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Nonlinear kinetic modeling of stimulated Raman scattering

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Despite its importance for many applications, such as or Raman amplification or inertial confinement fusion, deriving a nonlinear estimate of Raman reflectivity in a plasma has remained quite a challenge for decades. This is mainly due to the nonlinear modification of the electron distribution function induced by the plasma wave (EPW), which, in turn, modifies the propagation of this wave. In this paper is derived an envelope equation for the EPW valid in 3D and which accounts for the nonlinear change of its collisionless (Landau-like) damping rate, group velocity, coupling to the electromagnetic drive, frequency and wave number. Our theoretical predictions for each of these terms are carefully compared against results from Vlasov simulations of stimulated Raman scattering (SRS), as well as with other theories [1]. Moreover, our envelope model shows to be as accurate as a Vlasov code in predicting Raman threshold in 1D. Making comparisons with experimental results nevertheless requires including transverse dimensions and letting Raman start from noise. To this end, we performed a completely new derivation of the electrostatic fluctuations in a plasma, which accounts nonlinear effects. Moreover, based on our Multi-D simulations of Raman scattering with our envelope code BRAMA [2], we discuss the effect on SRS of wave front bowing [3], transverse detrapping [4] and of a completely new defocussing effect due to the local change in the direction of the EPW group velocity induced by the nonlinear decrease of Landau damping.

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