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Ion acceleration from solid and low-dense targets

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Recent progress in the technology of intense short pulse lasers and production of unique laser targets is making it possible to manipulate laser-target designs in the interest of proton acceleration with lasers for different applications. For example, the capability to modify the traditional very broad, thermal-like energy spectrum of the accelerated particles typically generated from short laser pulse interaction with plasmas has been demonstrated in several experiments. This step towards the generation of monoenergetic proton features shows a distinct improvement of energy spectra, which together with overcoming the 200 MeV threshold may open the way to practical implementation of laser-based proton accelerators for therapeutic applications.

In this work, based on 3D PIC simulations we study proton acceleration from laser interaction with low-density targets (dense gas jets or aerogels) and solid targets (ultra-thin foils) for the same laser energies to carry out a comparative analysis of the characteristics of the accelerated protons with energy in extend of 100 MeV. By using different laser light polarizations, pulse durations, radial intensity distributions and target parameters we studied the different regimes of laser-plasma interaction to find optimal conditions for the best quality of the proton beams. We discuss advantages and disadvantages of solid, gas jet, and aerogel targets. Gas jet targets are often used for electron acceleration in the concept of laser wakefield acceleration. At the same time, when laser pulse leaves a plasma slab (cross plasma-vacuum boundary) the ions from near rear side region start to accelerate and may gain significant energy. The most effective ions acceleration could be achieved from the targets with near critical electron density, where large enough number of hot electrons is accelerated in plasma channel to create essential electrostatic field at the plasma boundary. The finite back-side density gradient results in reduction of ion energy and, because of that, utilization of aerogel target with easy to do sharp target-vacuum interface is expected to have advantage for ion acceleration.

The 3D PIC simulation study demonstrates that proton beams with therapeutic energy and small energy spread can be generated from ultra-thin (submicron) mass-limited targets with embedded hydrogen impurity irradiated by powerful (with intensity of the order of 10^{22} W/cm²) ultra-short laser pulses.