Frustrated Brunel Heating by Relativistic Gyromagnetic Effects in Ultraintense Laser-Matter Interactions

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This presentation discusses a novel electron acceleration mechanism, frustrated Brunel heating, emerging in relativistic laser-matter interactions under ultrahigh contrast conditions. Conventional models of Brunel heating predict the generation of a single electron bunch per laser cycle when intense, p-polarized laser pulses interact with steep-density-gradient plasmas. However, our experiments using a 150 TW, 25 fs laser pulse and double plasma mirror setup have revealed the simultaneous production of two spatially separated electron beams, diagnosed via coherent transition radiation (CTR) emitted at both the fundamental and second-harmonic frequencies.

Complementary particle-in-cell (PIC) simulations indicate that when the relativistic electron gyrofrequency surpasses the laser frequency, a strong self-generated magnetic field confines electrons near the plasma-vacuum boundary. This magnetic trapping modifies the classical Brunel pull–push cycle, suppressing electron injection and resulting in micro-bunched beams with unique angular distributions. The confinement critically depends on maintaining a pre-plasma scale length shorter than the electron gyroradius; at larger scale lengths, the adiabatic confinement breaks down, and conventional J×B heating dominates.

These findings provide new insights into controlling electron beam divergence, energy distribution, and temporal bunching by precisely engineering plasma profiles at nanometer scales. Such control has significant implications for compact particle accelerators, ultrafast radiation sources, and fast-ignition inertial confinement fusion. Perspectives on future experimental strategies and theoretical modeling to further explore relativistic gyromagnetic effects will also be presented.

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References

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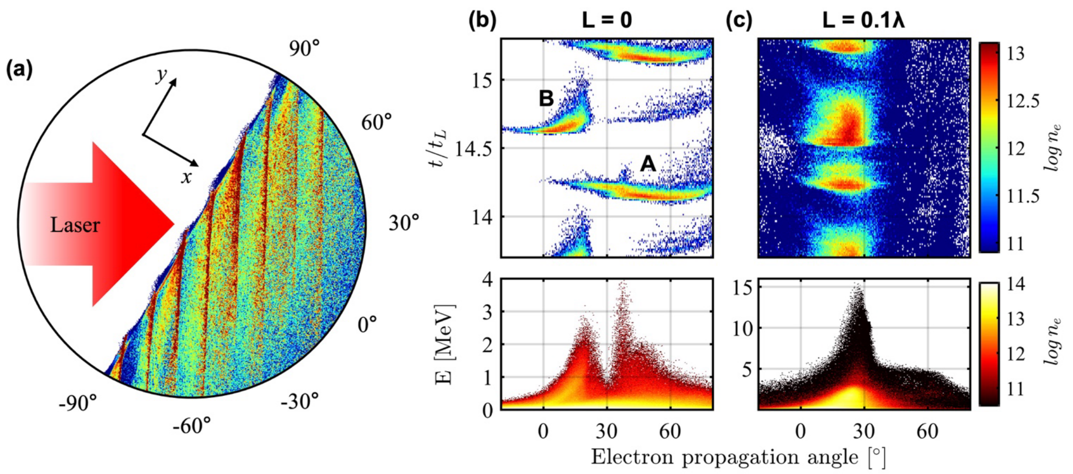

FIG. 1. (a) Snapshot of hot electrons within the target with a scale length $L = 0$. (b, c) Time-resolved angular divergence of hot electrons and the corresponding kinetic energy distribution for $L = 0$ and $L = 0.1\lambda$, respectively.