Title: New High Temperature Laboratory Plasmas to Explore the Science of Space Plasmas

During the recent experimental campaign with high power heating, researchers on the National Spherical Torus Experimental (NSTX) successfully confined high-temperature (i.e. low-collisionality) plasmas at high beta, a condition where the central plasma pressure approaching that of the confining magnetic field. While difficult to achieve in the laboratory, these conditions occur in many astrophysical and space plasmas [1]. Using a powerful neutral beam injection (NBI) system as well as an innovative radio-frequency (RF) heating technique, the core NSTX plasmas were heated to tens of millions of degrees Kelvin (both ions and electrons) [2]. The success of these heating techniques is a very good news for fusion concepts based on the spherical torus. In addition, this new laboratory plasma offers exciting prospects for investigating, in a well-diagnosed and controlled environment, such important physical processes as wave-particle interactions (waves giving the energy to particles and vice versa) relevant to space and solar plasmas. At high beta, the Alfvén wave velocity slows toward the ion thermal velocity, creating a condition conducive to these wave-particle interactions.

Compressional Alfvénwaves at multiples of the ion-cyclotron frequency are launched into the NSTX plasma by a twelve-element antenna array where the toroidal phase velocity of the waves is controlled by adjusting the relative phase of the antenna elements. The waves launched in this high beta condition can interact strongly with plasmas through a process similar to the ocean waves accelerating a surfboard. As shown in the figure, with application of 3.4 million watts of RF power, the central electron temperature in NSTX rises continuously from about 2 million degrees Kelvin in the initial resistively heated phase to near 40 million degrees Kelvin (a 20 fold increase). These waves were observed to also accelerate energetic NBI ions at multiple ion-cyclotron frequencies [4]. These wave-particle interaction processes may be relevant to the anomalous electron heating observed in the solar corona and to a possible acceleration mechanism for creating energetic ion populations recently observed in the solar wind.

In another series of experiments with NBI, the creation of a substantial population of energetic ions with velocities much faster than the Alfvén wave phase velocity excited a rich variety of Alfvén waves, both shear and compressional, [5]. This type of wave-particle excitation/absorption process could, for example, explain the mystery of the large corona ion temperature observed by the NASA TRACE satellite [6].

[1] S. Sabbaugh et al., invited paper BI1.003.
[2] R. Bell et al., invited paper LI1.002.
[3] J. R. Wilson et al., oral presentation GO1.001.
[4] A. Rosenberg et al., poster presentation GP1.010
[5] E. Fredrickson et al., invited paper LI1.003.
[6] R. White et al., invited paper FI1.006.

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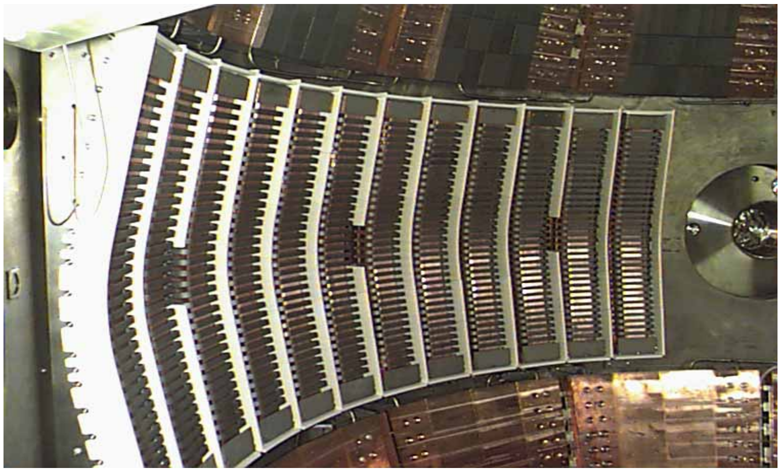
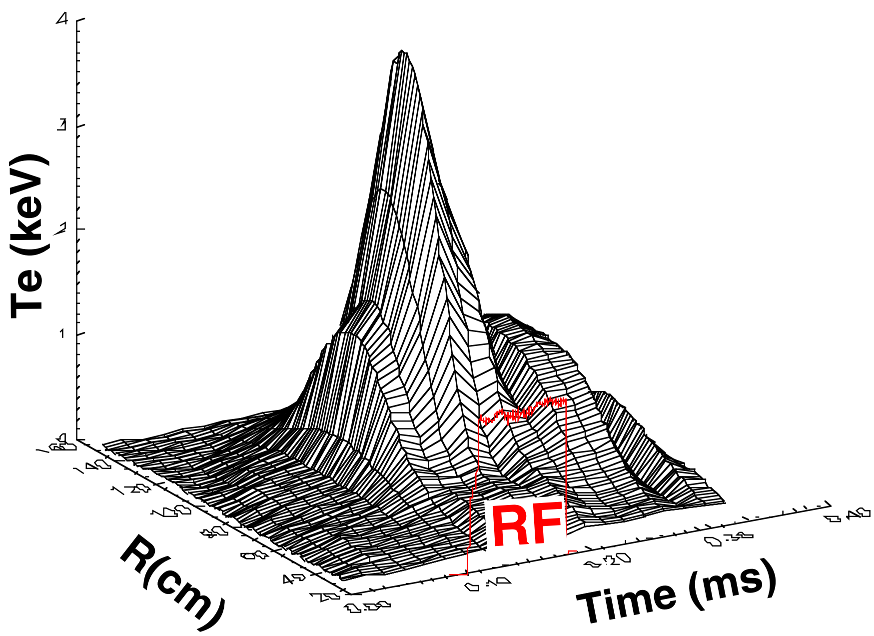


Twelve-element-rf antenna array for launching
real-time-phase-controlled compressional
Alfven waves in NSTX



Application of compressional Alfven wave heating produced very high central electron temperature and pressure in NSTX, where electrons were heated from 2 million degrees Kelvin to nearly 40 million degrees Kelvin.