Comparison of Optimized ECCD for Different Launch Locations in a Next-Step Tokamak Reactor Plasma

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Abstract. Utilization of electron cyclotron (EC) radio frequency sources for current drive and the stabilization of neoclassical tearing modes in next-step devices rests on the attainable currrent density and current drive efficiency. This work reports optimization of EC driven current density and current drive efficiency over source frequency as well as toroidal and poloidal launch angles for two launcher positions: a "midplane" position at the height of the magnetic axis, and an "upper port" position above the midplane. Plasma parameters were chosen to be representative of the next step towards a fusion reactor (B = 5.3 T, $\langle n_e \rangle = 1.0 \times 10^{20}\,\mathrm{m}^{-3}$, R = 6.2 m). The modeling is performed with the TORAY [K. Matsuda, IEEE Trans. Plasma Sci. **17** (1989); A.H. Kritz *et al.*, in Proc. of 3rd Joint Varenna-Grenoble Int. Symp. on Heating in Toroidal Plasmas, Brussels, Vol. 2 (1982) p. 707] code, launching a cone of EC rays to account for a finite angular spectrum

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of injected waves. Current drive at each location is obtained with the Cohen [R.H. Cohen, Phys. Fluids **30**, 2442 (1987)] linear model which includes the effects of toroidal trapping, relativity, and wave polarization. For the two launch locations, optimized central current drive efficiency is approximately equal. At plasma radius $\rho = 0.835a$ for stabilization of the $q = 2$ neoclassical tearing mode, the current *density* is 2.3 times greater and the integrated *efficiency* is 1.5 times greater, for the upper-port launch relative to the midplane launch. For a sequence of minor radii $0.4 < \rho/a < 0.8\,\mathrm{m}$ the launch-angle-optimized current density and efficiency show a broad maximum as a function of source frequency, in the range $f = 170-210\,\mathrm{GHz}$ for midplane launch and $f = 170-250\,\mathrm{GHz}$ for upper port launch. Since a key parameter of electron cyclotron current drive (ECCD) is (wave frequency/cyclotron frequency), the upper port launch will give good ECCD efficiency over a broader range of toroidal magnetic field. Twenty megawatts of EC power satisfies criteria for control of neoclassical tearing modes.

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