Ion acceleration from ultrathin foils irradiated at high laser intensities

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Ion acceleration driven by high intensity laser pulses is attracting an impressive and steadily increasing research effort. Experiments over the past 10-15 years have demonstrated, over a wide range of laser and target parameters, the generation of multi-MeV proton and ion beams with unique properties such as ultrashort burst emission, high brilliance, and low emittance [1]. Most of this prior work has been carried out employing the so-called Target Normal Sheath Acceleration method, where the accelerating field is set up at the target surface by laser-energised relativistic electrons. This mechanism provides beams with exponential spectra with cut-off of several 10s MeV depending on the irradiation parameters, but has shown limitations for what concerns scaling up ion energies and beam densities to match the requirements of advanced applications, including future use of laser-driven beams in cancer therapy. Recent work has focused on the theoretical investigation and experimental development of a number of different mechanisms, which hold the promise for acceleration to GeV/nucleon energies with next generation laser facilities (see [1] for a review). Working in the framework of large UK consortia (LIBRA until 2012, A-SAIL from 2013), our group has investigated in the last few years ion acceleration from laser-irradiated ultrathin foils, with the main aim of highlighting features related to one of such mechanisms, Radiation Pressure Acceleration, which is possibly the most promising for the future delivery of dense beams of narrow band ions at energies above the 100s MeV/nucleon. When applied to an ultrathin foil, the enormous pressure of radiation of an ultraintense pulse (up to 10s of GBar for current laser systems) can in principle lead to the effective acceleration of a dense layer of ions contained in the irradiated region, in the so-called Light Sail approach [2].

The talk will review recent theoretical/numerical understanding [3], and discuss the results of experimental activity carried out at the UK national facilities of the Rutherford Appleton Laboratory employing the PW-class VULCAN and GEMINI lasers. The experiments have highlighted a number of features emerging from ultraintense ($> 10^{20}$ W/cm^2) interactions with nm-scale foils which differ strongly from what observed on thicker foils via TNSA. This include the detection of dense, directional ion bunches with narrow-band energies [4]. Comparison with theoretical and numerical models suggest that these features are associated to the onset of Light Sail, and allow extrapolating the results to future intensity regimes.

In the prospective of a future biomedical use of laser-driven ions, we have also initiated a program of cell radiobiology (see, e.g. [5]) employing these laser accelerated beams, which will also be briefly discussed in the talk.

References:

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