Resonances of Energetic Particle Instabilities During Frequency Chirping

D.C. Pace[1], W.W. Heidbrink[2], M.A. Van Zeeland[1]

[1] *General Atomics, P.O. Box 85608, San Diego, CA 92186-5608, USA*

[2] *University of California Irvine, University Dr., Irvine, CA 92697, USA*

Convective energetic ion transport results from Alfvén eigenmodes (AEs) and energetic particle modes (EPMs) due to resonances between these modes and the orbit topology of the ions. Experiments at the DIII-D tokamak show that ion/EPM resonance space can be selectively probed as limited resonances produce energetic ion losses that are coherent at the mode frequency. These results demonstrate that the measured transport of energetic ions is highly sensitive to the region of experimentally observed phase space and this must be taken into consideration when quantifying the effects of AEs/EPMs on advanced scenarios.

Neutral beam injection in the DIII-D tokamak ($R = 1.7\,\mathrm{m}$, $a = 0.6\,\mathrm{m}$) occasionally results ($\approx 3\%$ of discharges) in the excitation of energetic ion modes characterized by a fast downward frequency chirp as shown in the density spectrogram of Fig. 1(a). These modes evolve in frequency much faster than the equilibrium (i.e., much faster than the more standard frequency evolution of a reversed shear Alfvén eigenmode), often chirping through $\Delta f = 20$ kHz in approximately 1 ms.

New analysis seeks to improve the understanding of this phenomenon by mapping the ion-wave resonance space. Figure 1(b) shows the $E = 80$ keV ion phase space resulting from deposition of a counter-current neutral beam. The set of resonances from the $n = 2, 3$ observed chirping modes shows a specific set of overlap with these beam ions. The modes emerge during a time period featuring only co-current beam injection, however, beam ion losses at the chirping frequencies are only observed on the fast ion loss detector (FILD) when counter-current beam injection is added. This is consistent with the proximity between the FILD, the counter-current beam ions, and the chirping resonances. Coherent losses therefore represent a small fraction of the ion/mode interaction space and suggest that careful utilization of beam injection can be used to experimentally probe energetic ion transport from these instabilities.

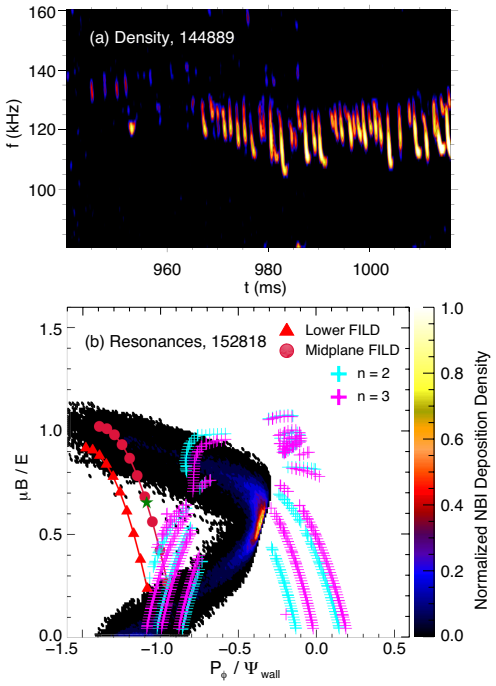

Figure 1: *(a) Cross-power spectrum from two channels of the interferometer diagnostic indicating density fluctuations. (b) Phase space of counter-current neutral beam deposition with mode resonances indicated by the +-symbols and the observed 80 keV space of the FILD highlighting the measurements of coherent losses ($\star$-symbol).*

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