Advanced approaches to high intensity laser-driven ion acceleration

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Since the pioneering work that was carried out 10 years ago, the generation of highly energetic ion beams from laser-plasma interactions has been investigated in much detail in the regime of target normal sheath acceleration (TNSA), fueling visions of compact, laser-driven ion sources for applications such as ion beam therapy of tumors or fast ignition inertial confinement fusion. However, new pathways are of crucial importance to push the current limits of laser-generated ion beams further towards parameters necessary for those applications.

We present advanced experimental approaches to high intensity laser-driven ion acceleration that reach beyond TNSA. Using nm-thin, free-standing diamond-like carbon (DLC) foils, a new regime of ion acceleration was found where the laser transfers energy to all electrons located within the focal volume. While for TNSA the accelerating electric field is stationary and ion acceleration is spatially separated from laser absorption into electrons, now a localized longitudinal field enhancement is present that co-propagates with the ions as the accompanying laser pulse pushes the electrons forward [1]. Unprecedented maximum ion energies were obtained, reaching beyond 0.5 GeV for carbon C\textsuperscript{6+}. When changing the laser polarization to circular, electron heating and expansion were shown to be efficiently suppressed, resulting for the first time in a phase-stable acceleration that is dominated by the laser radiation pressure which led to the observation of a peaked C\textsuperscript{6+} spectrum [2]. Compared to quasi-monoenergetic ion beam generation within the TNSA regime, a more than 40 times increase in conversion efficiency was achieved. The possibility to manipulate the shape of the ion acceleration front was successfully demonstrated by use of a spherically curved target surface [3].

References

