Accessing the relativistic transparency regime in laser-ion acceleration experiments

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In target normal sheath acceleration (TNSA), the onset of relativistic induced transparency (RIT) [1] can lead to increased proton energies due to volumetric heating of the target electrons by the transmitted laser light [2,3]. We present an experimental study investigating TNSA over a target thickness range spanning the typical TNSA-dominant regime ($\sim$ 1 μm) down to below the onset of relativistic laser-transparency (< 40 nm) [4]. The experiment was conducted with a single target material in the form of freely adjustable films of liquid crystals along with high contrast (via plasma mirror) laser interaction ($\sim$ 2.65 J, 30 fs, $I > 5 \times 10^{20}$ W cm^{-2}) under oblique incidence. The proton energy and spatial distribution, measured along the laser axis and in both front and rear target normal directions, evidence predominant proton acceleration along the target normal during high contrast interaction, even for ultra-thin targets. For the latter, changes in light transmission, maximum proton energy, and proton beam spatial profile indicate the onset of relativistic transparency.

References

[1] V. A. Vshivkov et al. Nonlinear electrodynamics of the interaction of ultra-intense laser pulses with a thin foil. Phys. Plasmas 5, 2727–2741 (1998).

[2] B. M. Hegelich et al. Laser-driven ion acceleration from relativistically transparent nanotargets. New J. Phys. 15, 085015 (2013).

[3] A. Higginson et al. Near-100 MeV protons via a laser-driven transparency-enhanced hybrid acceleration scheme. Nat. Comm. 9, 724 (2018).

[4] P. L. Poole et al. Laser-driven ion acceleration via target normal sheath acceleration in the relativistic transparency regime. New J. Phys. 20(1), 013019 (2018).