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Proton Acceleration from Mass-Limited Targets

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Due to isolation and mass-limitation of laser irradiated targets several phenomena have been predicted regarding to the emission of ions with high kinetic energy. Theoretical investigations predict higher proton energies [1] compared to foil targets of similar thickness. However, the expected increase in the ion energy has not yet been observed. In fact, the ion energies measured using mass-limited targets in the TNSA regime have been even lower than those achieved with the commonly-used extended foils in our experiments. We study laser driven ion acceleration using isolated mass-limited spheres with a diameter down to 8 µm for the first time. Proton imaging is used to investigate the acceleration process form irradiated micro water droplets [2]. Unlike most other common targets, water droplets are spherical, mass limited and not grounded. Furthermore such a target system can be used for ion acceleration with a high repetition rate. Such produced ion beams have unique attributes like quasi-monoenergetic spectra [3]. Due to the spherical geometry the protons are usually emitted over the full solid angle. However in the experiments a directional ion emission has been observed. The proton images obtained in our experiments show several indications that an ambient plasma (ionized water vapor) plays an important role for the whole processes of charge transfer which is essentially for the fields being responsible for ion acceleration [4]. Therefore, we studied fully isolated spheres made of glass. In this experiment, we realized a novel approach to investigate the mechanism of laser driven ion acceleration from mass-limited targets. To prepare fully isolated targets, without the influences of mountings, neighboring targets or ambient plasma, we set up a linear Paul trap. We measured ion spectra from different sphere diameters between 30 and 8 µm. 2D-PIC and hydro-code simulations were used to show that the pre-plasma at both the front and rear sides of the target crucially affect the efficiency of the ion acceleration. The mechanism, of the plasma flow around mass-limited targets, has not been recognized so far for laser driven ion acceleration. Our models indicate that this effect causes the observed limitation to the ion-beam energy in former as well as in our experiments.

References:

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