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Acceleration of energetic ion beams using ultra-thin targets interacting with the high intensity short pulse laser*

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Over the past several decades, the most intensively investigated concept for high intensity laser-driven ion acceleration has been target normal sheath acceleration (TNSA)[1,2]. In the vast majority of such previous studies, solid density foil targets ranging in thickness from a few to several tens of microns have been irradiated by linearly polarized, intense (10^{18}–10^{21} W/cm^2) laser pulses. However, the TNSA mechanism has the issue of a slow scaling law of $E \sim I^{0.5}$, where I is the laser intensity, and the produced ion beams are typically characterized by low particle density, large divergence and broad continuous energy spread. For applications such as in cancer therapy, isochoric heating and ion-driven fast ignition [3], it is important to improve both the laser-driven ion source energy and beam quality.

In this talk, we will present the results on ion acceleration as a function of various laser parameters such as the laser pulse length, energy, spot size and intensity using ultra-thin (35-500 nm) targets of various materials namely Si, Ti, Cu and Au. The data shows that the ion acceleration mechanism changes with the thickness of targets [4]. Also, interaction of high contrast laser pulses with ultra-thin targets shows the acceleration of quasi mono-energetic Ti ions with energies in excess of 100 MeV with an optimum acceleration for 100 nm thickness with two populations of nearly collimated and quasi-mono-energetic titanium ions. Simulations were performed using 2D particle-in-cell (PIC) EPOCH code [5]. The quasi mono-energetic Ti ions were observed, and the energy and directionality of these ions agree with the experimental data, with a similar optimum thickness of the 100 nm. The simulation results show that the laser breaks through the target due to relativistically induced transparency (RIT), which divides the ionization and acceleration processes into two stages. The quasi mono-energetic Ti ions at the target rear-side are accelerated first by the electric fields due to the Target Normal Sheath Acceleration (TNSA) before the laser breaks through the target, and then by the self-generated electric fields due to the electron pressure gradient during the plasma expansion in the late stage. Once the laser beam breaks through the target, the Ti ions are rapidly ionized by the laser field to Ti^{20+} near the laser axis and $Ti^{12\sim19+}$ off the laser axis.

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