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HEATING AND CURRENT DRIVE IN NSTX WITH ELECTRON BERNSTEIN WAVES AND HIGH HARMONIC FAST WAVES

Abhay K. Ram

Plasma Science and Fusion Center
Massachusetts Institute of Technology
Cambridge, MA 02139

We have continued our studies on current drive by electron Bernstein waves (EBW) particularly in NSTX, and generally in spherical tokamaks (ST). These studies are part of our ongoing research in which the primary focus is to determine the feasibility of heating and current drive by EBWs in NSTX. The EBWs are excited in the plasma by mode conversion, at the upper hybrid resonance, of an externally launched extraordinary X mode, or an ordinary O mode, or a combination of the two (see Refs. [1,2]).

We have further developed the code R2D2 [3–6] which solves the fully relativistic plasma dispersion for EBW characteristics. From R2D2 we find that relativistic effects are important in the description of EBWs as they propagate in STs. This applies particularly to the damping of EBWs near the Doppler-shifted electron cyclotron resonance frequency (or its harmonics). For electron temperatures greater than about 500 eV relativistic effects begin to affect the damping of EBWs. We have constructed an analytical model that gives insight into EBWs and their properties when relativistic effects are included. The effect on wave-particle interactions, important for current drive, has also been formulated. Analytical and computational results from our studies on relativistic description of EBWs have recently been published in *Physics of Plasmas* [7]. R2D2 has also been used lately to study the relativistic effects on the propagation and damping of conventional electron cyclotron waves in ITER [8.9].

R2D2 has been coupled to the DKE code which solves the kinetic equation for electrons [10]. DKE is being used to determine the current drive capabilities of EBWs. We find that, in NSTX, EBWs can drive plasma currents [6,11,12] in the outer part of the plasma using the Ohkawa scheme [13,14]. This scheme takes advantage of the trapped electron population that exists in this region of the plasma. Farther inside the plasma, near the core, EBWs can drive current using the conventional Fisch-Boozer scheme [15]. Thus, it is possible to control the current profile in NSTX using EBWs [6]. We have had two invited presentations at the EC-14 conference based on our studies of EBW propagation, heating, and current drive [16,17]

The scattering of RF waves at the edge of the plasma by density fluctuations has been observed in NSTX as well as in other fusion devices. We have developed a theoretical model for treating scattering of waves at the edge by density blobs [18]. These studies can be applied to the coupling of all waves that can be excited externally or by mode conversion at the plasma edge.

An understanding of wave-particle interactions is important for imparting energy or momentum to plasma constituents by RF waves. The traditional quasilinear theories are seriously flawed when considering wave-particle interactions in an effectively collisionless plasma. We have developed a kinetic theory for wave-particle interactions in the collisionless regime [19]. Part of this research has been published recently in *Physical Review Letters.* [20].

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