Guided post acceleration of high-energy protons using helical coil targets driven by sub-petawatt lasers

H. Ahmed1, S. Kar1, P. Hadjisalomou1, S. Brauckmann2, D. Doria1, A. Alejo1, T. Hodge1, R. Prasad2, M. Cerchez2, O. Willi2 and M. Borghesi1

1 School of Mathematics and Physics, Queen’s University Belfast, Belfast, BT7 1NN
2 Institut für Laser-und Plasmaphysik, Heinrich-Heine-Universität, Düsseldorf, Germany

Email: h.ahmed@qub.ac.uk

Laser driven ion beams provide a promising alternative to conventional accelerators as, in addition to the compactness and possible cost-effectiveness, exhibit remarkable properties such as high particle flux, short pulse duration and laminarity[1]. However, some of the inherent shortcomings of ion beams driven by target normal sheath acceleration (TNSA) mechanism, such as large divergence and broad energy spectra, have acted as bottlenecks for practical applicative usage [1]. The recently developed helical coil targets [2] provide a miniature and versatile setup for controlling effectively the spectral and angular properties of the proton beams directly at the source, by exploiting the transient self-charging of the laser irradiated target [3].

In this target geometry, a helical coil (HC) is attached to the rear surface of the interaction foil so that the protons generated from the rear surface of the foil propagate along the HC axis, while an EM pulse generated during the same interaction travels along the coil. The electric field (>10^9 V/m) within the coil, associated to the travelling EM pulse, act to simultaneously focus and accelerate a small slice of the transiting protons traveling in sync with the EM pulse [3]. In a proof of principle experiment at the ARCTURUS laser system (Dusseldorf), post-acceleration of laser driven protons at a rate of 0.5 MeV/mm was observed [3]. The rate at which protons are accelerated inside the coil depends, in addition to the coil dimensions, on the strength of the EM pulse created by the laser interaction with the foil target. Employing this technique on higher power lasers, such as the Vulcan Petawatt, CLF (UK) and Titan, LLNL (USA), collimated and quasi-monoenergetic proton beams containing >10^8 particles at ~ 45 MeV were obtained by simultaneous focusing and post acceleration of ~30 MeV protons. Particle tracing simulations are in agreement with the experimental data, suggesting an acceleration of gradient in excess of 1 MeV/mm in both experiments. The results underpin the potential of the technique for producing high-energy collimated ion beams for future applications.

References: