Dominance of hole-boring radiation pressure acceleration regime with thin ribbon of ionized solid hydrogen

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Ion acceleration driven by high-power femtosecond laser pulses has been attracting great interest for almost last two decades. Most experimental groups have been studying laser-ion acceleration from thin metal or insulator foil targets driven by thermal expansion of laser-heated electrons in the so-called Target Normal Sheath Acceleration (TNSA) mechanism [1]. However, this mechanism has a limited efficiency, i.e. usually only a few per cent of laser pulse energy is transferred into the kinetic energy of accelerated ions which are mostly protons from low-Z hydrocarbon deposits on the target rear surface. On the path towards increased efficiency of laser-proton acceleration, alternative mechanisms to TNSA have to be investigated. One of the most promising mechanisms different from TNSA is radiation pressure acceleration (RPA) [1]. In this scenario, a compressed cloud of electrons is created by the ponderomotive force driven by incident laser beam in the irradiated layer of the target, electrostatic field arises from this charge separation and accelerates ions.

The use of newly developed hydrogen solid cryogenic target with the thickness down to 25 μm was demonstrated in experiments with nanosecond laser [2] and experiments with these targets on high pico-/femtosecond laser facilities are foreseen. The target from ionized solid hydrogen should be relatively thin, low density, capable of producing only protons (with no contaminants) and of operating at a high repetition rate as both refreshable and debris free. Thus, this hydrogen solid ribbon is a good candidate for hole boring (HB) RPA regime which requires a relatively low density (but overdense) targets composed of light ions in order to reach a high hole boring velocity [3].

In this contribution, we demonstrate by multidimensional particle-in-cell simulations that HB RPA mechanism hugely dominates over TNSA both in numbers and maximum energy of accelerated protons for laser power of several PWs and pulse duration of several hundred femtoseconds by using ionized hydrogen ribbon of realistic thickness. For example, we should largely exceed 200 MeV for accelerated protons by using 25 μm thick ribbon irradiated by the laser pulse of power 4 PW and of duration about 300 fs. Such laser beam parameters should be available in near future in the frame of ELI-Beamlines project (L4 laser). Although the maximum energy of protons accelerated from the hydrogen target is near the maximum energy of protons accelerated from much thinner polyethylene target (of the thickness of about 5 μm), the number of high-energy protons is substantially higher in the case of hydrogen target.

References

[1] A. Macchi *et al.*,Rev. Mod. Phys. 85, 751 (2013)

[2] D. Margarone *et al.*, Phys. Rev. X **6**, 041030 (2016)

[3] B. Qiao *et al.*, Phys. Rev. Lett. **108**, 115002 (2012)