Steady Radiation Pressure Acceleration Driven by 10-100 PW Laser with Foil Thickness Adjustable within Micrometers

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Experiments failed to observe quasi-monoenergetic GeV-scale protons predicted by the radiation pressure acceleration (RPA) theory, because the matched thickness is too small, e.g., several nm to 100 nm with the laser intensity available in laboratory. Such thin foil is hard to bear insufficient laser contrast and foil surface roughness, and we here find that there is an upper-limit thickness, which is lower than or around the matching thickness with $10^{19} - 10^{22}$ Wcm^{-2} laser intensities used in the experiments, which causes inefficient and unsteady acceleration. As the laser intensity is enhanced by one to two orders of magnitude with the coming 10-100 PW laser facilities, the upper-limit thickness significantly exceeds the matching thickness and therefore the acceleration becomes efficient. In the new regime, the experiment could adopt the thickness in a larger range of micrometers, resulting in both efficient and steady acceleration. Particle-in-cell simulation shows that multi-GeV quasi-monoenergetic proton beams can be steadily generated. This work predicts that near future RPA experiments with 10-100 PW laser facilities will enter a new regime with a large-range of usable foil thicknesses that can be adjusted to the interaction conditions for steady acceleration.