Modification of the Current Profile in DIII–D by Off-Axis Electron Cyclotron Current Drive*

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The localized current which can be generated by electron cyclotron (EC) waves may be used to sustain optimized profiles of magnetic shear or to suppress instabilities. The first experiments to validate off-axis ECCD have been performed on the DIII–D tokamak using up to 1.2 MW of absorbed power at 110 GHz, corresponding to the second harmonic of the electron cyclotron frequency. The minor radius at which the current drive takes place can be controlled by adjusting the magnetic field or by changing the poloidal angle of the EC beam. When the deposition is near the axis, the measured EC-driven current is up to 100 kA, and the central safety factor falls more rapidly than in comparable discharges without the ECCD, as expected for central co-current drive. The current drive efficiency is close to the theoretical value and exhibits the expected linear dependence on the electron temperature T_e. When the EC power is steered off-axis, currents up to 80 kA have been driven, and again the behavior of the profile of the safety factor and the internal inductance are consistent with qualitative expectations for off-axis co-current drive. However, the experiments show that the current drive efficiency, including a normalization to compensate for the known temperature dependence, does not decrease over the tested range of 0.1 to 0.5 in normalized minor radius, and substantially more off-axis current is driven than predicted from theoretical calculations. This discrepancy between theoretical calculations of the off-axis CD efficiency and experimental measurements is likely a consequence of finite collisionality. The theoretical treatment of the effects of trapping has been based on the assumption that the electrons are collisionless, i.e., that the trapping boundary exists all the way to zero electron energy. This assumption is clearly invalid at electron energies near the thermal velocity which is where the bulk of the current is driven according to calculations. Fokker-Planck calculations with finite collisionality are underway to evaluate the impact of this effect quantitatively. These measurements of off-axis CD help substantiate the application of ECCD for current profile control in high performance advanced tokamak conditions in DIII–D.

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