Observations of Anisotropic Ion Temperature during RF Heating in the NSTX Edge.
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Abstract
A new spectroscopic diagnostic on the National Spherical Torus Experiment (NSTX) measures the velocity distribution of ions in the plasma edge with both poloidal and toroidal views. An anisotropic ion temperature is measured during the presence of high power HHFW RF heating in the plasma, with the poloidal T roughly twice the toroidal T. Moreover, the measured spatial distribution suggests that the population has temperatures of 500°C and 90°C with emission depths of 50 km and 20 km, respectively. This toroidal distribution is observed in both the poloidal and toroidal views (both He II and C IV ions) and is well correlated with the period of RF power applied to the plasma. The temperature of the edge ions is observed to increase with the applied RF power, which was scanned between 8 and 13 MW. The ion heating mechanism from HHFW RF power has not yet been identified.

Overview of the Edge Rotation Diagnostic (ERD)
- 80 ns time resolution
- 7 toroidal and 6 poloidal sightlines cover 360° to 12° at the outboard midplane.
- Spectra to 10,420 eV (862 eV at 10°).
- Poloidal (H) and toroidal (T) views are resolved through a single spectrometer.
- Poloidal and Toroidal views are sampled through a single grating.
- Ion dynamics from C III, C IV, and He II are studied.

Sample Shot 110144
Two separate time frames clearly show the spectral consequences of 30-MHz HHFW heating (RF on) in the edge plasma.

Observations of Carbon Distributions
Fitting the C III data with two Gaussians also suggests “hot” and “cold” populations in the edge plasma, which have trajectories correlated in the RF plane.

Observations of Helium Distributions
Time evolution of Shot 110144 shows that edge ion heating is well correlated with the application of HHFW power to the plasma.

Discussion
The observed anisotropic ion temperature is consistent with ions having a large perpendicular energy component. One interpretation of the observed anisotropic distribution is that there are two populations of like ions in the plasma. In this scenario, the RF creates (by some unidentifiable mechanism) a high-temperature population of He II ions. The emission time scale is ~10 ns, implying that light from both populations (hot and cold) would be readily observed, since the time scale for thermalization between two populations of He II ions is ~10 ns. However, the time scale for ionization is ~100 Ms. Hence, thermalization between the hot and cold populations would not be observed before ionization occurs. Presumably, thermalization occurs among fully stripped He II ions, which do not recombine.

Key to this interpretation of the observed anisotropic distribution is the heating mechanism of the RF which creates the hot component of He II ions. The HHFW launched by the NSTX antenna has a high plasma velocity compared to the ion thermal velocity and is not expected to heat edge ions[Ref.(1,2)]. The heating mechanism is expected to be ion heating. Ion heating at the ion cyclotron frequency (270 eV) for He II and 47° for C IV is unlikely. One possibility for ion heating is parametric decay of the launched HHFW into a dense HHFW and an ion sound wave at the fundamental ion cyclotron frequency, ion heating could then occur either directly at the fundamental cyclotron frequency or by stochastic heating. In the case of the antenna, a computational code could be generated which may substantially limit He II ion heating.

Negative poloidal velocity is observed to the midplane (poly). Negative toroidal velocity is opposite to the direction of the RF power.

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