Ion Acceleration from the Interaction of an Ultra-Intense Laser Pulse with a Thin Foil

Matthew Allen
Dept. Nuclear Engineering
UC Berkeley
mallen@nuc.berkeley.edu

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Abstract

The discovery that ultra-intense laser pulses ($I > 10^{18}$ W/cm$^2$) can produce short pulse, well collimated, high energy proton beams [1, 2, 3, 4] has renewed interest in the fundamental mechanisms that govern particle acceleration from laser-solid interactions (c.f. Ref. [5] and ref. therein). Experiments have shown that protons present as hydrocarbon contaminants on laser targets can be accelerated up to energies $> 50$ MeV [1]. Well diagnosed and controllable proton beams will have many applications: fast ignition [6], production of medical isotopes [7], and as a high-resolution radiography tool for diagnosing opaque materials and plasmas [8, 9, 10].

Different theoretical models that explain the observed results have been proposed. One model describes a front-surface acceleration mechanism based on the ponderomotive potential of the laser pulse [11]. Another model known as Target Normal Sheath Acceleration (TNSA) proposed by Hatchett et al. and Wilks et al. [12, 13] describes the mechanism as an electrostatic sheath, on the back surface of the laser target. We present experiments and simulation results that determine the dominant acceleration mechanism.

Au foils were irradiated with a 100-TW, 100-fs laser at intensities greater than $10^{20}$ W/cm$^2$ producing proton beams with a total yield of $\sim 10^{11}$ and maximum proton energy of $> 9$ MeV. Removing contamination from the back surface of Au foils with an Ar-ion sputter gun reduced the total yield of accelerated protons to less than 1% of the yield observed without removing contamination. Removing contamination the front surface (laser-interaction side) of the target had no observable effect on the proton beam. We present a one-dimensional particle-in-cell simulation that models the experiment. Both experimental and simulation results are consistent with the TNSA back-surface acceleration mechanism.
References