

Linear Stability of an Impulsively Accelerated Density Interface in an Ideal Two-Fluid Plasma

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Inertial confinement fusion (ICF) is a promising method for the generation of fusion energy. By imploding the target to very high densities, it is expected that the fusion reactions occur and the fuel is confined by its own inertia. A key bottleneck towards the achieving goal of ICF is hydrodynamic instabilities, such as Richtmyer-Meshkov instability (RMI) which occurs when a perturbed density interface is impulsively accelerated [1, 2]. Due to the high temperature and high energy-density scenario in ICF, it is expected the materials to be in a plasma state, and thus could be influenced by a magnetic field. An effective fluid description for the plasma is two-fluid plasma (TFP) [3]. In this model, ions and electrons are treated as two separate fluids and are coupled to the full Maxwell equations. In addition, the electron particle mass and light speed are finite.

We investigate the linear evolution of RMI in the framework of an ideal TFP model. The TFP equations of motion are separated into a base state and a set of linearized equations governing the evolution of the perturbations [4]. Different coupling regimes between the charged species are distinguished based on a non-dimensional Debye length parameter $d_{D,0}$. When $d_{D,0}$ is large, the coupling between ions and electrons is sufficiently small that the induced Lorentz force is too weak and the two species evolve as two separate fluids. When $d_{D,0}$ is small, the coupling is strong and the induced Lorentz force is strong enough that the difference between state of ions and electrons is rapidly decreased by the force. As a consequence, the ions and electrons are tightly coupled and evolve like one fluid, as seen in Fig. 1, which shows the base state in the interaction of the shock with the density interface.

Figure 2 shows the evolution of ion and electron perturbations under various magnetic field. The temporal dynamics is divided into two phases: an early phase wherein electron precursor waves are prevalent, and a post ion shock-interface interaction phase during which the RMI manifests itself. We also examine the effect of an initially applied magnetic field in the streamwise direction characterized by the non-dimensional parameter β_0 . For a short duration after the ion shock-interface interaction, the growth rate is similar for different initial magnetic field strengths. As time progresses the suppression of the instability due to the magnetic field is observed. The growth rate shows oscillations with a frequency that is related to the ion or electron cyclotron frequency. The instability is suppressed due to the vorticity being transported away

from the interface.

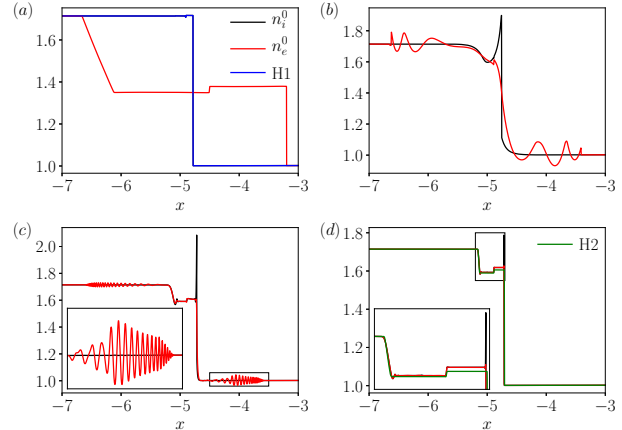


Fig. 1. Base number densities of ions and electrons at $t = 0.157$ for different Debye lengths; (a) $d_{D,0} = 10$, (b) $d_{D,0} = 0.1$, (c) $d_{D,0} = 0.01$, (d) $d_{D,0} = 0.001$. Hydrodynamic cases: H1 (limiting case when $d_{D,0}$ is infinite) and H2 (limiting case when $d_{D,0} = 0$).

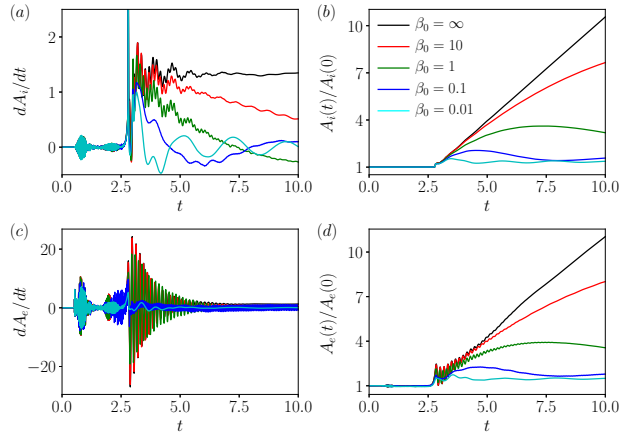


Fig. 2. Evolution of the growth rate and reference amplitude of the density interfaces for the cases with various β_0 ; the reference Debye length $d_{D,0} = 0.1$. (a) growth rate of ion interface, (b) amplitude of ion interface, (c) growth rate of electron interface, (d) amplitude of electron interface.

References

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