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Advancements in double-layer target production for enhanced laser-driven ion acceleration

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Laser-driven ion sources [1] represent a promising alternative over conventional ion and electron accelerators, with potential applications ranging from the medical field [2] to nuclear and material science [3]. Compact laser-driven ion sources would be a valuable asset in many of those applications, exploiting tabletop laser systems—in the range of tens of TW and capable of high repetition rate operation. To make up for the laser relatively modest characteristics, it is crucial to drive an efficient acceleration process, shifting the focus to advanced targetry. If the front side of a micrometric or sub-micrometric solid target is covered with a near-critical density layer, the laser-matter coupling and thus the acceleration process are enhanced, as demonstrated in numerical and experimental studies [4,5]. At high repetition rate operation, shot to shot variation in target properties should be minimized, a further challenge for target manufacturing.
In this contribution we present the full production and characterization of near-critical double-layer targets (DLTs), in the form of arrays on a perforated target holder, ready to be employed in particle acceleration experiments. The DLTs are composed of a near-solid density titanium thin film, coupled with a nanostructured carbon foam layer of near critical density.
The deposition of titanium (Ti) film on the hollow holder is achieved by first filling the holes with caramel, thus levelling its surface. The magnetron sputtering technique is then exploited to deposit a solid film, both in DCMS (Direct Current Magnetron Sputtering) and HiPIMS (High Power Impulse Magnetron Sputtering) regimes [6]. An ideal combination is found alternating the two techniques during the deposition, allowing a fine control of the film morphology, density, uniformity and internal stresses. All these properties are of great importance for the film mechanical stability, while the film thickness uniformity and its density could be relevant also for the acceleration process. After the deposition the caramel can be dissolved in water, leaving a flat freestanding Ti film with near bulk density, low residual stresses and high thickness uniformity over the whole target holder area. Freestanding Ti films ranging from 400 nm to 1.8 μm were successfully produced.
Nanostructured carbon foams are porous materials with a fractal structure and mean density down to a few mg/cm3 [7], thus one of the few possible candidates for the near-critical layer. They are deposited on the freestanding Ti film with femtosecond Pulsed Laser Deposition (fs-PLD), a variation of the conventional nanosecond PLD employing shorter laser pulses. This effectively extends the range of the experimental parameters available to the technique, allowing a better control of the carbon foam properties. The compatibility between film and foam is also explored.
Finally, 2D particle in cell (PIC) simulations are performed considering the DLT range of parameters obtained experimentally, assuming both TW and PW class lasers; the results show a significant enhancement in the acceleration process, acting as a useful support for the foreseen experimental ion acceleration campaigns.

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