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Contaminant layer depletion and ion focusing using the Target Normal Sheath Acceleration (TNSA) mechanism

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Abstract

When a relativistic laser (> 10^{18} W/cm^2) laser is incident on a solid target, the laser directly accelerates electrons to kinetic energies exceeding many MeV. If the solid target is relatively thin, less than 100 µm or so, the electrons will create a strong electrostatic field along the target-vacuum interface. This sheath field then accelerates ions normal to the target surface; a process called target normal sheath acceleration (TNSA) [1]. TNSA is a robust process that has been studied for more than 20 years [2]. An enduring feature of TNSA is the dominant acceleration of protons independent of the target material (e.g., Cu, Au, plastic). This is due to the presence of hydrocarbon contaminants on the target surface. These contaminants can be removed by heating or sputtering, which require external equipment. However, if the laser fluence is high enough, then the protons can be depleted by the laser itself [3]. Using this process, we show a factor of 100 increase in conversion efficiency into deuterons from a deuterated plastic target irradiated by a high-fluence laser [4].

In addition to accelerating ions, the electron-generated electric fields can be used to focus ions. This can be accomplished by using a separated plasma lens to focus ions many millimeters away from the target; for instance, at 30 mm a 1 mm focal radius of the ions can be attained [5]. Additionally, the TNSA target can be spherically curved in such a way that the fields accelerate ions inward to achieve focal radii of less than 10 µm at around 100 µm from the target surface [6]. In theory, the radius of curvature of these targets will adjust the focus distance of the ions. We will discuss the topics of contaminant layer depletion and ion focusing using a combination of experimental data and particle-in-cell simulations.

References

[1] Wilks et al., Phys. Plasmas 8, 542 (2001).
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[6] Bartal et al., Nature Phys 8, 139 (2012).