Research tool development for high performance steady-state plasma operations in the National Spherical Torus Experiment*

Masayuki Ono
Princeton Plasma Physics Laboratory, Princeton, N.J., USA
On behalf of the NSTX Team

Relevant Subject Areas: A.1, A.4, A.5, C, and D.

Achievement of high-performance, steady-state plasmas is an important goal of the spherical torus (ST) research. The Five Year Plan for NSTX proposed in 2003 calls for the sustainment of a high-beta, high-confinement plasma for a duration much longer than the current relaxation time to achieve "physics steady-state". Many research tools are being implemented to support this goal. A fast-response plasma control system enabled operation with high elongation, up to 2.6, and a triangularity up to 0.6. New poloidal field coils are now being installed to produce equilibria with higher triangularity, up to 0.8, at elongation ~2.5 as envisaged in the plan. To allow steady-state operation near the ideal MHD β-limits, a six-element array of resistive wall mode (RWM) coils powered by fast-response power supplies is now being readied. Experiments with one pair of these coils during the past campaign already yielded a number of important results for the control of locked modes and plasma rotation, and in the physics of the RWM. Control tools for the pressure and current profiles are also required to achieve the NSTX goals. High-harmonic fast-wave (HHFW) heating and current drive can provide the non-inductive current ramp-up and generate the bootstrap current needed for steady-state operation. During the past year, the HHFW-induced H-mode regime has been extended to higher current ~ 800 kA. The HHFW heating efficiency appears to depend sensitively on the antenna phasing which may be related to the observed edge ion heating, possibly driven by parametric instabilities. To provide current profile control in the outer region, an electron Bernstein wave (EBW) current drive scheme is being developed. The concept involves selectively coupling power to the passing electrons, thereby trapping them (the "Ohkawa" effect). In the ST, this can produce particularly high current drive efficiency at large minor radius where the trapped particle fraction is large. Measurements of thermal EBW emission from the NSTX plasma indicate an encouraging trend of relatively high coupling efficiency for elliptically polarized EBW. To achieve long-pulse discharges, the particle inventory must also be managed carefully. High temperature bakeout and between-shots helium glow are main tools now being used on NSTX. A 400-barrel lithium pellet injector has recently been commissioned which will be used to investigate the effect of lithium wall coating on particle inventory and recycling. A supersonic gas injector has also been commissioned and initial data suggests an improvement in the particle fueling efficiency, compared to standard gas puffing, thereby reducing the total particle inventory. For an attractive ST reactor, a complete elimination of the ohmic solenoid is essential and two promising solenoid-free start-up methods are being tested on NSTX. First, a new technique known as transient coaxial helicity injection (CHI) is being tested and has produced toroidal plasma current with very high efficiency. Second, an additional outer PF coil pair was energized to explore solenoid-free start-up using only the outer PF coils. Many plasma diagnostics have been and continue to be implemented on NSTX for profile measurement [multi-pulse Thomson scattering, charge-exchange recombination spectroscopy, motional Stark effect, far-infrared laser interferometer and polarimeter, reflectometers] and for fluctuation information [core fluctuation reflectometers, fast (500 kHz) tangential x-ray camera, and the higher resolution X-ray camera]. To explore short-wavelength fluctuations thought to be responsible for electron energy transport, a novel high-k tangential microwave scattering system is being installed. In the boundary area, far infrared cameras measure power flow to the divertor and a fast reciprocating edge probe, divertor tile probes, and Doppler spectroscopy provide important edge/scrape-off-layer profile information. Ultra-fast imaging of the edge region has revealed highly non-linear behavior, including "blobs", ELMs and L-H transitions.

*This work supported by DoE Contract No. DE-AC02-76CH03073.