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Different kλ_D Regimes for Nonlinear Langmuir Wave Behavior

JOHN KLINE, Los Alamos National Laboratory

As Langmuir waves (LW) are driven to large amplitudes in plasmas, they are affected by nonlinear mechanisms. Significant effort at LANL has resulted in a theoretical model of nonlinear Langmuir wave behavior based on the dimensionless parameter kλ_D (k is the Langmuir wave number and λ_D is the Debye length), as well as an experimental platform to test the model without spurious effects. Experiments conducted over a range of kλ_D are consistent with and support the model. kλ_D physically represents the ratio of the electron thermal to the LW phase velocity. When kλ_D is large, the LW phase velocity is near the electron thermal velocity and wave-particle kinetic effects such as electron trapping tend to dominate the nonlinear LW behavior. When kλ_D is small, the LW phase velocity is much greater than the electron thermal velocity where little wave-particle interaction can take place and wave-wave effects tend to dominate. One such mechanism is the Langmuir Decay instability where the Primary LW can parametrically decay into an oppositely propagating LW and a co-propagating ion acoustic wave, a process that can cascade with each successive daughter LW. Collective Thomson scattering measurements of LWs driven by Stimulated Raman Scattering in a diffraction limited single laser focal spot have been used to study both wave-wave and wave-particle nonlinearities [Kline *et al.*, *PRL*, **94**, 175003 (2005)]. For k$\lambda_D <\sim 0.29$, multiple waves are detected and are attributed to Langmuir decay instability, the wave-wave regime. For k$\lambda_D >\sim 0.29$, a single wave, frequency-broadened spectrum is observed associated with electron trapping, the wave-particle regime. The transition from the wave-wave to the wave-particle regime is qualitatively consistent with quasi-2D particle-in-Cell simulations and with crossing of the Langmuir decay instability amplitude threshold above that for LW self-focusing.