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Effects of hole-boring and relativistic transparency on particle acceleration in overdense plasma irradiated by short multi-PW laser pulses

Masahiro Yano

Osaka university,

Abstract
Propagation of short and ultra-intense laser pulses in a semi-space of overdense hydrogen plasma is analyzed via full-relativistic, real geometry particle-in-cell (PIC) simulations including radiation friction. Margins of relativistic transparency and hole- boring are found to be settled by transverse plasma field, Raman scattering, and laser pulse filamentation. For laser intensities approaching I~1024 W/cm2 the direct laser acceleration of protons is shown to become essential resulting in proton injection in the acceleration phase of the compressed electron wave in the front of laser pulses. Protons, accelerated up to 10-20 GeV energies, are observed in plasma with density around a few critical. The effect rapidly disappears with density growth and intensity decrease.