

Ultra-high intensity laser interaction with nanostructured near-critical foams: numerical modelling and experimental challenges

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Foam-based targets are appealing for driving high-efficiency radiation-matter coupling in high-energy-density and high-intensity physics experiments [1-4]. In particular, low-density foams enable the generation of a near-critical plasma in which laser pulses with relativistic field strength, $a_0 \gg 1$, propagate. In this plasma, the laser delivers its energy to a large number of electrons and ions, possibly creating efficient radiation sources from the acceleration of these species [5-6], and from the generation of secondaries such as gamma rays and positrons through processes mediated by laser or matter fields [7-12]. Such low-density foams can be produced with pulsed-laser deposition, a physical deposition technique that provides the material with a fractal nanostructured morphology [13], which affects the laser-foam interaction [7,10].

The present contribution discusses kinetic simulations on the efficient super-ponderomotive acceleration of electrons and generation of gammas and positrons with energies of hundreds of MeV that can happen in nanostructured foams [10]. The impact of foam morphology is taken into account and discussed considering how the multiple length and density scales of these targets, ranging from nanometric to micrometric scales, can affect the interaction. Indeed, foam morphology can suppress the highest energy tail of particle spectra compared to homogeneous targets and at the same time induce additional processes related to local inhomogeneities.

The discussion on laser-foam interaction is also extended to the preparation of experimental campaigns. At high-energy, high-power laser facilities, several non-idealities must be considered to achieve the results predicted with foam targets. The difficulties range from controlling crucial laser parameters, such as polarisation and the temporal and spatial contrast of the pulse, to designing and handling foam targets and diagnostics. By combining numerical studies with experience at PW-level laser facilities such as Apollon [14], we discuss solutions at the target and setup levels to the challenges mentioned above, which will help the preparation of the next experimental campaigns.

Our contribution aims to build all the theoretical and practical knowledge needed to use nanostructured foam targets in experiments relevant to the design of radiation sources, the study of laser-driven fusion, the creation of dense, relativistic pair bunches, and the exploration of strong-field quantum electrodynamics.

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