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Characterization of ion cyclotron emission in the DIII-D tokamak

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Fast-ion losses and radiation expected in fusion reactors challenge conventional fast-ion diagnosis techniques that rely on delicate components such as scintillating plates and cameras. Passive measurement of coherent ion cyclotron emission (ICE) via magnetic pickup loops offers a robust diagnostic alternative but requires improved experimental resolution and more detailed theory. To this end, the ICE diagnostic on DIII-D has been upgraded [1] to enable detailed mode characterization including determination of toroidal mode number, approximate polarization at the plasma edge, comparison of low and high-field side signal amplitude, and extension of the upper frequency limit into the lower hybrid range.

Dedicated experiments have been performed on the DIII-D tokamak to explore the dependence of ICE amplitude and spectrum on both thermal plasma and fast ion properties [2]. A database of nearly 200 shots has been constructed to investigate centrally-localized ICE in DIII-D L-mode plasmas. These discharges feature both hydrogen and deuterium beams in configurations varied over energy (55–81 kV), pitch (v||/v), radial origin (near-tangential or near-perpendicular), direction of injection (co- vs. counter-plasma current), and tilt (on- or off-axis). ICE depends strongly on the character of these highly anisotropic distributions. Moving counter-current neutral beams off-axis significantly decreases both the number of harmonics excited and their amplitude (cf. co-injecting beams [2]). On a finer scale, frequency splitting of the harmonics is common for many fast-ion distributions. For example, the dominant ˜2fcD harmonic excited by the high-power co-current tangential beam is split into bands spaced roughly 100–200 kHz apart in high BT plasmas, and the number of sidebands changes over the course of the beam pulse. The thermal ion population can also influence ICE, as increasing the hydrogen to deuterium ratio in mixed species shifts the dominant harmonic excited by the co-current beams from ˜2 fcD to ˜4 fcD, where fcD is the ion cyclotron frequency at the magnetic axis.

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[1] G. H. DeGrandchamp, Rev. Sci. Instrum. 92, 033543 (2021)
[2] K. E. Thome, Nucl. Fusion 59, 086011 (2019)

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