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Laser-accelerated protons above 65 MeV via Direct Laser-Light-Pressure Acceleration in micro-cone targets[1]

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Recent experiments conducted at the 200 TW LANL Trident high-contrast short-pulse laser system have broken the decade-long record [1] of 58 MeV for laser-accelerated protons, which had been obtained using the LLNL Nova PW laser with 423 J at an intensity of $\sim 2.6\times10^{20}$ W/cm^2 on flat targets. Our new highest achieved energy of 67.5 MeV [2] required only 80 J and an intensity of $\sim 1.5\times10^{20}$ W/cm^2 by using novel Cu flat-top cone targets, irradiated at a grazing incidence along the bottom cone wall with vertically polarized light. Prior work had already demonstrated an energy enhancement, compared to flat foils, at lower laser energies [3], but the origin was unclear in light of experimental variability in laser pointing. In all aforementioned experiments, the protons are accelerated by the Target Normal Sheath Acceleration mechanism [4]; however, in the present work, through a systematic study using collisional 2D PIC simulations, a new mechanism is identified, which is distinct from optical collection and electron guiding predicted for conical targets [5], and which increases the hot electron population by Direct Laser Light Pressure Acceleration of electrons along the cone wall surface when the laser is at grazing incidence, as diagnosed experimentally via Cu Kα x-ray imaging. This new result demonstrates that the 60 MeV barrier [6] can be reproducibly broken, using flat-top cone targets, and prospects and progress towards future, scalable target designs will be discussed.

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