Kinetic and finite ion mass effects on the transition to relativistic self-induced transparency in laser-driven ion acceleration

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We study kinetic effects responsible for the transition to relativistic self-induced transparency (RSIT) in the interaction of a circularly-polarized laser-pulse with an overdense plasma and their relation to hole-boring (HB) and ion acceleration. It is demonstrated using particle-in-cell simulations and an analysis of separatrices in single-electron phase-space, that ion motion can suppress fast electron escape to the vacuum, which would otherwise lead to transition to the relativistic transparency regime. A simple analytical estimate shows that for large laser pulse amplitude a_0 the time scale over which ion motion becomes important is much shorter than usually anticipated. As a result, the threshold density above which hole-boring occurs decreases with the charge-to-mass ratio. Moreover, the transition threshold is seen to depend on the laser temporal profile, due to the effect that the latter has on electron heating. We report a new regime in which a transition from relativistic transparency to hole-boring occurs dynamically during the course of the interaction. It is shown that, for a fixed laser intensity, this dynamic transition regime allows optimal ion acceleration in terms of both energy and energy spread.

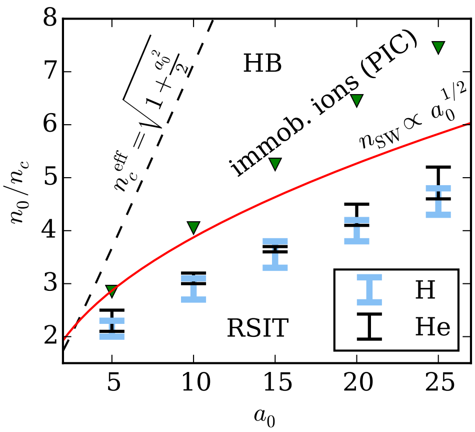

Figure 1: *Different transition thresholds between RSIT and HB: for infinite plane waves (black dashed line), cold-fluid threshold for existence of a standing wave [1] (red solid line), PIC simulations with immobile ions [2] (green triangles), PIC simulations for hydrogen and helium [3] (error bars). The dynamic transition regime lies within the error bars.*

References

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