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Laboratory Studies of Nonlinear Interactions Relevant to Alfvén Wave Decay Instabilities[1]

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Alfvén waves, a fundamental mode of magnetized plasmas, are ubiquitous in both laboratory and space plasmas. Many theoretical predictions show that these waves may be unstable to various decay instabilities (e.g. [1,2]). Despite the possible importance of these processes in problems such as the heating of the solar corona and the transfer of energy to small spacial scales in the solar wind, observational evidence is limited. The present work at UCLA's Large Plasma Device (LAPD) represents the first fundamental laboratory study of the non-linear Alfvén wave interactions responsible for this class of instabilities; in particular, we present 1) laboratory observation of the Alfvén-acoustic mode coupling at the heart of the Parametric Decay Instability [3] and 2) laboratory observations consistent with a decay instability in which a Kinetic Alfvén Wave (KAW) decays into two co-propagating KAWs. The first study is conducted by launching counterpropagating Alfvén waves from antennas placed at either end of the LAPD. A resonance in the beat wave response produced by the two launched Alfvén waves is observed and is identified as a damped ion acoustic mode based on the measured dispersion relation. Results are consistent with theoretical predictions for a three-wave interaction driven by a nonlinear ponderomotive force. In the second experiment, a single high-frequency $\omega/\omega_{ci} \sim 0.7$ Alfvén wave is launched, resulting in two daughter modes with frequencies and wave numbers that suggest co-propagating KAWs produced by decay of the pump wave. The observed process is parametric in nature, with the frequency of the daughter modes varying as a function of pump amplitude. Efforts are underway to fully characterize the second set of experiments and compare with decay instabilities predicted by theory and simulations.

[1] JV Hollweg, J. Geophys. Res. 99, 23 431 (1994).
[2] YM Voitenko, Journal of plasma physics 60.03 (1998).
[3] S Dorfman and T Carter, Phys. Rev. Lett. 110, 195001 (2013).

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