Envelope equation of an electron plasma wave: Linear and nonlinear propagation in a non-uniform and non-stationary plasma

D. Bénisti

CEA, DAM, DIF 91297 Arpajon Cédex

This talk addresses the linear and nonlinear three-dimensional propagation of an electron plasma wave in a collisionless plasma that may be inhomogeneous, nonstationary, anisotropic and even weakly magnetized. Most of the talk is devoted to the situation when the wave amplitude, together with any hydrodynamic quantity characterizing the plasma (density, temperature,…) are supposed to vary very little within one wavelength or one wave period. Hence, the geometrical optics limit is assumed, and the wave propagation is described by a first order differential equation. This equation explicitly accounts for three-dimensional effects, plasma inhomogeneity, Landau damping, and the collisionless dissipation and electron acceleration due to trapping. It is derived by mixing results obtained from a direct resolution of the Vlasov-Poisson system and from a variational formalism involving a nonlocal Lagrangian density. In a one-dimensional situation, abrupt transitions are predicted in the coefficients of the wave equation. They occur when the state of the electron plasma wave changes, from a linear wave to a wave with trapped electrons. In a three dimensional geometry, the transitions are smoother, especially as regards the nonlinear Landau damping rate, for which a very simple effective and accurate analytic expression is provided.

The envelope equation needs to be solved together with the ray tracing equations, which requires the knowledge of the nonlinear dispersion relation. Consequently, in this talk, we will discuss the nonlinear frequency shift of the plasma wave, and the way it is affected by plasma inhomogeneity and three-dimensional effects.

As an application of our theory, we show how to predict the nonlinear Raman reflectivity, which is still an issue for Inertial Confinement Fusion. We also show how to generalize our results when the wave amplitude varies rapidly. This yields a theoretical solution for the nonlinear growth rate of the beam-plasma instability, and a generalized description of nonlinear Landau damping.