Validation of the Physics Model for ECCD in the DIII-D Tokamak*

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Accurate projection of the magnitude and profile of electron cyclotron current drive (ECCD) in ITER requires the experimental validation of a predictive physics model. Experiments have been undertaken in the DIII-D tokamak to validate the first-principles physics models encoded in the TORAY-GA/CQL3D suite of codes. The TORAY-GA ray tracing code calculates the trajectories of a bundle of rays which simulate the propagation of a Gaussian beam far from the beam waist. The ray trajectories and the wave polarizations are used as input to the CQL3D Fokker-Planck code in order to include quasilinear effects of the wave on the distribution function. The calculated ECCD can be compared with the current measured in experiments on the DIII-D tokamak. The DIII-D experiments use data from the motional Stark effect (MSE) diagnostic to determine the pitch angle of the magnetic field with radial resolution around 4 cm over much of the minor radius. An extensive set of experiments has been carried out in which the minor radius, the parallel index of refraction, and the poloidal location of the interaction are varied in an orthogonal manner, as well as the plasma parameters like electron temperature and density. In order to accurately model the physics, the effects of the radial profile of the self-consistent electric field must be included, where the electric field is obtained from the evolution of the magnetic flux in a series of equilibrium reconstructions constrained by the MSE data. The magnitude of the measured ECCD plotted against the calculated ECCD for the complete set of experiments shows excellent agreement, as shown in the figure. Measurements of the profile peak and width are also in excellent agreement. Even in high performance discharges with edge localized modes (ELMs), sawteeth, and tearing modes present, the width of the profile of driven current does not seem to be measureably wider than that calculated assuming no MHD activity. The principal limitation on the data set is the maximum normalized radius of deposition < 0.4, while applications in DIII-D and ITER will require ECCD at radii of 0.5 to 0.8, where trapping of electrons is stronger. Theory indicates that the effects of stronger damping due to higher temperature and density as well as the larger gradient length for the magnetic field, coupled with stronger relativistic effects, will reduce but not eliminate the deleterious effects of trapping. Experimental tests of ECCD at larger radii are planned for DIII-D.