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Fast Particle-Driven Ion Cyclotron Emission (ICE) in Tokamak Plasmas and the Case for an ICE Diagnostic in ITER

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Fast particle-driven waves in the ion cyclotron frequency range (ion cyclotron emission or ICE) have provided a valuable diagnostic of confined and escaping fast ions in many tokamaks. This is a passive, non-invasive diagnostic that would be compatible with the high radiation environment of DT plasmas in ITER, and could provide important information on fusion alpha-particles and beam ions in that device. In JET ICE from confined fusion products scaled linearly with fusion reaction rate over six orders of magnitude [1] and provided evidence that alpha-particle confinement was close to classical [2]. In TFTR ICE was observed from super-Alfvenic alpha-particles in the plasma edge [3]. The intensity of beam-driven ICE in DIII-D is more strongly correlated with drops in neutron rate during fishbone excitation than signals from more direct beam ion loss diagnostics [4]. In ASDEX Upgrade ICE is produced by both super-Alfvenic DD fusion products and sub-Alfvenic D beam ions [5]. The magnetoacoustic cyclotron instability (MCI), driven by the resonant interaction of population-inverted energetic ions with fast Alfven waves, provides a credible explanation for ICE. One-dimensional PIC and hybrid simulations have been used to explore the nonlinear stage of the MCI [6,7], thereby providing a more exact comparison with measured ICE spectra and opening the prospect of exploiting ICE more fully as a fast ion diagnostic. For realistic values of fast ion concentration, the nonlinearly-saturated ICE spectrum closely resembles the measured spectrum. The PIC/hybrid approach should soon make it possible to simulate the nonlinear physics of ICE in full toroidal geometry. Emission has been observed at a wide range of poloidal locations, and so there is flexibility in the requirements of an ICE detector. Such a detector could be implemented in ITER by installing a toroidal loop or adding a detection capability to the ICRH antennae.

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