COAXIAL HELICITY INJECTION CURRENT DRIVE ON THE NSTX AND HIT–II SPHERICAL TORII

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Spherical torii require non-inductive current drive for startup and steady-state sustainment. Coaxial Helicity Injection (CHI) is used to produce and sustain non-inductive discharges with over 200 kA toroidal plasma current in both the National Spherical Torus Experiment (NSTX, $R = 0.85$ m, $a = 0.67$ m, $B_o = 0.3$ T) at the Princeton Plasma Physics Laboratory [1,2] and the Helicity Injected Torus experiment (HIT-II, $R = 0.3$ m, $a = 0.2$ m, $B_o = 0.5$ T) at the University of Washington [3].

HIT–II Results HIT–II produces CHI plasmas with toroidal currents exceeding 200 kA for several ms, with $J_{\mathrm{tor}} = 0.8$ MA/m^2. HIT–II has 28 close-fitting poloidal field coils that use active feedback control in real time to provide extremely flexible flux boundary conditions. Flux boundary conditions can be programmed to optimize the HIT–II plasma boundary, and also to explore "NSTX-like" conditions. A (non-symmetric) double-null divertor configuration is found to produce high-quality discharges with low gas fill pressures, shown in Fig. 1. These high-quality discharges are characterized by a rotating

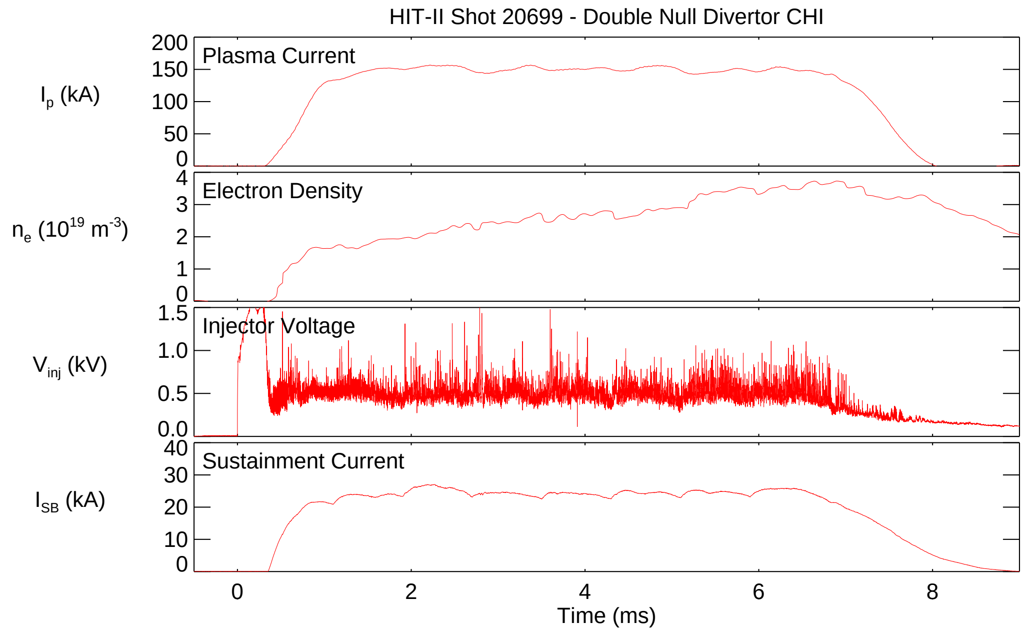

Figure 1: CHI only discharge in HIT–II in DND configuration.

n=1 distortion near the outer midplane, and symmetric poloidal fields above and below the midplane. The n=1 oscillation exhibits the same pitch as the edge magnetic field lines.

NSTX Results In NSTX, 260 kA peak toroidal currents (toroidal current density $J_{\rm tor} = 0.26$ MA/m^2) are obtained with CHI, with lower current pulses driven for up to 200 ms [4]. A pulse with I_p over 150 kA for 50 ms is given in Fig. 2. Recent analysis has shown the existence of frequent, though intermittent, several-cycle bursts of n=1 rotating distortions. This n=1 rotating distortion has features similar to those seen in high-performance CHI HIT–II discharges: 1) observed only on the outboard side, 2) rotates in the direction of $\mathbf{E} \times \mathbf{B}$, and 3) rotation frequency in the range of 10 – 60 kHz. Incomplete data from an outboard poloidal probe array (3 probes with six degrees of separation) show some poloidal structure, though the m number is not clear.

NSTX has also added CHI to Ohmic discharges, as shown on an expanded time scale in Fig. 3. A divertor (injector flux) is produced, starting at 140 ms, during a 600 kA Ohmic discharge. A low level of CHI current is seen when this injector flux is being added, notably before the CHI voltage is applied at 185

