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Hot Electron Generation and Laser–Plasma Instabilities in Shock Ignition Relevant Experiments¹

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Shock ignition (SI) is an alternative inertial confinement fusion scheme, which uses a strong convergent shock generated by a $\sim 10^{16}$ W/cm² spike laser pulse to ignite a pre-compressed fusion capsule. Understanding nonlinear laser–plasma instabilities (LPIs) and hot electron generation is critical for SI. LPIs can reduce energy coupling through scattering but can also accelerate electrons that assist in shock generation. We have conducted a series of experiments on the OMEGA EP and OMEGA-60 laser facilities demonstrating that stimulated Brillouin scattering (SBS) can deplete the laser energy nearly 100% during the first ~ 0.5 ns of a 10^{16} W/cm² ultraviolet laser in an SI-relevant plasma ($L_n \sim 260 - 330$ μm). The pump-depletion starts from the ~ 0.02 critical density (n_c) region and progresses to the $0.1-0.2n_c$ region, which is evidenced by the shape of the laser-generated blast wave and the time-resolved stimulated Raman backscattering spectra. This dynamic pump-depletion is consistent with an ion-acoustic wave-breaking SBS saturation model. Strong SBS is also observed in our large-scale particle-in-cell modeling. Although the pump-depletion would inhibit the collisional laser absorption, LPIs convert 2–6% of the laser energy into hot electrons with $T_{\text{hot}} \sim 45 - 90$ keV, inferred from the bremsstrahlung x-ray spectra and Cu K-shell fluorescence from a target tracer. Overlapping beams doubled the energy conversion compared with the single beam configuration. Analytical models suggest that these hot electrons are suitable to generate the required 300 Mbar shock for SI in a megajoule laser facility.

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