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Transient CHI Startup

Solenoid Free Plasma Startup

R. Raman, T.R. Jarboe, B.A. Nelson

University, of Washington, Seattle, WA, USA

M.G. Bell, D. Mueller et al.,

Princeton Plasma Physics Laboratory

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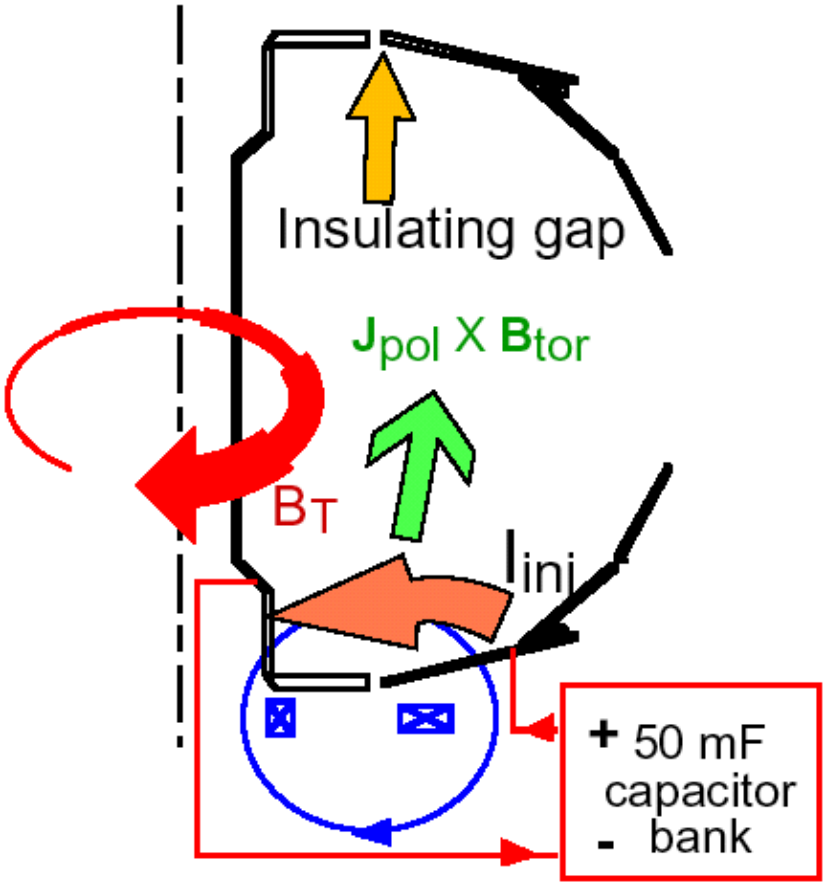
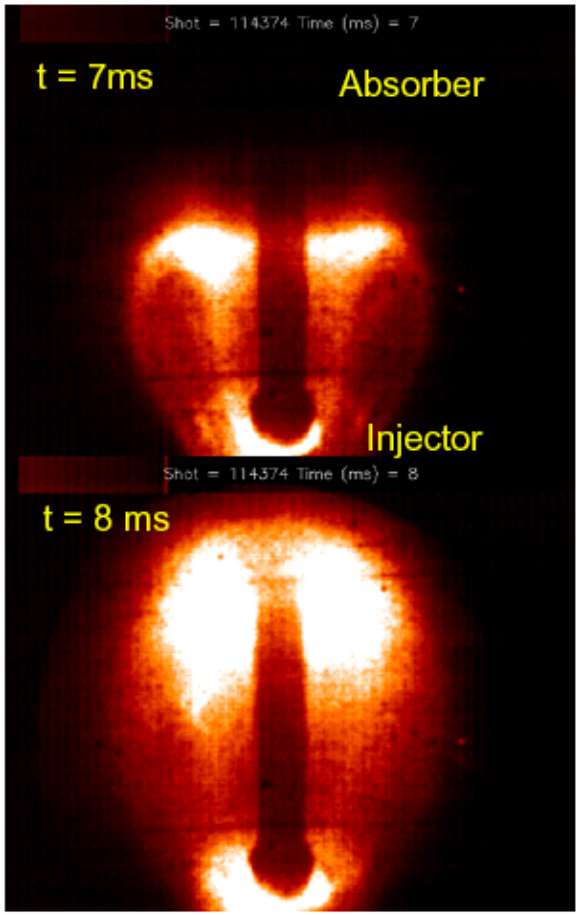
Outline

- Summary of Fy04 results
- Power supply requirements
- Improvements needed for Fy05
- Modifications to XP406 for Fy05

Implementation of Transient CHI





Expect axisymmetric reconnection at the injector to result in formation of closed flux surfaces

