BP9.00071 POLOIDAL FLUX FROM COAXIAL HELICITY INJECTION IN NSTX*

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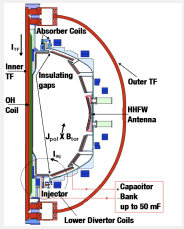
* *Work supported by US DOE Contract No.* DE-AC02-09-CH11466, DE-FG03-96ER54361, and DE-AC52-07NA27344

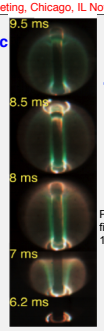
Supported by U.S. DEPARTMENT OF ENERGY Office of Science

Presented at the 52nd APS-DPP Meeting, Chicago, IL Nov. 8-12, 2010

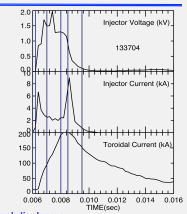
NSTX is designed to permit coaxial helicity injection



The limited space for the center column in an ST necessitates alternative start-up and current drive.



Axisymmetric reconnection leads to formation of closed flux surfaces

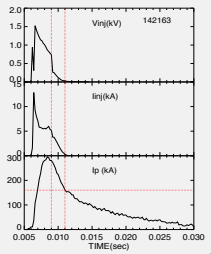


Plasma nearly fills vessel in 1.5 ms

Starts as helical discharge following the magnetic field J_{pol} X B_{tor} is up into vessel

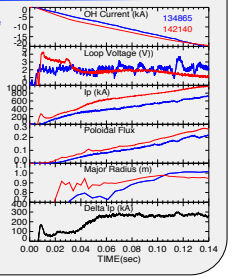
Between 160 and 280 kA of plasma current is produced on closed field lines with CHI

- CHI discharge using 60 mF at 1.46 kV.
- A crowbar circuit is used to interrupt the injector at 9 ms and reduces the applied voltage then.
- The injector current decays after the crowbar is fired and is gone at 11 ms.
- The toroidal current is 160 and 280 kA at 9 and 11 ms respectively.
- The relatively long decay time of the toroidal current is achieved only when impurities are controlled.



Poloidal flux is larger in CHI initiated discharges

- An increase in I_p of 200 to 300 kA is observed in the CHI initiated discharge shown in red compared to the inductive discharge in blue.
- The CHI initiated discharge shown in red used 30 mF of capacitance at 1.65 kV.
- The discharge in blue is an inductively driven discharge that is among those on NSTX that reached 1 MA with the lowest ohmic flux.
- The poloidal flux is $I_p \cdot R_p \cdot l_i \cdot \mu_0/2$.
- The internal inductance (l_i) and plasma major radius (R_p) are from EFIT analysis.
- Both shots had the benefit of neutral beam injection.



Demonstrated additional poloidal flux with CHI

- **CHI discharges with low levels of low Z impurity radiation can be coupled to inductive ramp-up**
  - Lithium evaporative coating (LITER) reduces low Z impurities
  - Buffer flux prevents plasma from reaching the absorber gap and causing an absorber arc
- **CHI start-up plasmas with current of over 300 kA have been ramped inductively to produce a plasma current increase of over 250kA compared to inductively driven discharges.**
- **Goal use the full 50 mF injector capacitance and lengthen period of injector current while avoiding arcs and keeping impurities low**

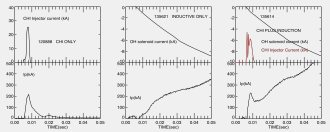
CHI Scaling

- From helicity and energy conservation, for a Taylor minimum energy state $\lambda_{inj} \geq \lambda_{tok}$
  - $\lambda_{inj} = \mu_0 I_{inj}/\psi_{inj}$; ψ_{inj} = poloidal injector flux
  - $\lambda_{tok} = \mu_0 I_p/\psi_{tok}$: ψ_{tok} = toroidal flux in vessel
- $I_p \leq I_{inj}(\psi_{tok} / \psi_{inj})$
- For similar B_T NSTX has 10 times ψ_{tok} of HIT-II
- Bubble burst condition:

  $I_{inj} = 2\ \psi_{inj}^2/(\mu_0^2 d^2 I_{TF})$
  - For HIT-II, ψ_{inj} = 8mWb, d = 8 cm is flux footprint width
  - For NSTX, ψ_{inj} = 10mWb, d = 16 cm is flux footprint width
  - $I_{inj} \geq 15$ kA for HIT-II, I_{inj} <10 kA for NSTX
- NSTX has achieved $I_p > 60\ I_{inj}$
  - (HIT-II - $I_p > 6\ I_{inj}$)

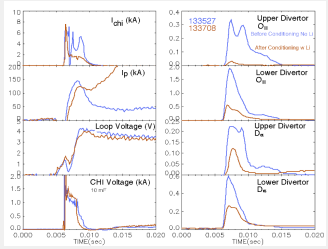
Add inductive drive to CHI formed plasma

CHI START-UP ✚ INDUCTIVE RAMP ➡ HIGHER CURRENT



- The goal is to use CHI to establish a discharge that can be ramped up by other means
- Just as in purely inductive discharges, it is necessary to limit oxygen and carbon impurities to permit inductive ramp-up
- The divertor plates at the top and bottom of the machine can be sources of carbon and oxygen.
- Avoiding unwanted arcs at the top of the machine can limit impurities from that area
- Conditioning, Li-coating and use of metal electrodes can limit the influx of carbon and oxygen from the lower divertor

It is necessary to reduce Low-Z Impurities to achieve coupling of CHI to ohmic ramp-up

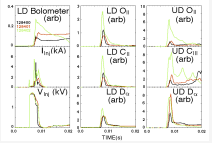


- LD is view of Lower Diverter, UD is view of Upper Diverter
- No discharges with high O_{II} emission coupled to inductive ramp-up.
- The lower divertor plates) were conditioned with long (0.4 s) injector discharges using a 1 kV rectifier ~9 kA .
- The discharge in red was taken after the conditioning campaign and with evaporation of Li between discharges
  - –Li evaporation has been shown to reduce oxygen in NSTX
  - –No CHI discharges with low oxygen were produced prior to conditioning and LI evaporation

More of the available injector capacitance on NSTX must be used to produce higher flux

2008 and earlier

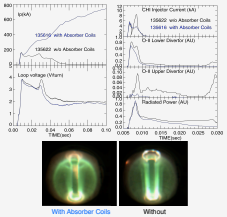
- Little or no flux increased with CHI initiation.
- Suspected cause was low Z impurity radiation.
- Radiation higher with more injector energy



- The CHI capacitance used is indicated by the color.
  - 5 mF (black), 10 mF (red) and 15 mF (green)
- Need to reduce low-Z impurities

2009

- Approximately 110 kA of additional plasma current was observed with CHI initiation
- Result of electrode conditioning, Li coating and use of absorber coils to avoid or reduce arcs using up to 15 mF



- Only the discharge without the arc couples to inductive ramp-up

2010

- Over 250 kA of additional plasma current was observed with CHI initiation
- Result of Li coating, and use of absorber coils to avoid or reduce arcs
- Used up to 35 mF without arcs, need to reduce impurity radiation fu