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Initial experimental evidence of self-collimation of TNSA proton beam in a stack of conducting foils

PAVEL NI, Lawrence Berkeley National Laboratory

Phenomena consistent with self-collimation (or weak self-focusing) of laser target-normal-sheath-accelerated (TNSA) protons was experimentally observed for the first time, in a specially engineered structure ("lens") consisting of a stack of 300 thin aluminum foils separated by 50 μm vacuum gaps. The experiments were carried out in a "passive environment," i.e. no external fields applied, neutralization plasma or injection of secondary charged particles was imposed. Experiments were performed at the petawatt "PHELIX" laser user facility (E=100 J, Δt=400 fs, λ =1062 nm) at the "Helmholtzzentrum für Schwerionenforschung–GSI" in Darmstadt, Germany. The observed rms beam spot reduction depends inversely on energy, with a focusing degree decreasing monotonically from 2 at 5.4 MeV to 1.5 MeV at 18.7 MeV. The physics inside the lens is complex, resulting in a number of different mechanisms that can potentially affect the particle dynamics within the structure. We present a plausible simple interpretation of the experiment in which the combination of magnetic self-pinch forces generated by the beam current together with the simultaneous reduction of the repulsive electrostatic forces due to the foils are the dominant mechanisms responsible for the observed focusing/collimation. This focusing technique could be applied to a wide variety of space-charge dominated proton and heavy ion beams and impact fields and applications, such as HEDP science, inertial confinement fusion in both fast ignition and heavy ion fusion approaches, compact laser-driven injectors for a LINAC or synchrotron, medical therapy, materials processing, etc.