Fast camera: C. Bush (ORNL)

Injector flux and gas pressure scanned at Vcap ~ 1kV

- PF1B coil current (measure of Ψ_{inj}) varied from 3.3 to 9.4kA

At high injector flux:

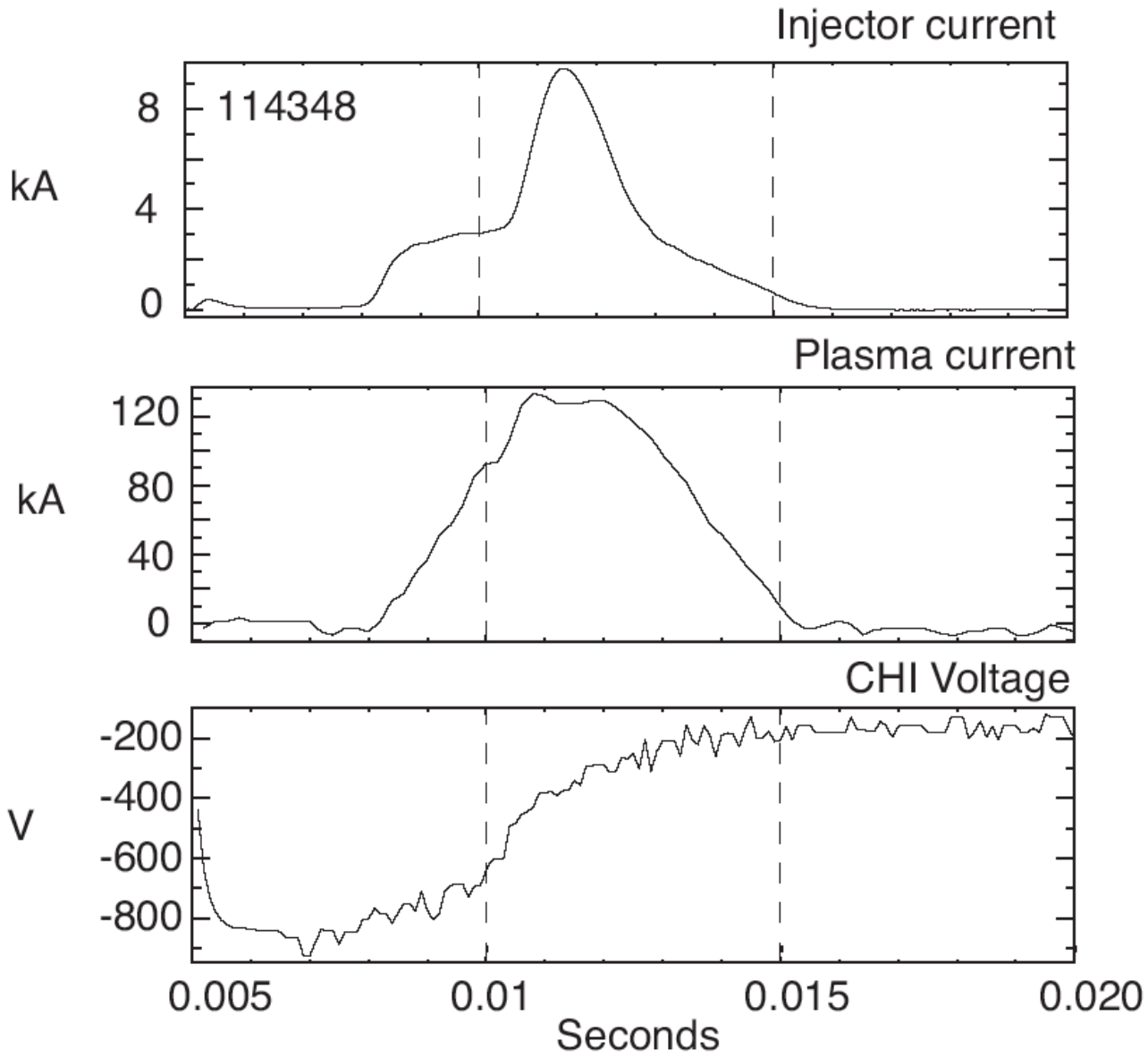
- No bubble burst at I_PF1B of 9.4kA (even at I_{inj} ~ 20kA)
- High gas pressures needed for I_PF1B ≥ 6.5kA (1 x 10^{-3} Torr)
- Low current multiplication in high injector flux discharges

