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Laser-driven generation of collimated quasi-monoenergetic proton beam using double-layer target with interface modulations

2D PIC simulation of high-intensity laser pulse and double-layer deuterium-hydrogen target with modulated interface. The laser pulse (grey-green color in the image) initiates instability on the interface between deuterium (blue) and proton (purple to orange) layers. It results in generation of collimated quasi-monoenergetic proton bunch of high energy.

With the advent of multi-petawatt laser systems like the ELI-Beamlines (Czech Republic), APOLLON (France) and SEL (China) the laser-driven ion accelerators will enter the acceleration regimes dominated by radiation pressure [1]. High quality ion beams with low emittance and narrow energy spectrum will be generated when these lasers irradiate tailored targets.

Pre-modulated targets can undergo relativistic Rayleigh-Taylor and Richtmyer-Meshkov like instabilities, which can improve the properties of generated ion beams [2,3].

We study the effects of the interface modulations in double-layer targets with 2D numerical particle-in-cell (PIC) simulations using the code EPOCH [4].

The target consists of deuterium (blue color scale in the image) and proton (purple to orange scale) layers. The color scales represents deuterium and proton densities with maximum value (light blue and orange, respectively) set to the initial density. Full density is indicated by the vertical height. The electric field of linearly s-polarized (electric field is perpendicular to the plane of incidence) Gaussian laser pulse is represented by both the vertical height and by the grey-green scale.

Small perturbations originated from the interface modulation grow during the laser-target interaction. This leads to the formation of low-density regions and high-density ion bunches between them at the positions determined by the pre-modulation geometry. The ion bunches are then accelerated by the laser radiation pressure. The collimated central bunch of proton beam has the average energy in the multi-GeV range with narrow energy spread. The laser accelerated ion beams from composite targets may also find applications in material sciences and nuclear physics research [5]. Further information can be provided during the poster presentation P1.2007 and in the corresponding EPS conference paper [6].

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The image was produced in collaboration with our colleagues from the Virtual Beamline (VBL) team at ELI-Beamlines.

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