Contributions to the linear and nonlinear theory of the beam-plasma interaction

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Abstract:
We focus our attention on some relevant aspects of the beam–plasma instability in order to refine some features of the linear and nonlinear dynamics. After a re-analysis of the Poisson equation and of the assumption dealing with the background plasma in the form of a linear dielectric, we study the non-perturbative properties of the linear dispersion relation, showing the necessity for a better characterization of the mode growth rate in those flat regions of the distribution function where the Landau formula is no longer predictive. We then upgrade the original N-body approach in O'Neil et al. (Phys. Fluids, vol. 14, 1971, pp. 1204–1212), in order to include a return current in the background plasma. This correction term is responsible for smaller saturation levels and growth rates of the Langmuir modes, as result of the energy density transferred to the plasma via the return current. Finally, we include friction effects, as those due to the collective influence of all the plasma charges on the motion of the beam particles. The resulting force induces a progressive resonance detuning, because particles are losing energy and decreasing their velocity. This friction phenomenon gives rise to a deformation of the distribution function, associated with a significant growth of the less energetic particle population. The merit of this work is to show how a fine analysis of the beam–plasma instability outlines a number of subtleties about the linear, intermediate and late dynamics which can be of relevance when such a system is addressed as a paradigm to describe relevant nonlinear wave–particle phenomena (Chen & Zonca, Rev. Mod. Phys., vol. 88, 2016, 015008).