Energy dispersion of radiation pressure accelerated ion beams

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Radiation pressure acceleration of ion beams with high-intensity laser has recently attracted a lot of attention as it provides a possibility for highly-efficient generation of quasi-monochromatic ion beams. Numerous works have already discussed, in both the relativistic and non-relativistic regimes, the ion energy, conversion efficiency and target optimal parameters for both thick or ultra-thin targets where ion acceleration proceeds in the regimes of hole-boring or light-sail, respectively. While most of these works discuss the generation of quasi-monochromatic ion beams, the omnipresent mechanisms responsible for energy dispersion have however not yet been addressed in details.

In this work, various sources of energy dispersion are investigated using analytical modeling and particle-in-cells simulations. First, we discuss the ion energy dispersion which arises from the finite time required for the ions to be reflected by the piston. During this time the accelerating electrostatic field can vary so that ions are reflected by the laser piston at different velocities. In the hole-boring of a semi-infinite target, such a phenomenon gives rise to the so-called piston oscillations. We revisit this mechanism and discuss its consequences on the acceleration of ion bunches from thin targets.

Furthermore, the effects of the laser pulse duration and its temporal profile are discussed. In particular, it is shown that during the irradiation of a thin-target, a part of the laser energy is stored in the electrostatic field. Once the laser pulse is turned off, this energy stays with the electrons which start to quiver around the ion layer, then inducing an adiabatic expansion of the quasi-neutral plasma. The consequences of this expansion in terms of ion energy dispersion can be important and ways to limit them are proposed.

Finally, guidelines for optimization of laser-target parameters to generate high-quality ion beams suitable e.g. for hadron-therapy are given.