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Global Alfvén eigenmode scaling and suppression

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The spherical tokamak NSTX has been upgraded to include a second neutral beam line, with three independent beam sources, and to be capable of higher toroidal fields and longer duration plasmas [1]. During the first experimental campaign, it was observed that small amounts of high pitch-angle beam ions from the new sources can strongly suppress the counter-propagating Global Alfvén Eigenmodes (GAE) excited by the Doppler-shifted cyclotron resonance drive [2]. GAE have been implicated in the redistribution of fast ions and degradation of plasma performance in previous experiments on NSTX [3]. The ability to predict the stability of Alfvén modes, and developing methods to control them, is important for fusion reactors like the International Tokamak Experimental Reactor (ITER) which are heated by a large population of non-thermal, super-Alfvénic ions consisting of fusion generated alphas and beam ions injected for heating and current profile control. We present a qualitative interpretation of these observations using an analytic model of the Doppler-shifted ion-cyclotron resonance drive responsible for GAE instability which has an important dependence on $k_{\perp}\varrho_L$ [4,5]. A quantitative analysis of this data with the HYM stability code predicts both the frequencies and instability of the GAE prior to, and suppression of the GAE after the injection of high pitch-angle beam ions[6,7]. The Doppler-shifted cyclotron resonance drive theory of GAE stability is also found to qualitatively predict the experimental scaling of the GAE frequency and toroidal mode numbers with toroidal field, providing additonal validation for the DCR model. A representative selection of NSTX full power H-mode plasmas, with various toroidal field and plasma currents, has been used to create a database of GAE parameters. From this database, the experimental scaling of the GAE toroidal mode number and the GAE frequency was constructed. It is found that GAE toroidal mode number and frequency increase roughly linearly with increasing toroidal field. A simple algorithm based on the Doppler-shifted cyclotron resonance drive was constructed which predicts the frequency and mode number range of potentially unstable GAE. Application of the algorithm to the shots in the database predicts a qualitatively similar scaling of toroidal mode numbers and frequencies as observed experimentally.

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