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Electron Cyclotron Wave Experiments on DIII–D*

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Electron cyclotron waves offer a unique ability to probe and modify the transport and stability properties of magnetically confined plasmas. A versatile experimental program on the DIII–D tokamak uses high power electron cyclotron waves to probe the transport properties, control instabilities, and modify the plasma current profile. Two interesting and important transport phenomenon associated with off-axis electron cyclotron heating (ECH) are the heat pinch, where net energy is observed to flow up the electron temperature gradient, and the electron internal transport barrier (ITB) caused by turbulence suppression. Ongoing electron cyclotron current drive (ECCD) experiments are solidifying the physics basis for localized, off-axis current drive in both standard and advanced operating modes on DIII–D, the goal being to validate a predictive model of ECCD. The ECCD radial profile can be found from the internal magnetic field measurements by motional Stark effect (MSE) spectroscopy either by comparing the total and Ohmic current profiles determined by equilibrium reconstruction, or by comparing the measured MSE signals to simulations of the expected MSE response to localized current drive. Experiments in low-density L–mode plasmas have concentrated on validating the expected strong dependencies of the ECCD efficiency on the toroidal injection angle, electron trapping, and the quasi-linear effect. A scan of the toroidal injection angle shows clearly that off-axis ECCD switches from the co to the counter current direction, with radial injection driving no current. Electron trapping is found to strongly affect ECCD since the normalized current drive efficiency decreases with increasing radius and with decreasing poloidal angle (moving from the inboard to outboard side of the plasma at fixed radius) for both the co and counter current drive directions. The experimental ECCD is found to be in better agreement with Fokker-Planck models than with linear models that neglect the quasi-linear effect. In H–mode plasmas, experiments using modulated electron cyclotron wave power verify that the wave absorption remains localized despite ELMs and the steep edge density gradient. Clear evidence of localized current drive using electron cyclotron waves in H–mode plasmas is seen by MSE spectroscopy. Further evidence of localized current drive in H–mode plasmas comes from the ECCD stabilization of m/n = 3/2 neoclassical tearing modes, which depends sensitively on the current drive being located on the q = 3/2 surface (q is the safety factor).

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