NSTX National Spherical Torus Experiment • PROGRAM HIGHLIGHTS

JANUARY 2001

High Harmonic Fast Wave Heating in NSTX

The National Spherical Torus Experiment (NSTX) is a low-aspect-ratio spherical torus with the scientific mission of demonstrating high-beta operation of plasmas for controlled fusion. While the toroidal field ranging 0.3 - 0.45 T, is a factor of 10 smaller than in usual tokamaks, NSTX has already demonstrated electron temperatures in excess of 1 keV, density in the high 10^{19} m^{-3} range with beta toroidal values in excess of 22%, (based on magnetic signals).

High-harmonic fast wave (HHFW) heating is a new approach to radio-frequency plasma heating, which has been selected as a core element of the NSTX research program. HHFW heating and current drive have two advantages:

(1) The utilization of established conventional fast-wave heating techniques at 25 -80 MHz in frequency;

(2) The prospect of driving plasma current without relying on an inductive solenoid, which is very limited in the NSTX low-aspect ratio geometry.

HHFW can provide efficient electron heating in a high-beta plasma, and with proper phasing of a multi-component antenna, it is also possible to drive current. The first HHFW heating demonstration was done at PPPL on the CDX-U spherical torus. NSTX is the first device of its size making use of HHFW. Implementation makes maximum use of the equipment left over from the Tokamak Fusion Test Reactor. The HHFW antenna assembly comprises 12 toroidally adjacent current elements, extending poloidally and centered on the horizontal mid-plane. The present frequency of operation is 30 MHz.

***NSTX RF juggernaut.** Joel Hosea, Dave Swain (ORNL), Ben LeBlanc, Randy Wilson, Bob Pinsker (GA) and Jon Menard stand in front of the HHFW transmission lines.*

The HHFW project on NSTX is a national effort utilizing talent as follows:

- **Oak Ridge National Laboratory** - RF launching technology/ coupling experiments;
- **General Atomics** - RF experiments;
- **Massachusetts Institute of Technology** - Modeling;
- **University of California, San Diego** - Modeling;
- **Princeton Plasma Physics Laboratory** - RF-plasma interactions/modeling/RF systems/ collaboration support.

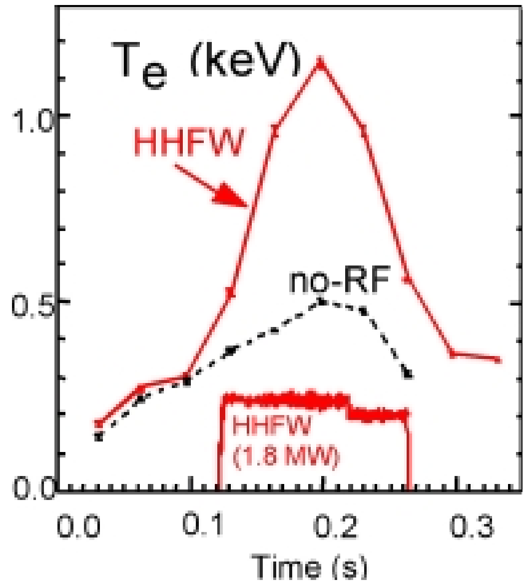

Figure 1: Time evolution of T_{e0} during HHFW (red) in helium plasma, reference no-RF plasma (black).

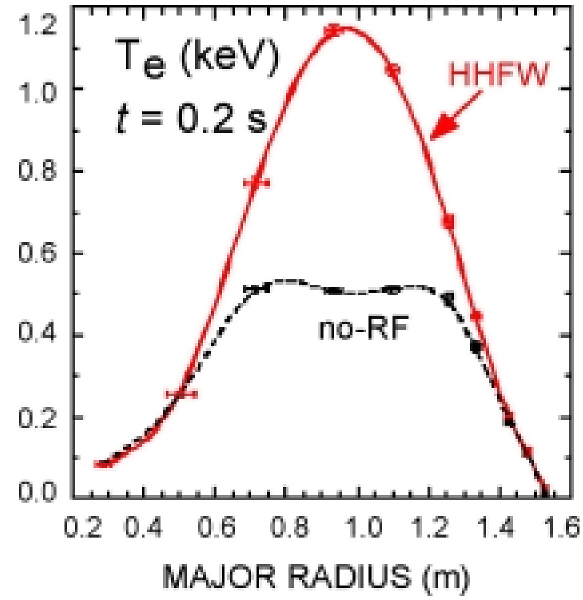

Figure 2: Profile of T_e at 0.2 s with HHFW heating (red) in helium plasma, reference no-RF plasma (black).

Initial investigations have proven successful. HHFW brought the electron temperature to above 1 keV in helium plasma. Figure 1 shows a time evolution of the central electron temperature, T_{e0}, measured by Thomson scattering, at every 33 ms, during a discharge where a 1.8-MW HHFW pulse is applied. The central temperature quickly rises, from 0.3 keV before the HHWF pulse, to 1.15 keV. A reference "no-RF" discharge is overlaid in Figure 1, and shows that in absence of

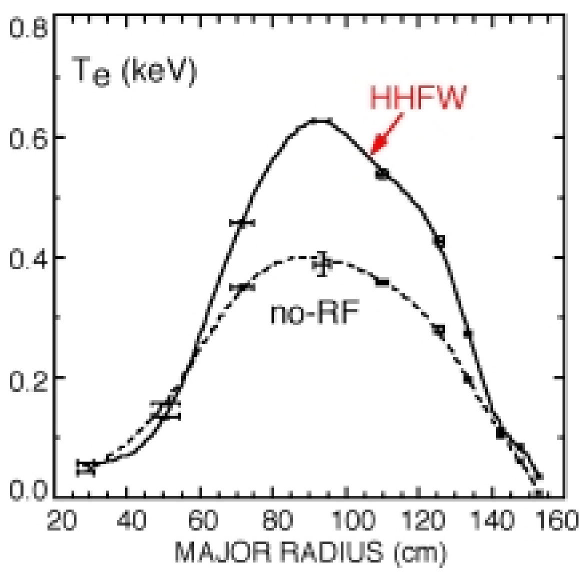

Figure 3: Profile of T_e at 0.2 s with HHFW heating (red) in deuterium plasma, reference no-RF plasma (black).

HHFW, the temperature rises to 0.5 keV. The more than doubling of T_{e0} occurs even if the loop voltage during HHFW heating is slightly lower (by 0.25 - 0.5 V) than during the no-RF plasma.

We can see in Figure 2 the electron temperature profiles at t = 0.2 s for the two discharges shown in Figure 1. The electron temperature increase occurs over a broad region in the plasma core.

In deuterium plasmas, HHFW was found less efficient with a T_{e0} increase of the order of 60% during a 2.5-MW HHFW pulse. Figure 3 shows that, as is the case for helium, the electron heating occurs over a wide fraction of the core region.

The lower HHFW heating efficiency in deuterium is being investigated. Explanations being sought include wave scattering caused by enhanced edge turbulence in deuterium plasmas and/or formation of a hydrogen high-energy population, which would drain some of the applied power.

Overall, these first NSTX HHFW heating results are very encouraging. Thomson scattering measurements have confirmed routine core plasma heating and validated the HHFW heating concept. Magnetically obtained measurements have corroborated the heating effect with an increase of the stored energy.

With the heating demonstration done, we will begin using the phasing capability of the antenna elements to launch directional waves to drive plasma current.