CONTACT: Roger Raman
Phone: (609) 243-2855

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Novel Method Developed for Generating Plasma Current in Tokamaks

Generating plasma current in tokamaks using Coaxial Helicity Injection (CHI) could lead to smaller, more economical fusion power plants.

PHILADELPHIA, Pennsylvania, Oct. 30, 2006 – Researchers at the Princeton Plasma Physics Laboratory have successfully used Coaxial Helicity Injection (CHI) to generate plasma current at the National Spherical Torus Experiment (NSTX) fusion experiment. While the CHI method has previously been studied in smaller experiments, such as the Helicity Injected Tokamak (HIT-II) at the University of Washington, the results from the much larger NSTX demonstrate the exciting potential of this method on a scale much closer to that of a fusion reactor.

Until now, most tokamak plasma confinement devices have relied on a solenoid through the center of the device to induce the initial startup plasma current needed for confinement. The spherical torus is a specialized form of the tokamak in which the hole through the center of the doughnut-shaped plasma is made very small. This saves space and allows the externally produced magnetic field to be utilized much more efficiently than in a conventional tokamak. Little room is left for a solenoid, however, so future reactors based on the spherical torus will require an alternate method such as CHI for starting the plasma current.

The generation of the plasma current by CHI involves a process called magnetic reconnection, which is also involved in the eruption of solar flares on the surface of the sun. The process of magnetic reconnection leads to the formation of a magnetic "bubble," in much the same way as blowing a soap bubble stretches a soap film sufficiently so that it detaches from the ring and reconnects to form a bubble. In magnetic reconnection, the magnetic "film" is initially attached to the edges of a gap with opposite polarity, like the north and south poles of a magnet. Once adequately stretched the magnetic field has a tendency to attract and reconnect, leading to the formation of a doughnut-shaped magnetic bubble.

This process of reconnection has been experimentally controlled in NSTX to allow this potentially unstable phenomenon to reorganize the magnetic field lines to form closed, nested magnetic surfaces in the shape of a doughnut carrying a plasma current up to 160,000 Ampères. This is a world record for non-inductive closed-flux current generation, and demonstrates the high current capability of this method.

Detailed Information

The process of CHI in NSTX and a summary of recent results are illustrated in Figures 1 and 2. To generate plasma current by this method, a special combination of poloidal and toroidal magnetic fields is initially produced using conventional magnetic coils located outside the NSTX vacuum vessel. After puffing a small amount of deuterium gas into the vacuum vessel, a voltage of up 2000 Volts is then applied between insulated coaxial electrodes in the bottom of the vacuum vessel. The gas breaks down into a plasma and begins to conduct electrical current along the magnetic field lines joining the electrodes. This causes the magnetic field lines to stretch, carrying an expanding bubble of plasma into the vacuum chamber. When this plasma fills the chamber, the injected current is rapidly decreased, causing the magnetic field lines to disconnect from the external coils and reconnect to form the closed field line configuration. In NSTX all of this happens within 5 milliseconds. It is particularly important that in the recent NSTX experiments, the ratio of the toroidal plasma current obtained to the current injected by the electrodes exceeded 60. Comparison with the earlier results from the HIT experiment, suggests that even higher current multiplication can be obtained in future larger spherical torus devices. The method is also applicable to tokamaks and could be used to simplify the design of a future fusion reactor.

CHI research on NSTX is a collaboration between researchers from the University of Washington and Princeton Plasma Physics Laboratory. This work is supported by US Department of Energy contracts DE-FG03-96ER5436, DE-FG03-99ER54519 and DE-AC02-76CH03073.

