High-energetic proton bunches from double-layer target driven by Laguerre-Gaussian laser

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Ultrashort (ps) high-energetic proton beams from high-intensity laser-plasma interactions find applications in various areas, such as in isochoric heating of solid-density matter [1], the generation of neutrinos [2], or as diagnostics for laboratory astrophysics experiments [3]. These applications require at least multi-10-MeV energies. Studies have demonstrated that double-layer targets can support enhanced proton energies in comparison to single foil targets due to an improved laser energy coupling [4] and Laguerre-Gaussian lasers [5] can support a lower divergence of the proton beam [6]. Here, we study a new setup dedicated to exploit the benefits of both, double-layer targets and Laguerre-Gaussian (first mode) drivers, by combining them. The self-consistent laser–plasma dynamics is investigated analytically and with three-dimensional particle-in-cell simulations in OSIRIS [7]. The work was devoted to examining the effects of relativistic self-focusing of Gaussian and Laguerre-Gaussian drivers in the near-critical plasma part of the target. The results demonstrate that by utilizing the cylindrical symmetry and the more stable self-focusing properties of a Laguerre-Gaussian driver, the laser can drive high-energetic proton bunches with a significantly reduced divergence, in comparison to a Gaussian driver containing the same energy. We identified a simplified relation between the laser pulse energy and the target composition which always leads to high-quality proton bunches, for a broad range of laser pulse energies under experimentally feasible conditions. The potential use of these proton bunches will also be discussed.

References

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