High-energetic proton beams with low divergence driven by twisted laser from double-layer target

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The study of compact high-intensity plasma-based proton sources is motivated by potential applications ranging broadly from high-brightness injectors for accelerators to inertial fusion and medical applications [1]. To fully realize their potential, it is critical to reduce the proton bunch divergence while maintaining energy gain.

Recent investigations demonstrated enhanced proton beam energies driven by Gaussian lasers from double-layer targets compared to thin solid targets [2]. In addition, it was recently proposed that twisted lasers can reduce the proton beams' divergence from single-layer targets [3]. However, it is yet to be determined if twisted light can also decrease the divergence from double-layer targets.

Here, we show that twisted laser drivers can substantially reduce the divergence of the accelerated proton bunches from double-layer targets. The self-consistent laser–plasma dynamics is investigated analytically and with three-dimensional particle-in-cell simulations in OSIRIS [4]. We found a weaker relativistic self-focusing [5] in the near-critical plasma layer to play a crucial role in improving the proton beam quality compared to Gaussian laser drivers. Furthermore, we identified a simplified scaling for a consistent generation of high-quality proton bunches for a broad range of laser pulse energies under experimentally feasible conditions.

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