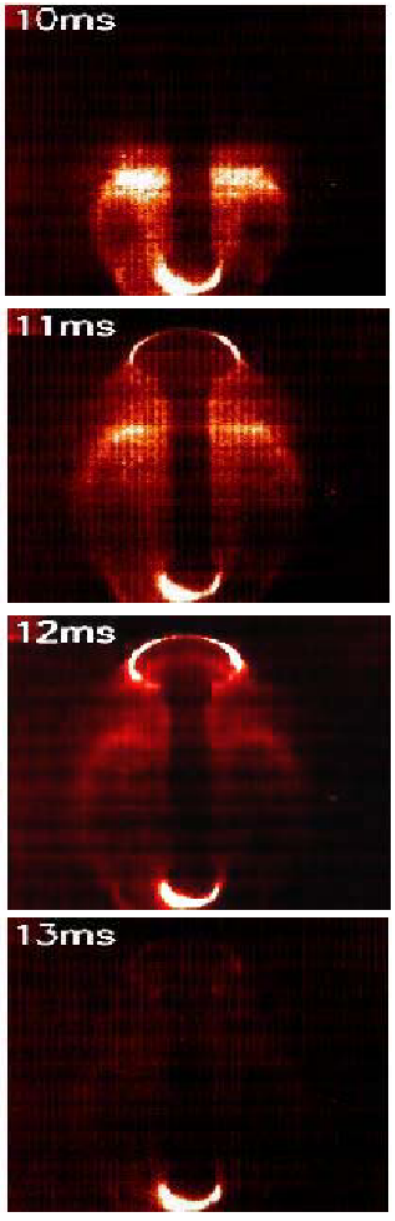
At low injector flux:

- For I_PF1B < 4kA, current multiplication up to 40 (I_{inj} ~ 4kA)
- Allowed operation at lowest fill pressures (2 x 10^{-4} Torr)

- Operated in 1, 2 capacitor configuration to study breakdown
- Operated in 4 and 7 capacitor configuration to increase energy

Initial transient CHI discharge in NSTX





Current persistence not yet observed

Capacitor bank requirements for Transient CHI

Bubble burst current that is equal I_{inj}

- $I_{inj} \propto \Psi^2_{inj}/\Psi_{toroidal}$ (easily met)

Volt-seconds to replace the toroidal flux

- For $\Psi_{toroidal}$ 600 mWb, at ~500V need ~1.2ms just for current rampup - *OK, but will improve at higher voltage*

Energy for peak toroidal current ($LI^2/2$, L=1μH)

- Maximum possible Ip (at 17.5 kJ) ~ 190 kA (achieved ~ 140 kA)
- *Need to increase Ecap*

Energy for ionization of all injected gas and heating to 20eV (~50eV/D)

- At lowest gas pressure 16.8 Torr.L injected, need ~21kJ just to ionize and heat – *Need to reduce total injected gas*

Equilibrium and pre-ionization requirements

The equilibrium coil currents provide the following:

- An equilibrium for the target closed current when the open field line current is back to zero
- The initial injector flux with a narrow enough footprint and high enough value so that λ_{inj} is higher than the target λ_{ST}.

$$\lambda_{inj} = \mu_o I_{inj} / \Psi_{inj} \quad \lambda_{ST} = \mu_o I_p / \Psi_{toroidal}$$

Gas puff provides the following:

- Just enough gas for breakdown (need $j/n > 10^{-14}$Am, Greenwald)
- Highest density at the injector

ECH provides the following:

