Stability analysis of a periodic system of relativistic current filaments

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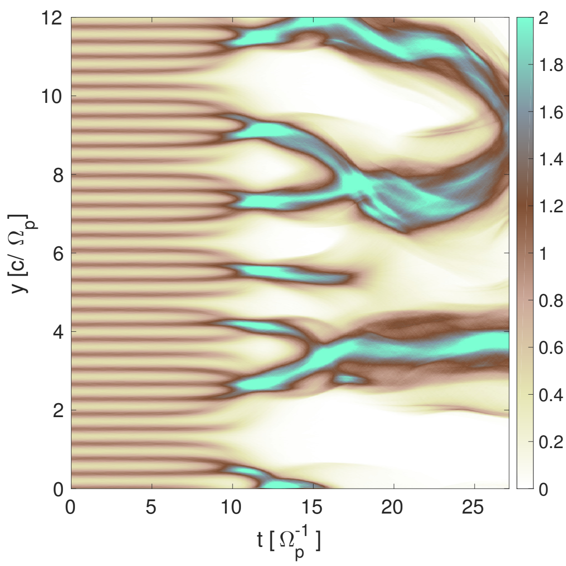
Homogeneous counterstreaming plasmas are subject to the transverse filamentation (or Weibel) instability that leads to the formation of magnetically pinched current filaments. The nonlinear evolution of this instability is of prime interest in astrophysics where it is held responsible for generating the magnetic turbulence in the precursor region of relativistic collisionless shocks [1]. It also plays an important role in high-intensity laser-plasma interactions in accounting for the angular spread of the laser-accelerated particles [2].



Space-time evolution of an initially y-periodic chain of current filaments in a plasma composed of two counterstreaming pair beams. The latter drift along the x-axis, and are described by Jüttner-Synge distributions of proper temperature $T_0 = m_e c^2$ and Lorentz factor $\gamma_0 = 10$. Space and time coordinates are normalized by the relativistic plasma frequency Ω_p associated with the peak density of a single electron beam .

In this presentation, we perform a linear stability analysis of a periodic system of relativistic current filaments described by a relativistic warm-fluid model. Using the Floquet theory, we compute the exact eigenmodes of the system, and show that the dominant modes transit from coalescence-type to kink-type instabilities with increasing nonlinearity and asymmetry between the plasma streams. Our theoretical predictions are supported by particle-in-cell simulations. In a strongly nonlinear symmetric configuration, the stationary state consists of a chain of Harris-type current sheets, for which we derive a new analytic expression for the relativistic kink instability. This formula closely matches the numerical results, and allows us to delimit the coalescence and kink-dominated parameter regions.

References

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