Electron Bernstein Wave Research on NSTX & CDX-U

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Electron Bernstein waves (EBWs) have the potential to heat and drive current in spherical torus (ST) high β plasmas. These waves propagate in the over-dense ($\omega_{pe}/\omega_{ce}>>1$) regions of plasma while electromagnetic waves at low harmonics of the electron cyclotron frequency do not. Electromagnetic waves can mode-convert into the electrostatic EBWs via two paths. W-7AS stellerator has demonstrated effective coupling of the O-mode to EBW to heat the core of its plasma. This process is used in low-β over-dense plasmas, where the upper hybrid resonance layer and the X-mode cutoff are too far apart for tunneling to be effective. Alternately, in high-β ST plasmas $(\omega_{pe}/\omega_{ce})^2$ ~ 10 the distance between the cutoff layer for the X-mode and the mode conversion layer are only a few millimeters apart. Tunneling of the fast X-mode to the upper hybrid layer where it mode converts to the EBW is a viable option.

Initially, the localization of the EBW emission at the cyclotron layer was established by following a cold pulse created by a gas puff in CDX-U. On NSTX, sudden increases of mode conversion efficiency, greater than a factor of three, were observed at H-mode transition. The efficiency was found to depend on the density scale length at the mode conversion layer on CDX-U and NSTX, consistent with theoretical prediction, but the efficiency was < 20%. Recently, conversion efficiencies have approached 100% by reducing the density scale length in the mode conversion region. With $(\omega_{pe}/\omega_{ce})^2$ ~10 the mode conversion layer for EBWs at $\omega = \omega_{ce}$ lies outside the last closed flux surface on high β ST plasmas. A new in-vessel antenna and Langmuir probe array were installed on CDX-U to characterize and enhance the EBW mode conversion process. A local adjustable limiter encircles the antenna in order to modify the density scale length at the mode conversion layer in front of the antenna. The mode conversion efficiency was increased to ~ 100% when the limiter and antenna were inserted near the mode conversion layer.

Detailed modeling of EBW heating and current drive scenarios for NSTX equilibria with plasma β's ~ 10 - 40% have been conducted with EBW ray tracing (GENRAY) and bounce-averaged Fokker-Planck (CQL3D) codes. Typical EBW current drive efficiencies of ~ 0.1 A/W were obtained for B_o ~ 3 kG NSTX plasmas with T_{eo} = 1 keV and $n_{eo} = 2x10^{19} m^{-3}$. Plans for future EBW research on NSTX will be discussed.