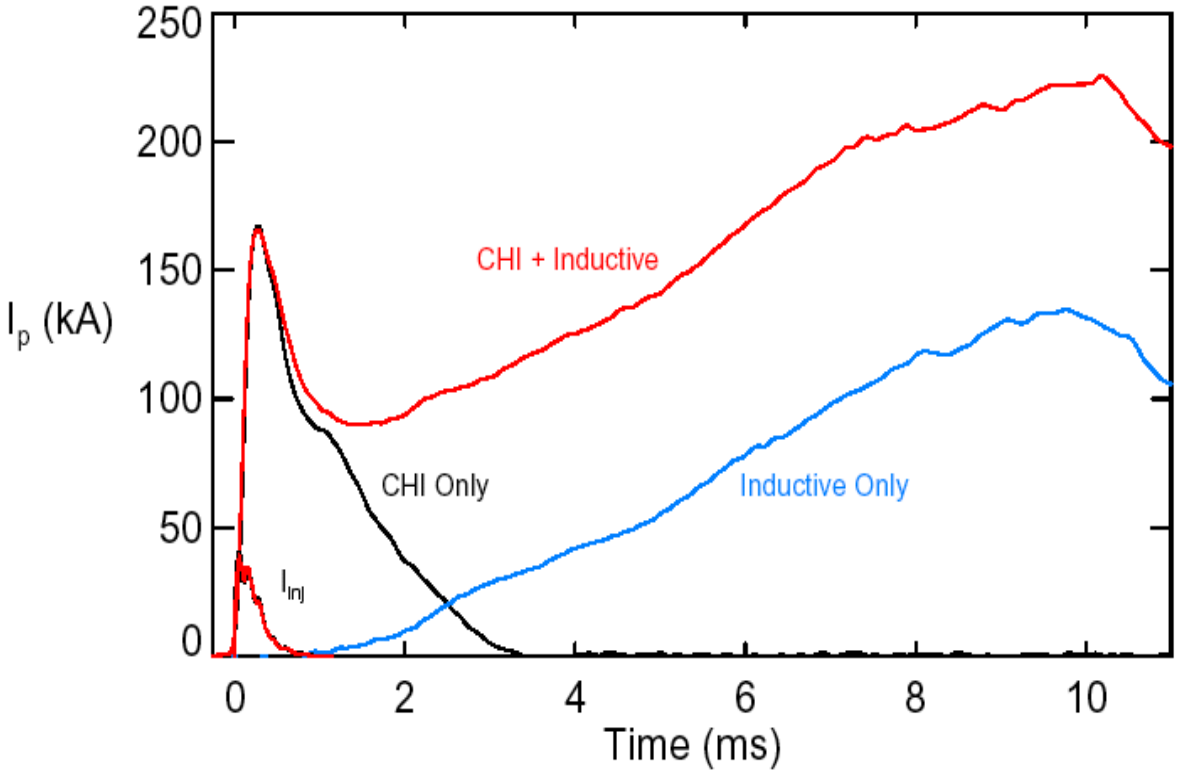
- Pre-ionization for rapid and repeatable breakdown
- Initial plasma in the injector gap

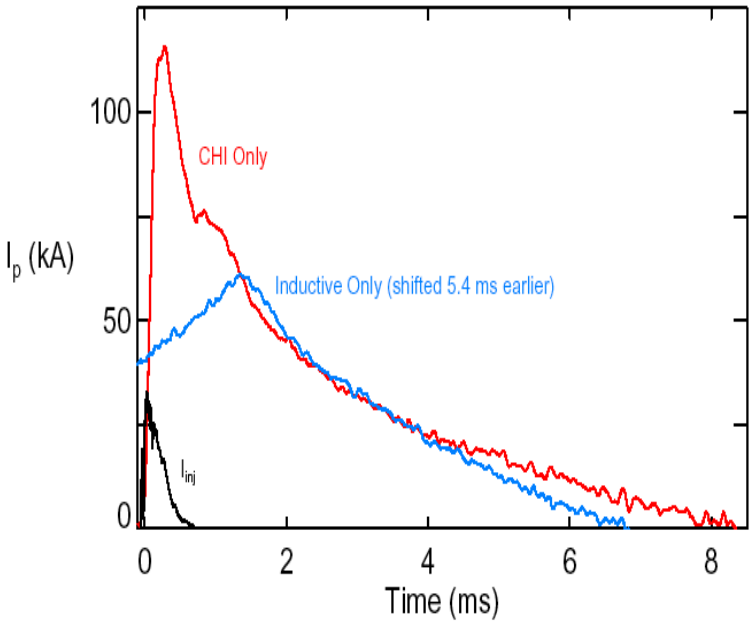
Capacitor bank for Transient CHI commissioned

- Maximum rating:
  50 mF (10 caps), 2 kV
- Operated reliably at up to 1kV (7 caps, 17.5 kJ)
- Produced reliable breakdown at ~ 1/ 3rd the previous gas pressure
  - Constant voltage application allowed more precise synchonization with gas injection
  - HHFW used for Pi assist

A CHI startup plasma has sufficient quality to be ramped up by induction. The startup discharge was produced with CHI followed by relaxation on HIT-II.

HIT-II





Both discharges (CHI + induction and induction-only) have identical loop voltage programming

The CHI discharge has the same current decay time as the inductively produced discharge

Required NSTX machine improvements

- Capability for gas injection with ECH Pi beneath the lower divertor plates

- Hi-pot of the NSTX inner vessel to 7kV to enable higher voltage CHI operation

- Inspection of and replacing the ceramic bolt insulators (if necessary)

- Upgrading the CHI cap bank, snubber and MOV's for 2kV capability

- Energizing the absorber PF coils

Improvements to XP406

- Use PF1AL to further reduce the flux footprint
- Use PF4 to pull the CHI discharge closer to the passive plates to stabilize it and to reduce the incidence of absorber arcs
- Operate with the new gas injection system below the lower divertor plates and with ECH assist to reduce the total injected gas by about 4 to 8
- Increase the cap bank voltage in steps (1.5kV initially)
- If the absorber PF coils are available, use them to make the absorber more robust.