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Laser energized traveling wave accelerator – a novel scheme for simultaneous focusing, energy selection and post-acceleration of laser-driven ions

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All-optical approaches to particle acceleration are currently attracting a significant research effort internationally. Where intense laser driven proton beams, mainly by the so called *Target Normal Sheath Acceleration* mechanism, have attractive properties such as brightness, laminarity and burst duration, overcoming some of the inherent shortcomings, such as large divergence, broad spectrum and slow ion energy scaling poses significant scientific and technological challenges.
High power lasers are capable of generating kiloampere current pulses with unprecedented short duration (10s of picoseconds). The large electric field from such localized charge pulses can be harnessed in a traveling wave particle accelerator arrangement. By directing the ultra-short charge pulse along a helical path surrounding a laser-accelerated ion beams, one can achieve simultaneous beam shaping and re-acceleration of a selected portion of the beam by the components of the associated electric field within the helix. In a proof-of-principle experiment on a 200 TW university-scale laser, we demonstrated post-acceleration of $\sim 10^8$ protons by $\sim$5 MeV over less than a cm of propagation - i.e. an accelerating gradient $\sim$0.5 GeV/m, already beyond what can be sustained by conventional accelerator technologies, with dynamic beam collimation and energy selection. These results open up new opportunities for the development of extremely compact and cost-effective ion accelerators for both established and innovative applications.