Spatial-temporal growth of filamentation instability

V B Pathak¹, T Grismayer¹, A Stockem¹, R A Fonseca¹,² and L O Silva¹

¹GoLP/Instituto de Plasmas e Fusão Nuclear, Instituto Superior Técnico, Universidade de Lisboa, Lisbon, Portugal

²Departamento de Ciências e Tecnologias da Informação, Instituto Superior de Ciências do Trabalho e da Empresa, Lisboa, Portugal

Abstract

Interaction of relativistic particle streams is ubiquitous in laboratory as well as astrophysical plasmas, and so are the instabilities such as Weibel, filamentation, Kelvin-Helmholtz and two stream instabilities. The available theoretical models for transverse instabilities, like filamentation and Weibel instabilities, are restricted only to purely temporal analysis and do not catch any spatial characteristics of the instabilities, which can be relevant for finite size beams.

Here we show spatial-temporal evolution of purely transverse filamentation instability by obtaining single differential equation governing the instability, as well as the exact analytical solutions for physically relevant initial conditions. The instability grows from the beam front to the back spatially up to a certain beam length, and then the instability acquires purely temporal behavior. This critical beam length increases linearly with time and also depends upon the beam velocity and instability characteristics. In ultra-relativistic regime the instability acquires purely temporal behavior. The analytical results are in good agreement with the multi-dimensional particle-in-cell simulations performed using OSIRIS.