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Monoenergetic proton beams accelerated by radiation pressure driven shocks[1]

ZULFIKAR NAJMUDIN[2], Imperial College, London

The radiation pressure of an intense high intensity laser will bore a hole into the surface of an opaque (overdense) plasma forming an electrostatic shock. Ions bounced off this shock front can gain twice the hole-boring velocity, which corresponds to an energy $E = 4I/nc$. By using a lower density (n) target, it should be possible to witness radiation pressure driven phenomena at greatly reduced intensity (I). This can be achieved by using a longer wavelength (infrared) driver, which reduces the critical density, and thus the minimum density at which these effects can be observed. In experiments performed with the $\lambda = 10\,\mu$m CO_2 laser at Brookhaven National Laboratory, we have observed the radiation pressure driven recession of the critical surface of a plasma formed by ionisation of a hydrogen gas target at densities as low as $n_e = 2 \times 10^{19}\,\mathrm{cm}^{-3}$. The motion of the electrostatic shock is directly observed by transverse optical probing. Perhaps most interesting is the observation of a proton beam with small energy spread ($< 4\%$), and low background. The beam also features low emittance (nm) and high spectral brightness ($> 10^{12}$ protons $\mathrm{MeV}^{-1}\mathrm{sr}^{-1}$). These properties are a major improvement on previous schemes for producing narrow energy spread ion beams, which have been achieved at the expense of reduced charge and increased complexity. Hence they demonstrate that radiation pressure acceleration (RPA) provides an alternative route to producing high quality laser-driven monoenergetic ion beams.

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[2]In collaboration with C. A. J. Palmer, N. P. Dover, I. Pogorelsky, M. Babzien, G. I. Dudnikova, M. Ispiriyan, M. N. Polyanskiy, J. Schreiber, P. Shkolnikov, V. Yakimenko.