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GeV Laser Ion Acceleration from Ultrathin Targets: The Laser Break-Out Afterburner[1]

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A new laser-driven ion acceleration mechanism has been identified using particle-in-cell simulations. After a brief period of target normal sheath acceleration (TNSA) [S. P. Hatchett, et al., Phys. Plasmas, 7, 2076 (2000)], two distinct stages follow: first, a period of enhanced TNSA during which the cold electron background converts entirely to hot electrons, and second, the "laser break-out afterburner" (BOA) when the laser penetrates to the rear of the target and generates a large longitudinal electric field localized at the rear of the target with the location of the peak field co-moving with the ions. This mechanism allows ion acceleration to GeV energies at vastly reduced laser intensities compared with earlier acceleration schemes. The new mechanism enables the acceleration of carbon ions to greater than 2 GeV energy at a laser intensity of only 10^{21} W/cm^2, an intensity that has been realized in existing laser systems. Other techniques for achieving these energies in the literature [D. Habs et al., Progress in Particle and Nuclear Physics, 46, 375 (2001); T. Esirkepov et al., Phys. Rev. Lett. 92, 175003-1 (2004)] rely upon intensities of 10^{24} W/cm^2 or above, i.e., 2-3 orders of magnitude higher than any laser intensity that has been demonstrated to date. Also, the BOA mechanism attains higher energy and efficiency than TNSA where the scaling laws [Hegelich et al., Phys. Plasmas, 12, 056314 (2005)] predict carbon energies of 50 MeV/u for identical laser conditions. In the early stages of the BOA, the carbon ions accelerate as a quasi-monoenergetic bunch with median energy higher than that realized recently experimentally [Hegelich et al., Nature, 441, 439 (2006)].

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