Application of Electron Cyclotron Current Drive on ITER

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Plans for the International Thermonuclear Experiment Reactor (ITER) tokamak include electron cyclotron waves for heating and driving current in the plasma. Key objectives for electron cyclotron current drive (ECCD) include sustaining the current profile required for higher ("advanced") performance in the high bootstrap fraction regime and stabilizing magnetohydrodynamic (MHD) modes like neoclassical tearing modes and sawteeth, as well as contributing to the heating to temperatures where alpha heating becomes dominant. Modeling can be employed to evaluate the power needed to carry out these objectives. The validity of the computational models used to predict the heating and current drive effects have been largely confirmed by recent experimental results worldwide. In this study, the linear ray tracing codes TORAY-GA and GENRAY and the quasilinear Fokker-Planck code CQL3D are used to model the current drive in ITER under a range of conditions. These calculations show that the linear model is adequate for application to ITER under most conditions. This code has been benchmarked extensively against other linear ray tracing and beam propagation codes.

The fulfillment of the objectives of ECCD in ITER is greatly complicated by the range of the engineering parameters over which ITER is expected to operate. The TORAY-GA modeling shows that for the reference launcher locations it may be possible to drive sufficient current density at the rational q surfaces (3/2 and 2/1) of the Scenario 2 equilibrium to stabilize the neoclassical tearing mode using modulated power in the range of 20 MW and using the upper launcher, but only for a rather narrow range of optimized conditions of toroidal field and electron cyclotron (EC) source frequency. Unavoidable geometric effects place a limit on the degree to which the ECCD can be localized even if the EC beam is extremely narrow. This limit depends primarily on the launch location and the geometric relationship of the cyclotron resonance to the targeted flux surface, with the greatest localization occurring when the EC beam is traveling tangentially to the flux surface in the neighborhood of the resonance. Greater flexibility in the range of operating parameters may be obtained by a more suitable choice of launch locations. Alternatively, an EC power source step-tunable in frequency would be highly advantageous (although frequency changes would complicate the implementation of the remote steering approach). Other applications like current profile control are not so sensitive to the toroidal field as stabilization of MHD modes. In either case there are disjoint ranges of toroidal field where ECCD can be effective for a given set of conditions of equilibrium, kinetic profiles, and launcher arrangement.

This work was supported by the U.S. Department of Energy under DE-FC02-04ER54698, DE-FG03-95ER54309, and DE-FG03-99ER54541.