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Basic Physics of Fast Ions and Shear Alfvén Waves

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A campaign is underway at the Large Plasma Device (LAPD) to study fast-ion physics issues of relevance to magnetic fusion. So far, two basic physics experiments have been completed. In the first [1], a multiple magnetic mirror array creates periodic axial variations in the index of refraction of shear Alfvén waves. Waves are launched by antennas inserted in the LAPD plasma and diagnosed by B-dot probes at many axial locations. As in fusion devices and other periodic media, spectral gaps are formed due to the Bragg effect. The measured width of the propagation gap increases with the modulation amplitude as expected theoretically. Simulations with a 2D finite-difference code resemble the observed spectra. In the second experiment, a Li^+ source [2] launches a population of nearly monoenergetic fast ions in a helium plasma. A loop antenna launches shear Alfvén waves at frequencies ω below the helium cyclotron frequency ω_{ci} ($\omega/\omega_{ci} = 0.3$-0.8). The fast ions interact with the waves through the Doppler-shifted cyclotron resonance, $\omega - k_z v_z = \Omega_f$. (Here k_z is the axial wavenumber, v_z is the fast-ion axial speed and Ω_f is the fast-ion cyclotron frequency.) A collimated energy analyzer measures the non-classical spreading of the beam, which is proportional to the resonance with the wave. To compare with theory, a Monte Carlo Lorentz code launches fast ions with an initial spread in real/velocity space and random phases relative to the wave fields, which are derived from measured magnetic field data. Both the magnitude and frequency dependence of the calculated beam-spreading agree with experiment. Planned experiments include a study of fast-ion transport by turbulent fluctuations and the nonlinear interaction of fast ions with larger amplitude Alfvén waves. In addition to these test-particle experiments, an intense fast-ion source is under development.

[1] Yang Zhang et al., Phys. Plasmas 15 (2008) 012103. [2] Y. Zhang et al., Rev. Sci. Instrum. 78 (2007) 013302.