Staged ion acceleration from ultrathin foils with sub-ps, near-PW pulses

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Acceleration of ions using ultrashort intense laser pulses is an ongoing area of research with a wealth of possible applications. Ions are typically accelerated via the target normal sheath acceleration (TNSA) mechanism [1], whereby the laser generates a hot electron sheath on the rear surface of the target, creating a very large electric field, which accelerates protons and heavier ions present on the target rear surface to MeV energies over much shorter distances compared to conventional RF accelerators.

Beyond TNSA, as the laser ramps up in intensity, radiation pressure acceleration (RPA) progressively acquires more importance. If the target is sufficiently thin, the bulk of the target is accelerated as a whole, in the so-called light sail (LS) mechanism. However, in order for LS to work, the plasma must remain opaque to the laser radiation, meaning that effects such as relativistic transparency must be suppressed. This has been achieved previously by using circularly polarized laser pulses, as opposed to linearly polarized, to minimize the **J×B** heating of electrons [2]. Another method to delay the onset of transparency and enhance the effect of RPA is to split the main pulse into multiple pulses at lower intensities in a staged acceleration scenario – subsequent pulses will irradiate the target at later times and focussed deeper into the target. This scheme works because in the LS regime, the ion energy scales with the laser fluence, rather than the intensity [3].

Presented here are the latest results from an experimental campaign undertaken on the Vulcan Petawatt laser system at the Central laser facility in the UK. In this experiment ultrathin gold, plastic, and deuterated plastic foils were irradiated with picosecond pulses in both single and double stage scenarios. Deuterated foils were chosen because, during the LS acceleration phase, D-D reactions in the compressed target produces a beam of high energy neutrons, allowing the ability to diagnose the efficiency of the LS mechanism without the influence of any TNSA field post-RPA. Examining the proton, ion and neutron spectra together allows to identify the optimal conditions under which the LS regime is most dominant.

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