Collisional effects on ultrarelativistic beam-plasma instabilities

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The E-305 experiment at the SLAC/FACET-II accelerator [1] will aim to probe the development of beam-plasma instabilities [2] under extreme conditions, involving an ultrarelativistic (10 GeV), high-density (~10^{19-20} cm^{-3}) electron beam propagating through a millimeter-scale solid-density medium.

Here, we will first report on particle-in-cell (PIC) simulations which show the impact of the instabilities on the beam's phase space, and reveal how the plasma collisionality, along with the beam's peak density, affects the hierarchy between the competing instability classes. Specifically, Coulomb collisions between the plasma electrons and ions are found to hamper the oblique two-stream instability (OTSI), usually dominant in the regime considered [2,3], and instead to favor the current filamentation instability (CFI), which prevails at ≥ 10^{20} cm^{-3} beam densities. The plasma collisionality is either set by the initial plasma temperature at low beam density, or evolves with time as the plasma is resistively heated at high beam density.

Those findings are interpreted by solving numerically the 2D collisional dispersion relation of the beam-plasma instability, in which the nonrelativistic Vlasov-Fokker-Planck equation is used to treat the plasma electrons [4]. Consistent with the PIC results, linear theory predicts that collisions tend to dampen the OTSI and exacerbate the CFI, while reducing the range of their transverse wavenumbers.

References

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