LASER DRIVEN ION ACCELERATION FROM A CRYOGENIC HYDROGEN RIBBON

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Laser driven ion acceleration is a widely investigated research topic in the field of physics nowadays as a result of the recent fast development of high power laser systems allowing to explore laser-matter interaction at ultrahigh laser intensities (10^{19}-10^{22}W/cm^2). Among different physical mechanisms of laser-driven ion acceleration that have been investigated to date, Target Normal Sheath Acceleration (TNSA) is the most robust and experimentally investigated one. In this regime ions are accelerated at the rear side of a thin (micrometer) target in a quasi-electrostatic sheath formed by fast electrons propagating from the target front side. The acceleration process takes place till restore of charge neutrality and finally both ions and electrons move together in a ballistic way. The ion energy distribution depends on both laser power and target nature.

Laser accelerated ion beams draw attention for their potential multidisciplinary applications, e.g. inertial confinement fusion, probing of ultrafast field dynamics or, ultimately, laser-based radio oncology (namely hadrontherapy). Multidisciplinary applications, especially medical ones, have stringent requirements for laser-accelerated ions, such as high-energy (60–250 MeV), high average current (in principle achievable by using 1–10-Hz lasers), target purity, repeatable generation, and monochromaticity.

The recently built new research infrastructure ELI Beamlines, which is a part of the Extreme Light Infrastructure (ELI) project, is intended to provide high repetition rate PW-class laser beam for basic and applied research. Besides lasers, it is equally important to develop novel target media specifically tailored to advanced interaction regime. Traditional targets like metals or carbon foils usually have some limitations which make laser-accelerated beams not suitable for applications. Thin cryogenic targets (1–50 μm) of high purity with relatively low electron density (5×10^{20}–5×10^{22} cm^{-3}), capable of producing only protons (with no contaminants) and of operating at a high repetition rate as both refreshable and debris free are very promising.

From this perspective, both liquid and solid cryogenic targets are currently being considered and several approaches are being explored and developed. The ELISE cryogenic target delivery system designed and developed at the Low Temperature Laboratory of CEA enables the production of the continuous flow of a solid-H_2 slab (ribbon) through a newly designed extrusion apparatus that does not contain any movable parts [2]. A research group from SLAC National Accelerator Laboratory, USA has designed a cryogenic microjet source, which can deliver a continuous stream of liquid hydrogen with a diameter of a few microns that is compatible with high-intensity and/or high-repetition-rate laser-plasma experiments [3].

Using a cryogenic target both liquid and solid, it was demonstrated that a multi-MeV pure proton beam can be produced through high-intensity laser interaction [3]. The high purity, limited size, moderate density, and ability to use hydrogen isotopes make this target highly favorable for innovative studies. The generation of pure hydrogen plasma has advantages from the experimental point of view in terms of plasma modelling and characterization (single ion species), as well as for future multidisciplinary applications of laser-accelerated proton beams in cancer therapy.

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