Towards all-optical ion accelerator by an innovative target scheme

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In the context of developing compact, high current ion accelerators, the study of intense laser driven acceleration mechanisms and optimisation of the ion beams produced, have been, over the past decade, very active areas of research. For instance, demonstrating capability of a controlled, all-optical acceleration of protons and other low-Z ion species in the 60-300 MeV/nucleon range would be of significant interest for therapy of deep-seated cancer. Emerging laser-driven ion acceleration mechanisms, including the Radiation Pressure Acceleration approaches, are highly promising for this purpose and currently pursued internationally. A novel scheme of guided post-acceleration of the laser driven ion beams was recently developed [1], which brings the all-optical scheme one step closer to the realization of compact beam lines.

High power lasers are capable of generating giant electromagnetic (EM) pulses due to prompt escape of hot electrons from the interaction region. The large electric field associated to the EM pulses can be harnessed in a travelling-wave particle accelerator arrangement, by directing the ultra-short EM pulse along a helical path surrounding a laser-accelerated ion beam. The radial and longitudinal components of the associated electric field within the helix leads to simultaneous beam shaping and re-acceleration of a selected portion of the proton beam. In a proof-of-principle experiment on a 200 TW university-scale laser, post-acceleration of ~108 protons by ~5 MeV was demonstrated with dynamic beam collimation and energy selection. The acceleration gradient in this case was ~0.5 GeV/m, which is already beyond what can be sustained by conventional accelerator technologies. Employing this technique recently at the Vulcan Petawatt laser and Titan laser, LLNL, USA, produced a narrow band, pencil beam of ~ 45 MeV, where preliminary analysis indicates fast scaling of the post-acceleration gradient with laser power. Furthermore, there is significant scope for optimising the acceleration by using extended helical coils of variable pitch and diameter. While this technique may provide the platform for a practical 'table-top' accelerator by staging multiple coils, achieving this objective requires a coordinated effort involving development of targetry, understanding and controlling the physical processes of the relevant interaction regimes, and developing innovative solutions to a number of technical bottlenecks.

References

[1] S. Kar et. al., Nature communication, 7, 10792 (2016)