Ion acceleration from ultrathin foils: dependence on target thickness and laser polarization

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Laser-driven acceleration of ions is currently receiving significant attention worldwide, with recent experiments giving new insights into the acceleration mechanisms and expanding the possibilities of application to interdisciplinary fields. Until recently, most experimental research has been interpreted in terms of the so-called Target Normal Sheath Acceleration (TNSA) process, while the highly promising mechanisms based on Radiation Pressure Acceleration (RPA), although extensively studied from a theoretical point of view, remain still not adequately explored experimentally. The processes coupling laser energy to the ions of an ultrathin foil have a complex dependence on laser intensity and target thickness: a key requirement for the experimental implementation of RPA (in the so-called Light Sail mode) is that the target stays opaque to the laser radiation during the acceleration process, while the onset of target transparency leads to different dynamics associated to an enhanced electron heating (relativistic transparency acceleration). As proposed in numerous theoretical works, the polarization of the laser pulse can have a role in controlling the level of electron heating, with circularly polarized light advantageous in preserving the integrity of the target. We will present the results obtained at the Astra GEMINI laser system at the Rutherford Appleton Laboratory, STFC, UK by irradiating ultra-thin foils with 50 fs laser pulses, focused to an intensity in excess of 10^{20}W/cm^2. The irradiation was performed on amorphous carbon foils with thickness in the nanometer range. The experiment shows two different trends of the maximum particle energy versus target thickness, for linear and circular polarization, with circular polarization leading to the highest energies for both Carbon ions and protons (25-30 MeV/nucleon) Furthermore, the beam profile obtained shows striking differences when using the two different polarizations, providing a clear indication that the two beam patterns are produced by two distinct mechanisms. These features are supported by particle-in-cell (PIC) simulations, which closely reproduce the results and provide an insight into the different acceleration dynamics.