Low proton bunch divergence from double-layer target driven by twisted light

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The study of ultrashort (ps) multi-MeV proton bunches generated during high-intensity laser-plasma interactions is motivated by a wide range of applications such as the modification of material parameters or 'fast ignition' of inertial confinement fusion [1]. Plasma-accelerated multi-10-MeV protons are already in use [2], but applications such as radiation therapy require an improvement of the proton bunch properties, e.g. collimated bunches with energies in excess of 200 MeV [3]. While lasers with orbital angular momentum (OAM) [4] can lead to a reduction in beam divergence [5], double-layer targets can support enhanced proton energies in comparison to single foil targets due to an improved laser energy coupling [6].

Here, we study how to exploit the benefits of both, lasers with OAM and double-layer targets, by combining them. The self-consistent laser–plasma dynamics is investigated analytically and by relying on three-dimensional particle-in-cell simulations in OSIRIS.

The work was devoted to examining the effects of relativistic self-focusing of Gaussian and OAM laser 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 an OAM laser, 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, accelerated by the same mechanism, for a range of laser pulse energies under experimentally feasible conditions.

References

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