EX-W

Demonstration of 200 kA CHI Startup Current Coupling to Transformer Drive on NSTX

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Toroidal magnetic configurations based on the tokamak concept might be simplified and their cost reduced if the central solenoid, which is a large engineering component in conventional tokamak reactor designs could be eliminated. Solenoid-free startup is a critical issue for future spherical torii (STs) designs, as the central-axis region is limited both physically and by the nuclear environment.

Transient Coaxial Helicity Injection (CHI) initiated discharges in NSTX [R. Raman *et al*., *Nuc. Fus.*, **49**, 065006 (2009)] have increased the peak currents achieved to up to 300 kA for the first time, and when these discharges are coupled to induction, up to 200 kA additional current over inductive-only operation has been produced. CHI in NSTX has shown to be energetically quite efficient, producing a plasma current of about 10 A/Joule of capacitor bank energy. In addition, for the first time, the CHI-produced toroidal current that couples to induction continues to increase with the energy supplied by the CHI power supply at otherwise similar values of the injector flux, indicating the potential for substantial current generation capability by CHI in NSTX and in future toroidal devices.

Previously, up to 50 kA of toroidal plasma current produced by the non-inductive method of CHI was successfully coupled to inductive ramp-up in NSTX. However, in these experiments, the CHI current that could be successfully coupled was limited by impurity production in the divertor region and the occurrence of absorber arcs (*i.e.* parasitic discharges across the insulating gap in the upper divertor). In FY2009, extensive conditioning of the divertor plates that serve as the electrodes for the CHI discharge greatly reduced impurity production during CHI. Further, by energizing, for the first time, the axisymmetric absorber field-nulling coils [T.R. Jarboe, *Fus. Tech.* **15**, 7 (1989)] located near the upper divertor in NSTX, the absorber arcs could be delayed or suppressed. In addition to these combined improvements, the use of lithium evaporative coatings using the LiTER system [H.W. Kugel *et al*., *J. Nuc. Mat.*, **390-391**, 1 (2009)] increased the current at the hand-off from CHI to induction to nearly 200 kA. Furthermore, later in the inductive ramp-up, the discharges with CHI applied reached significantly higher plasma current than discharges with only the inductive loop voltage applied.

These results represent a factor of four improvement in the magnitude of current that was ramped up by induction, a factor of three increase in the initial start-up current, and the first results demonstrating flux savings in NSTX. The CHI started discharge, when coupled to induction produces about 60% more current than the comparison inductive-only case. These results confirm that CHI could be an important tool for non-inductive start-up in next-step STs.