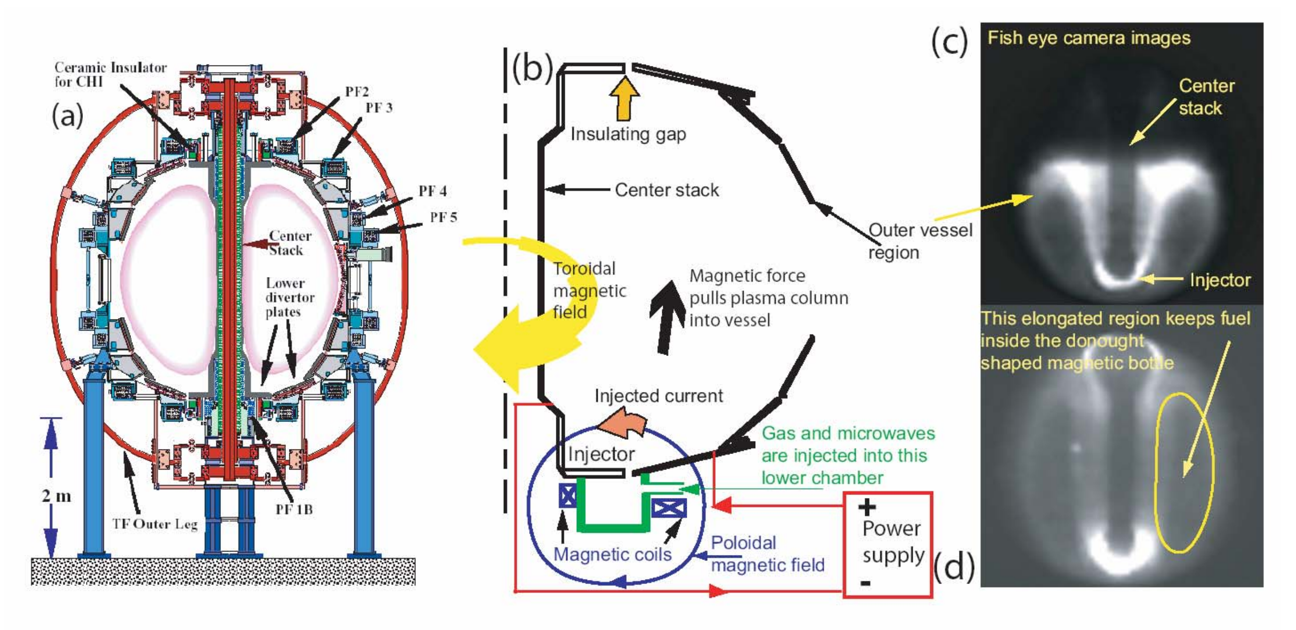

Figure 1: (a) NSTX machine layout showing the toroidal field coil in red and the poloidal field coils (labeled PF1 to 5), (b) simplified CHI schematic and (c, d) fast camera images of a CHI discharge inside NSTX.

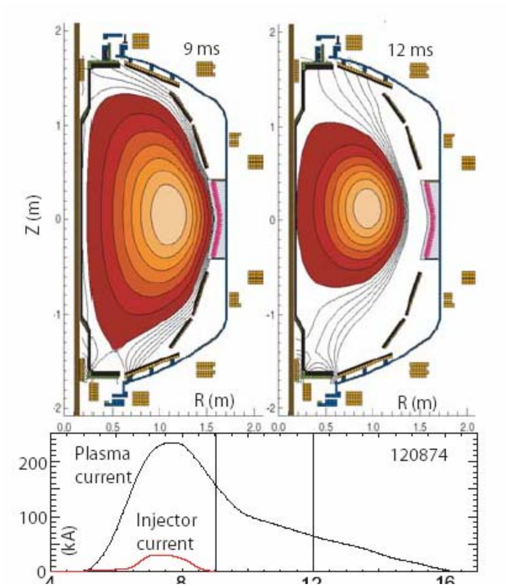

Figure 2: The measured magnetic fields for this discharge are used to reconstruct the shape of the plasma.

Contact

Roger Raman, University of Washington, rraman@pppl.gov

Abstract: BI1.00002

Solenoid-free Plasma Start-up in NSTX using Transient CHI

Invited Session BI1: Current Drive, Energetic Particles, and Steady State
10:00 AM–10:30 AM Monday, October 30, 2006
Philadelphia Marriott Downtown - Grand Salon ABF

Abstract: QP1.00004

NSTX Plasma Start-up using Transient CHI

Invited Session QP1: Poster Session VI: NSTX; C-Mod; Non-Neutral Plasmas; Acceleration and Heating in Space; Mini-Conf. on Interface Between Fluid and Kinectic Processes
2:00 PM–5:00 PM, Wednesday, November 1, 2006
Philadelphia Marriott Downtown - Franklin Hall AB