)

Francesca Poli (PPPL) attended the EC-19, a joint workshop on Electron Cyclotron Heating and ECE in Ahmedabad, India, April 04-07. Poli presented an invited talk entitled "Electron Cyclotron power management in ITER, from the commissioning phase to the demonstration baseline". The focus of the paper was on EC power requirements for NTM stabilization in plasma scenarios at half-field and full field, both in the pre-DT and in the DT phase. (F. Poli)

NSTX-U researchers and collaborators attended the US Transport Task Force meeting on March 28 – April 1 in Denver, CO (http://www-internal.psfc.mit.edu/TTF2016/index2016.html). Talks were presented by John Canik (ORNL), Travis Gray (ORNL), Walter Guttenfelder (PPPL), Mario Podesta (PPPL), Yang Ren (PPPL) and Juan Ruiz Ruiz (MIT). Posters were presented by Ahmed Diallo (PPPL), Shige Kubota (UCLA), Douglas Ogata (U. Alaska-Fairbanks) and Stewart Zweben (PPPL). Francesca Poli (PPPL) led a Working Group discussion on modeling the so-called No Man's Land (the transitional region between core and top of the H-mode pedestal). (W. Guttenfelder)

Vlad Soukhanovskii (LLNL) attended the 19th International Conference on Atomic Processes in Plasmas (ICAPiP) in Paris, France, where he presented an invited talk titled "Near-infrared spectroscopy of tokamak divertor plasmas". In the talk, experimental results from NSTX and DIII-D and recent calculations from the non-LTE and line shape code Cretin were used to demonstrate how extending conventional spectroscopic methods to the near-infrared region can augment plasma-surface interaction studies and temperature and density measurements from Stark-broadened Paschen series deuterium lines in recombining divertor plasmas. Discussions were held with atomic physics data community scientists on the status and availability of state-of-the-art atomic structure and transition rate data for low and high-Z impurities in support of planned NSTX-U radiative divertor experiments and molybdenum spectroscopy for divertor erosion and core transport measurements. (V. Soukhanovskii)

R. Kaita (PPPL) gave a seminar entitled "The Dusty Road to Fusion: Addressing First Wall Erosion in the National Spherical Torus Experiment-Upgrade" at Baylor University in Waco, Texas on April 5, 2016. The topics included results from the Materials Analysis and Particle

Probe (MAPP), which allows samples of plasma-facing components (PFCs) to be exposed to plasmas and withdrawn into a surface analysis chamber without breaking vacuum. Experiments conducted to study lithium coatings on PFCs in the Magnum-PSI linear plasma device were also summarized. They showed a significant reduction in lithium erosion compared to expectations from temperature-dependent thermal sputtering and evaporation, and the mechanism has been explained by first-principles molecular dynamics calculations that model the mixed material formed by the lithium and the incident deuterium. Problems common to effects of plasmas on PFC on NSTX-U and studies of plasma-surface interactions in complex ("dusty") plasmas were also discussed with students and faculty at the Center for Astrophysics, Space Physics, and Engineering Research (CASPER) at Baylor University. (R. Kaita)

Physics Analysis (S. Kaye)

The first ideal MHD stability computations run for NSTX-U H-Mode plasmas using DCON were performed on kinetic equilibrium reconstructions of shots 204112 and 204118, which reached normalized beta above 4. For each discharge, the plasma is shown to move above the n = 1 no-wall limit during the discharge evolution. A composite no-wall beta limit model by J.W. Berkery (Columbia University), et al. (Nucl. Fusion 55 (2015) 123007) which includes internal inductance, pressure peaking and plasma aspect ratio as parameters is shown to well-represent the no-wall beta limit. The model will be further tested against NSTX-U plasmas and DCON calculations as the first component of a simplified model for kinetic RWM evaluation, to be used for disruption forecasting. (S.A. Sabbagh, Columbia University)

Run Coordination (J. Menard, S. Gerhardt)

The first 4 shots of Monday, 4/4/2016, were dedicated to XMP-143, degassing the walls from the boronization on the previous evening. These shots also tested various phases of the n=1 correction, scanning over about 60 degrees toroidal (from the optimal phase inferred in the XMP-140 to the optimal phase inferred from XP-1506). The rotation from the rtVphi diagnostic was used as the metric. There were no immediate conclusions regarding the optimum n=1 phase, but the phase inferred from to be optimal from the XP-1506 compass scan at least did no harm.

