Interpretation of ion cyclotron emission from beam-injected ions in the
Large Helical Device

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Ion cyclotron emission (ICE) is detected from all large toroidal magnetic confinement
fusion plasmas. Its power spectrum typically comprises narrow, strongly suprathermal,
peaks at frequencies corresponding to sequential cyclotron harmonics of ions located in
the outer regions of the plasma. ICE is driven by collective instability of energetic ion
populations that have a spatially localised inversion in velocity space. The
magnetoacoustic cyclotron instability (MCI) is the most likely emission mechanism. ICE
is proposed as a diagnostic for confined energetic ions in ITER; see K G McClements, R
d’Inca et al., Nucl. Fusion 55 043013 (2015). Here we analyse ICE spectra generated by
neutral beam injected (NBI) energetic ions in the outer regions of plasmas in the Large
Helical Device (LHD) heliotron-stellarator. Importantly, these spectra span plasma
regimes where the ratio of the velocity of the energetic ions \( V_{\text{NBI}} \) to the local Alfvén
speed \( V_A \) is larger or smaller than unity: in particular, we examine cases where \( V_{\text{NBI}} / V_A = 1.125 \) and 0.872. We report studies using a 1D3V hybrid particle-in-cell code which
simulates the self-consistent full gyro-orbit kinetics of energetic and thermal ions, the
electric and magnetic fields, and a massless neutralising electron fluid. We follow these
simulations through the linear phase of an instability that is identifiable as the MCI, and
then deeply into its nonlinear saturated phase. The Fourier transforms of the excited fields
yield frequency spectra that are excellent proxies for the observed ICE spectra from these
LHD plasmas. These simulation results for stellarator plasmas complement and confirm
earlier interpretation of ICE observations driven by sub-Alfvénic NBI ions in TFTR
tokamak plasmas, which was based on linear analytical theory. They also serve to link
beam ion physics in the LHD stellarator to fusion-born ion physics in tokamaks.

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