PHYSICS OF OFF-AXIS ELECTRON CYCLOTRON CURRENT DRIVE*

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Electron cyclotron current drive is a key option for driving current off-axis in a tokamak, as needed for example for current profile control or for suppression of neoclassical tearing modes. Experiments in DIII–D at low beta have shown that the partial cancellation of the Fisch-Boozer current by the Ohkawa current can cause strong deterioration of the CD efficiency with minor radius. However, more recent experiments at higher power have shown that the loss in efficiency can be recovered if the target plasma has higher electron beta, β_e. The improvement in efficiency with beta can be understood by applying the Fokker-Planck code CQL3D to the flux surface where the peak of the absorption takes place. The separation in frequency between the cold cyclotron resonance and the location of peak absorption is a critical parameter which determines—and is determined by—how far into the bulk of the electron distribution the resonance extends. The effect of increasing the absorption is to shift the resonance toward larger $v_{||}$, away from the trapped-passing boundary in velocity space. At the same time, increasing the electron temperature causes the resonance to curve away from the trapped particle region of velocity space due to relativistic effects, for outside launch. These effects combine to shift the region of velocity space which is affected by the waves away from the trapping boundary. This reduces the flux of particles across the trapping boundary, thereby reducing the Ohkawa counter-current and increasing the net efficiency. The flux driven by the EC power represents the source term in the Fokker-Planck equation, and in steady-state a pattern of collisional return flux is generated. This flux can extend well beyond the region where the source is large, so interaction with the trapping boundary may still take place. The magnitude of the net effect on the driven current can be determined by integrating the $v_{||}$-weighted flux across the trapping boundary. Comparison of theory, as embodied in the Fokker-Planck code, and experiment shows excellent agreement over a wide range of parameters, including β_e, $n_{||}$, and the magnetic well depth, validating the code as an effective means of predicting the ECCD.

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