This activity was followed by XMP-142 (Establish H-mode with reduced MHD over a range of I_p and B_t). These shots were successful in developing long H-mode scenarios at 900 kA and 1 MA. The 1 MA scenario (204118), which was the first 1 MA H-mode in NSTX-U, set an NSTX-U record stored energy of 330 kJ. This shot also demonstrated the longest period yet of low internal inductance (l_i=0.65 for about a 0.9 second duration). The best discharge at 900kA (204112) maintained a normalized beta near 4 and minimal MHD activity for 0.5s. Key features enabling these advances were use of the new n=1 EFC phase established in XP-1506, higher beam power (5.4MW from four beams: 1B,1C, 2A, 2C) and higher plasma current, both of which helped maintain ELMs at high density (60 - 90% of the Greenwald density limit). The increased power also provided more consistent entry to H-mode as the oxygen content increased after many shots following the boronization.

A new boronization sequence was started on the evening of 4/4, and continued each evening through 4/7. A ~¼ bottle boronization was performed each night, followed by a ½ hour helium

GDC session. An additional ½ hour of He GDC was also done on the mornings of 4/6, 3/7, and 4/8.

Tuesday 4/5/2016 was dedicated to additional shots towards XMP-142, following an extended delay to remedy problems in FCPC. These shots were unable to replicate the excellent results on 4/4/2016, due to an inability to achieve and/or sustain H-mode plasmas. This observation motivated the additional morning He GDC on following days, as noted above.

The morning of Wednesday 4/6/2016 was dedicated to running XMP-147 (Improve L-mode Fiducial). This activity involved moving the start of the ISOFLUX X-point control phase earlier so that the X-point feedback control could be used to determine the time of diverting and the early evolution of the inner gap. The approach was successful in reducing and sometimes eliminating vertical oscillations at the time of diverting that had been observed in earlier shots. The improved control transitions will make the scenario easier to use in future L-mode XMPs and XPs, and will be applied to H-mode scenario development. The shots in XMP-147 were also used to tune aspects of the controlled ramp-down of the plasma current (beam modulation, plasma current ramp rate, vertical control, etc.), resulting in a successful disruption free ramp-down (204155). Finally, the flattop of the XMP-147 shots was used to try aspects of XMP-146 (n=2,3 error field correction) in piggyback. Changes to the plasma rotation and density were observed as n=2 fields were applied, and analysis is ongoing. Operations were terminated at ~12:00 due to a leak in a cooling water flow switch for a vacuum ruffing pump in the NSTX-U Test Cell.

Operations resumed at ~1:30 on 4/7/2016, following final recovery from the water leak. The first shots of the day finished the present XMP-147 activities using a 1 MW L-mode plasma, demonstrating both upper and lower biasing of the plasma, from the time of diverting through the entire flat-top. Shots were then taken towards XMP-142. These shots used the H-mode gas fuelling, beam power, and shape evolution recipe developed on 4/4/2016, and combined them with the improved shape control developed under XMP-147. These resulted in a 1 second, 900 kA H-mode plasma (shot 204172) with performance largely comparable to discharges on 4/4, but with improved shape control capabilities.

The most of the run day on 4/8/2016 was dedicated to XMP-142. Some progress was made in improving the vertical position control in these H-mode plasmas, but difficult in achieving and sustaining H-mode hindered progress. The final two hours of the day were dedicated to XMP-148 (BEAST Validation, S. Kaye & R. Bell). These shots used only beamline #1, and were able to collect good data for the CHERS diagnostic and for validation TRANSP calculations.

Engineering Operations (A. von Halle, P. Titus)

NSTX-U plasma operations continued this past week after a weekend vessel boronization. Procedures and training have been updated to allow for shorter boronizations which are now being performed on the latter parts of the second shifts. This week's experiments in L-mode plasmas were effective in establishing early X-point control, and in fine tuning plasma/beam injection ramp-down performance. Positive control of plasma shape, fueling, and neutral beam injection helped to achieve reliable H-mode access at record plasma currents and pulse lengths. All six neutral beam ion sources were actively conditioned this week with improvements in both operating levels and reliability. We are planning on an Motional

Stark Effect (MSE) diagnostic calibration when NB1A is available for reliable 90kV operation. Low Voltage excitation tests are nearing completion on RF source #5. This is one of the last corrective actions related to the crowbar circuit failure, and all six of the RF sources should be ready to support HHFW antenna conditioning following the completion AC Power switchyard work. Experimental operations had to be interrupted on Wednesday to address a cooling water leak at a failed flow switch on a vacuum roughing pump (away from the vessel). Operations were able to resume on Thursday.

A two week maintenance period will start this coming week. Access to the NSTX-U Test Cell is available for approved work.