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Pulse Ramp Effects on Target Normal Sheath Acceleration at Relativistic Intensities

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This contribution demonstrates (through particle-in-cell simulations) that the rising edge of ultrashort laser pulses substantially alters the dynamics of laser-driven ion acceleration and leads to reduced cutoff energies in the Target Normal Sheath Acceleration (TNSA) regime for petawatt-level lasers.

The idealized ultrashort pulse with a Gaussian temporal shape, commonly assumed in most theoretical and numerical models of laser-driven ion acceleration, is accompanied by a relatively slow-rising leading edge, which is usually neglected. However, this leading edge—also referred to as a picosecond ramp—can significantly affect both the energy spectra and angular distribution of accelerated ions. At mildly relativistic peak laser intensities (up to 10^{20} W/cm^2), the picosecond ramp can exert a beneficial effect by enhancing laser energy absorption in the preplasma it generates.

In contrast, at highly relativistic intensities (above 10^{21} W/cm^2), relevant for PW-class laser pulses, the ramp reduces acceleration efficiency. This is due to substantial expansion of the target's rear side during the interaction of the rising edge with the target front. Such pre-expansion, occurring before the peak intensity interacts with the target, leads to a broader accelerating sheath with a significantly lower maximum accelerating field and a curved sheath surface. This results in reduced ion cutoff energies and broader angular distributions of high-energy ions compared to those produced by an idealized, clean ultrashort pulse.

References

[1] J. Psikal, *Effect of the rising edge of ultrashort laser pulse on the target normal sheath acceleration of ions*, Plasma Phys. and Control. Fusion **66**, 045007 (2024).