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Ultra-relativistic laser-plasma interaction and beyond[1]

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Relativistic laser-plasma interaction (LPI) is of broad interest in modern physics, with applications ranging from particle acceleration, laboratory astrophysics, to fast ignition for inertial confinement fusion. LPI is a highly dynamic process, especially in the relativistic regime. The plasma conditions evolve rapidly upon intense laser irradiation, which modifies laser absorption and energy partition. This talk summarizes recent advances in understanding laser absorption and dynamics of ultra-relativistic LPI. It is found that the total absorption of laser pulses by solid targets is strongly enhanced in the ultra-relativistic regime, reaching a surprisingly high level of ~90% at intensities above $10^{20} W/cm^2$. Both presence of preplasma and hole boring contribute to the high absorption. The dynamics of hole boring is studied with a novel single-shot time-resolved diagnostic based on Frequency Resolved Optical Gating (FROG). Time history of the Doppler shift in the reflected light indicates that ponderomotive steepening occurs rapidly and majority of the laser pulse interacts with a sharpened density profile. Two-dimensional (2D) Particle-In-Cell (PIC) simulation results agree well with measurements for short pulses ($<$ 5 ps), however discrepancy showing up after 5ps for longer pulses, indicating 3D effect starts to play a role. In case of high-contrast laser pulses interacting with solid targets, the preplasma is minimal and the delicate competition between plasma creation and ponderomotive pushing results in a snake-like structure in the reflected spectrum. Finally, the talk will briefly cover potential schemes utilizing LPI as an amplification process of laser pulses for next-generation laser systems, which could enable "vacuum boiling" laser intensities for future experiments.

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