Velocity-space representations of MHD modes and imaging diagnostic data

B. Tobias[1], B. Grierson[1], C.M. Muscatello[2], X. Ren[2], C.W. Domier[2], N.C. Luhmann, Jr.[2], S. Zemedkun[3], T. Munsat[3], I.G.J. Classen[4], and the DIII-D Team

[1]*Princeton Plasma Physics Laboratory, Princeton, NJ 08543, USA*
[2]*Universtiy of California at Davis, Davis, CA 95616, USA*
[3]*University of Colorado at Boulder, Boulder, CO 80309, USA*
[4]*Eindhoven University of Technology, 5600 MB Eindhoven, The Netherlands*

bjtobias@pppl.gov

Multiple neoclassical tearing modes (NTMs) of different n-number are shown to interact nonlinearly, exchanging angular momentum through three-wave coupling. This places constraints on the saturated toroidal and poloidal rotation profiles. The selection criteria for harmonic and inter-rational mode couplings (other than those induced by toroidicity and plasma shaping) have been identified by 2D imaging diagnostics on DIII-D and are contrasted in two types of discharges: those having multiple NTMs with phase-locked island rotation, and those with finite differential rotation between the modes. For the purpose of exploring the physics of these phenomena, we introduce a multi-dimensional velocity-space mapping of localized, 2D data obtained by the simultaneous ECE-Imaging and Millimeter-wave Imaging Reflectometer (ECEI/MIR) diagnostic on DIII-D.

Transformation of imaging data to a poloidal velocity phase-space involves casting the variation of eigenmode phase in the poloidal direction as a wavenumber. Combined with the frequency of the oscillation as it is observed in the laboratory frame, each coherent mode then takes on a well-defined phase velocity. In this space one may readily identify three-wave selection criteria. For H-mode discharges with multiple NTMs, the fulfilment of this selection criteria is accompanied by statistically significant bicoherence (phase-locking of island rotation). We will also show that for multiple, related modes, e.g. sawtooth or ELM precursors, simultaneous components of edge harmonic oscillations (EHOs), or spectra of Alfvén eigenmodes on DIII-D, it is useful to define an MHD group velocity that constrains the propagation and natural frequency of the chosen branch of instability. The ease with which these relationships are observed in velocity phase-space is testament to the value of this transformation as a visualization tool.

This work was supported by the US Department of Energy under DE-AC02-09CH11466, DE-FG02-99ER54531, DE-FC02-05ER54816, and DE-FC02-04ER54698.