Potential of Helicons at 0.5 GHz and Lower Hybrid Waves at 4.6 GHz for Off-Axis Current Drive in DIII-D

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The ray-tracing code GENRAY in conjunction with the Fokker-Planck solver CQL3D has been used to compare wave penetration and damping of 0.5 GHz helicon waves (fast waves in the lower hybrid range of frequencies) and 4.6 GHz lower hybrid (slow) waves in a variety of experimentally-realized DIII-D high-beta equilibria, with good current drive efficiency predicted for both techniques in the mid-radius region. ELMy H-mode discharges in different Advanced Tokamak regimes were examined, including discharges in which off-axis neutral beams were used in an effort to sustain broad profiles, a 'hybrid' discharge with central current drive, and a discharge with a peaked current profile ('high li'). The relatively low toroidal field of DIII-D (central $B_T < 2.15$ T) requires a launched index of refraction along the static magnetic field ($n_{||}$) for the 4.6 GHz slow wave of ~3 or greater to achieve penetration to the core at all but the lowest examined line-average densities, and the poorer accessibility associated with the higher frequency means that only high-field-side launch [1] yields acceptable core penetration. At a given $n_{||}$ value the quasi-electrostatic slow wave has much stronger electron Landau damping than the electromagnetic fast wave in the linear regime; thus, in cases examined so far, helicon wave deposition and current drive is within ρ~0.5 while slow wave deposition occurs at ρ~0.6-0.8. For both waves, efficient coupling at relatively high values of $n_{||}$ is a crucial issue. Though the relevant cutoff density for the slow wave at 4.6 GHz is much lower than for the fast wave at 0.5 GHz at $n_{||}=3$, more rapid evanescence of the wave at higher frequency at a fixed $n_{||}$ produces poor coupling for both cases if conventional wave launchers are used. We are evaluating the practicality of innovative traveling-wave launchers for both waves and have tested such a helicon wave launcher at very low power in DIII-D, with good coupling obtained in a discharge with single-pass absorption of the helicon waves at mid-radius.

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