All-Optical, Staged Acceleration of Proton Beams Using Helical Coils

S. Ferguson¹, H. Ahmed¹, B. Greenwood¹, B. Odlozilik¹, M. Alanazi¹, D. Doria¹, M. Cerchez², E. Aktan², J. Green³, O. Willi², M. Borghesi¹ and S. Kar¹

¹School of Mathematics and Physics, Queen’s University Belfast, Belfast BT7 1NN, UK
²Institut für Laser und Plasmaphysik, Heinrich Heine Universität, Düsseldorf D-40225, Germany
³Central Laser Facility, Rutherford Appleton Laboratory, Didcot, Oxfordshire OX11 0QX, UK

All-optical approaches to ion acceleration are attracting a significant research effort internationally. Energetic ion beams can be readily generated by high intensity lasers via the target normal sheath acceleration (TNSA) process [1]. While the ion energies of such beams remain constrained by available laser intensities and limitations related to target fabrication, methods of post-accelerating the TNSA ions have lately gained significant interest. In 2016, a concept channelling the extremely high electromagnetic pulse emanating from a laser irradiated target along a miniature helical coil was demonstrated capable of post-accelerating TNSA ions from the same initial laser interaction [2]. Furthermore, synchronous propagation of the electromagnetic pulse and the protons within the helical coil reduces beam divergence during acceleration providing a collimated, narrow energy band of protons suitable for applications. Recent experiments have demonstrated pencil beams up to 50 MeV by deploying helical coil targets at petawatt-class lasers [3]. In a proof-of-principle experiment, we are currently investigating the possibility of staging helical coil modules at the Vulcan Laser of the Central Laser Facility located in the United Kingdom. The experiment employs a dual beam laser configuration and a two-stage target geometry, where each beam interacts with a separate helix target. This arrangement allows the second helix’s effect on the proton beam, produced by the first helix, to be studied through varying the time delay between the two laser beams. Results from this experiment will be presented with supporting particle tracing simulations.