Collisional effects on beam transport in dense plasma

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The transport of high currents in dense plasma is an important issue relevant with the fast ignition scheme of laser fusion, which has been received significant interest in the last 10 years. In most previous studies, collisional effects on the beam transport have been ignored.

In this work, collisional effects on the transport of relativistic electron beams through cold dense plasma have been studied theoretically and numerically. Dispersion relation for kinetic beam-plasma instabilities in full k-space is solved by the Padé approximation of the plasma dispersion function and by rotating the coordinate system. It is shown that the electrostatic components of the general oblique mode are suppressed by the collisional effect while the electromagnetic components are enhanced by it. As a special case of the electromagnetic instabilities, the current-filamentation instability has the largest growth rate, which becomes dominant in the nonlinear stage as shown in our two-dimensional particle-in-cell simulations. It is also shown that, even though a beam appears divergent during the transport in dense plasma in the collisionless case, it becomes collimated in the collisional case due to stabilization of the electrostatic instabilities and magnetic collimation. This is favorable for the fast ignition scheme of laser fusion.

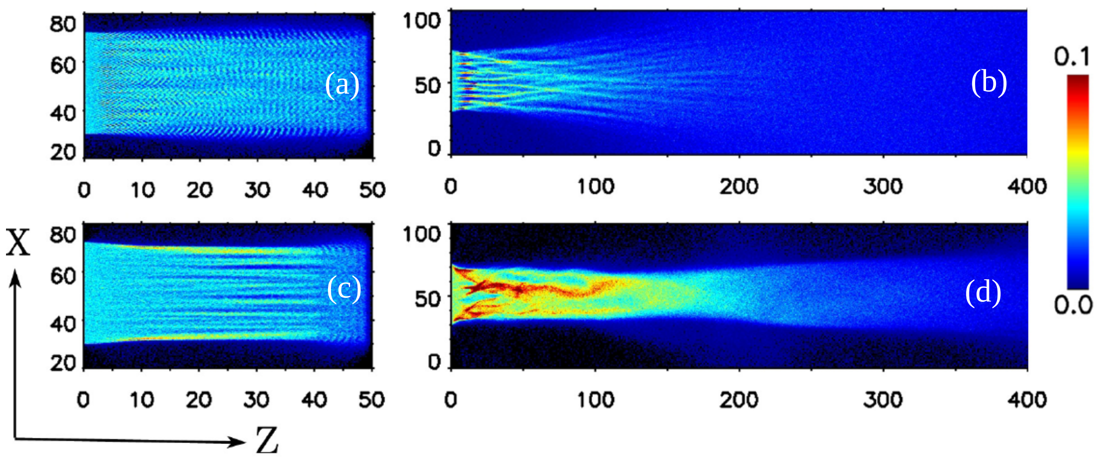

Figure 1: Snapshots of the beam electron density obtained by PIC simulation. Plots (a) and (b) show the results for collisionless plasma at different time, while plots (c) and (d) show the corresponding results for collisional plasma.

We have also invited the background plasma temperature on the filamentation instability. Earlier studies mainly consider the beam-temperature effect, the effect of background plasma is largely ignored. The beam temperature usually tends to suppress the filamentation instability. In the fast ignition scheme, the background plasma may be heated to keV level after pre-compression. We find that background plasma temperature can enhance the filamentation instability. In the simulation, it is found the forward beam current and the returning plasma current will pinch at first, resulting in space charge separation. The electrostatic fields tend to balance the magnetic pinch force and inhibit further filamentation. As the plasma temperature grows, the thermal suppression of the electrostatic fields becomes stronger, as a whole the current filamentation instability is enhanced as the plasma temperature grows.

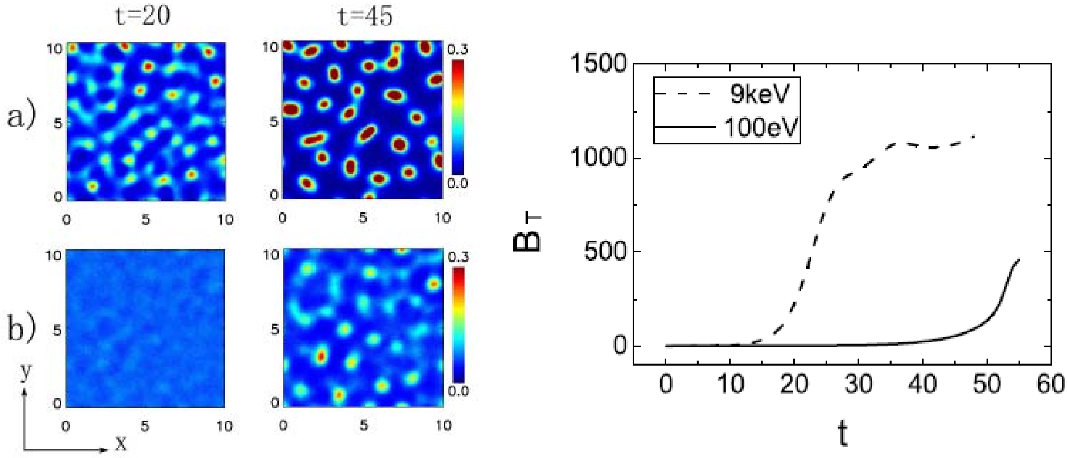

Figure 2: Snapshots of the evolution of the beam filament densities during the linear and the nonlinear stage for hot plasma T_p=9 keV (case a) and cold plasma T_p=100 eV (case b). Here x and y are normalized by c/ω_p. The right frame plots the energy of the magnetic field as a function of time for two initial plasma temperatures.

References

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