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Enhanced laser-driven proton acceleration through Formvar film production

Conventional accelerators, which use radio-frequency fields, can only reach maximum acceleration field strengths on the order of 1 MV/cm [1], resulting in large footprints and high associated costs, especially for low-energy (MeV range) applications. In contrast, laser-driven accelerators have consistently reached acceleration field gradients on the order of GV/cm to TV/cm, rendering them a promising, more compact alternative [1,2].
While in the last decade developments in ultra-short-pulse high-intensity lasers have made laser-driven acceleration an emerging alternative [1,2], several challenges are yet to be overcome to produce stable beams, capable of operating for prolonged periods of time, with optimum fluxes and energies. For laser-driven proton acceleration specifically, one crucial area for further improvements is target production, as targets are the site where high-intensity laser-plasma interactions occur [1]. At the Laser Laboratory for Acceleration and Applications (L2A2) facility, the use of 8 μm Al foils in multi-shot operation has produced proton beams with energies on the order of ~1.2 MeV [3]. However, most foreseen applications, such as radionuclides-based medical imaging, can require energy of tens of MeV.
Our work addresses this challenge by developing ultrathin (below 1 μm) plastic films, with and without silver-coatings, to improve the performance of laser-driven proton acceleration at the L2A2 facility. Protocols were developed to produce films as thin as 250 nm using Polyvinyl formal, also known as Formvar. The silver-coatings were produced via vacuum thermal evaporation, a well-known physical vapor deposition technique [4]. The films were characterised by two previously established techniques, transmission alpha-energy loss and Rutherford backscattering spectrometry, as well as a new X-ray attenuation technique, which was benchmarked in this work. At the L2A2 facility, protons were accelerated by the Target Normal Sheath Acceleration (TNSA) mechanism. Results from time-of-flight beam diagnostics show that plain Formvar films performed better than the silver-coated one, with achieved energies more than doubled when compared to previous reported values [3]. Thinner films reached peak energies of 3.5 MeV, and increased the proton flux as well, reaching orders of ~10^10 MeV−1·srad−1.
Our results demonstrate the significant impact that improvements on film production can have on laser-driven proton acceleration, leaving the door open for further improvements, to increase the feasibility of laser-driven proton acceleration as an alternative to conventional acceleration.

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