DPP10-2010-000629

Abstract for an Invited Paper
for the DPP10 Meeting of
the American Physical Society

Investigation of LH Physics Through Power Modulation Experiments on C-Mod

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Lower hybrid current drive (LHCD) is an attractive tool for off-axis current profile control in present devices and burning plasmas (ITER), because these waves damp at high parallel phase speeds relative to the electron thermal speed. The LHCD system on Alcator C-Mod operates at 4.6 GHz, with $\sim$ 1MW of coupled power, and can produce spectra over a wide range of peak parallel refractive index ($n_{||}$). A 32 chord, horizontally viewing hard x-ray camera has been used to measure the spatial and energy distribution of fast electrons generated by LH waves, providing valuable data for validating LHCD simulation models. Theory predicts that LH power deposition location is strongly dependent on $n_{||}$. Square-wave modulation of LH power on a time scale much faster than the current relaxation time does not significantly alter the poloidal magnetic field inside the plasma and thus allows for realistic modeling and consistent plasma conditions for different $n_{||}$ spectra. Inverted hard x-ray profiles show clear changes in LH-driven fast electron location with differing $n_{||}$. Boxcar binning of hard x-rays during LH power modulation allows for $\sim$ 1 ms time resolution, which is sufficient to resolve the build-up, steady-state, and slowing-down phases of fast electrons. The time histories of hollow x-ray profiles have been used to measure a fast electron pinch velocity. Ray-tracing/Fokker-Planck modeling in combination with a synthetic hard x-ray diagnostic show quantitative agreement with the x-ray data at low densities. However, simulations do not reproduce the experimentally observed LH density limit, above which the x-ray count rates drop dramatically, unless strong absorption of the waves in the plasma edge region is invoked. X-ray profile shapes suggest that LH power is being deposited in the divertor region near the active x-point location. Inclusion of a scrape-off layer in the ray tracing allows for a detailed comparison of measured x-ray profiles with those predicted by modeling. This work is supported by the US DOE awards DE-FC02-99ER54512 and DE-AC02-76CH03073.