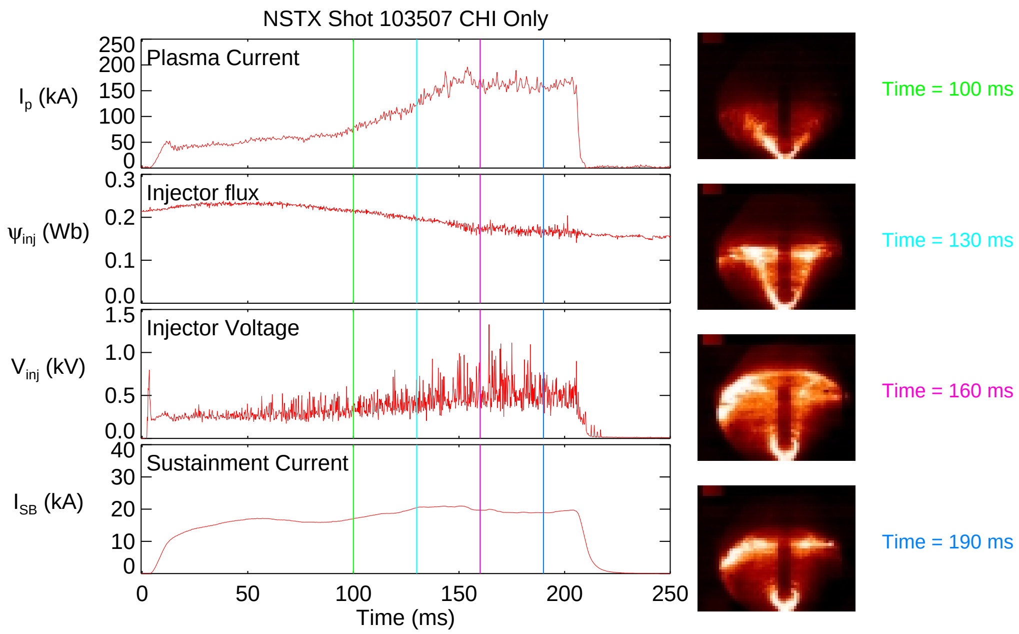

Figure 2: CHI only discharge in NSTX. Vertical lines correspond to the fast camera images on the right.

ms. The CHI current does not increase above a few hundred amperes until an internal reconnection event around 201 ms. CHI current increases to 4 kA for about 10 ms. Another IRE occurs later at 240 ms.

Discussion The behaviour of the n=1 rotating oscillation in NSTX differs from that of HIT–II in that the n=1 in NSTX occurs in intermittent bursts of several cycles each. High-performance CHI discharges in HIT–II have continuous n=1, perhaps suggesting that NSTX is on the "verge" of producing continuous n=1 rotating oscillations. Future NSTX experiments will have optimization of the n=1 oscillations as an operating goal.

When CHI voltage is applied to an NSTX Ohmic plasma, significant CHI current is seen after an IRE. The typical plasma current peak and decay following an IRE appears to be modified by the CHI current. Note in Fig. 3 the plasma current remains higher following the IRE at 201 ms (with CHI current) than the IRE at 240 ms (no CHI current). The plasma current also has "features" coincident with those found on CHI current and voltage traces. This may be initial evidence of enhancement of I_p by CHI in NSTX.

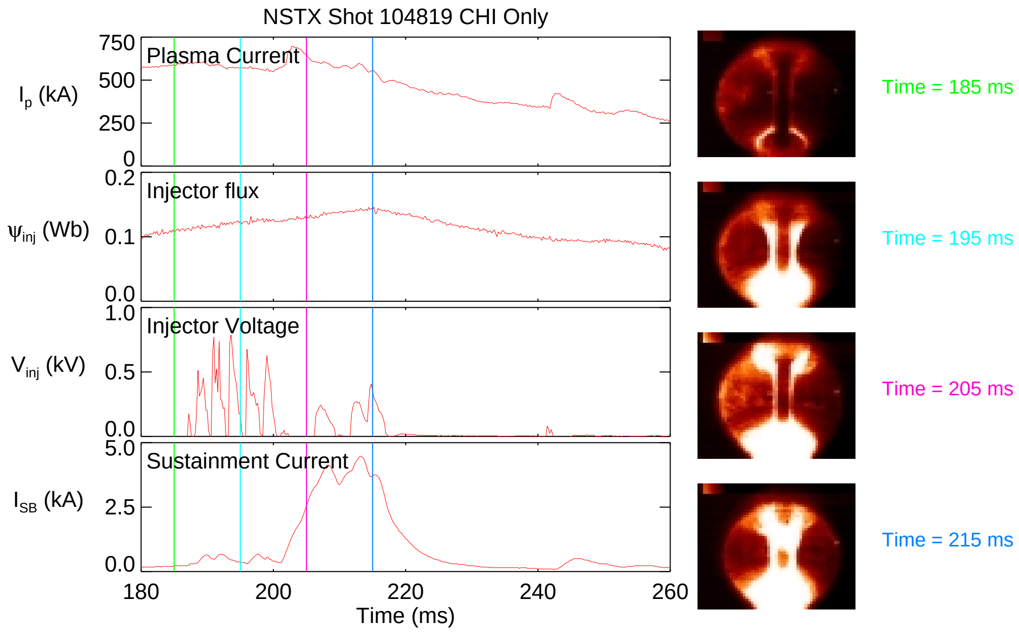

Figure 3: Addition of CHI edge current to an Ohmic discharge (expanded time scale). Vertical lines correspond to the fast camera images on the right.

Summary CHI has produced over 200 kA in both HIT–II and NSTX. Rotating n=1 oscillations have been observed in HIT–II (continuously) and in NSTX (in frequent several-cycle bursts). In NSTX, the oscillations have similar characteristics as those seen in HIT–II [3]. These oscillations are strongly correlated with high-performance discharges in HIT–II. CHI has been applied to Ohmic plasmas in NSTX with no deleterious effects. Plasma current may be sustained by the edge CHI current. These results bode well for future CHI studies on NSTX.

1. M. Ono and the NSTX-Team, *Nuc. Fusion*, 40:557, 2000.

2. S. M. Kaye and the NSTX-Team, *Phys. of Plasmas*, (**8**) 5:1977, 2001.

3. T. R. Jarboe *et al.*, *Phys. of Plasmas*, 5:1807, 1998.

4. R. Raman *et al.*, *Plasma Phys. Cont. Fus.*, (**43**) 3:305, 2001.