Enhanced ion acceleration from thin foils driven by ultra-intense femtosecond lasers

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State-of-the-art high-power lasers are reaching ever-higher focal intensities, enabling discoveries in high-field science. One key application is the generation of high energy particles from irradiation of solid foils. We will present a summary of our recent investigations on laser driven ion acceleration using femtosecond-class laser systems operating with ultra-high focal intensities exceeding 10^{21} W/cm^2. Initially, we irradiated >μm thickness foils to investigate the target normal sheath acceleration (TNSA) regime and scaling to ultrahigh intensities [1]. Using increasingly small focal spots to boost intensity leads to marginal improvement in electron and proton energies. Nevertheless, we demonstrated generation of proton beams up to 40 MeV at 0.1 Hz using a tape target [2].

To further boost the ion energies, we subsequently investigated other acceleration mechanisms. Using the J-KAREN-P and DRACO-PW lasers, we irradiated sub-μm thickness formvar foils to explore the relativistic transparency regime driven on femtosecond timescales [3]. Despite a modest laser energy (~10 J) and no contrast-enhancing plasma mirrors we generated high energy protons (>60 MeV) and carbon (>30 MeV/u) at an optimum thickness of ~250 nm.

In this talk we will discuss in detail high-fidelity 3D PIC simulations of the acceleration process. Acceleration is optimised when prepulse driven expansion primes the target density to be matched to the relativistic critical density threshold for relativistically induced transparency. The laser ponderomotively blows out electrons from the transparent target, causing a strong transient space charge in the densest region. Ions accelerated from this region are post-accelerated in large-scale sheath fields. These results pave the way for the establishment of repetitive laser driven ion sources using current femtosecond-class lasers, providing high peak current beams ideal for radiobiology and materials science.

References

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