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Enhancing proton acceleration by using composite targets

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Radiation pressure acceleration (RPA) is a highly efficient mechanism of laser-driven ion acceleration, with the laser energy almost totally transferrable to the ions in the relativistic regime. However, there is a fundamental limit on the maximum attainable ion energy, which is determined by the group velocity of the laser. The tightly focused laser pulses have group velocities smaller than the vacuum light speed, and, since they offer the high intensity needed for the RPA regime, it is plausible that group velocity effects would manifest themselves in the experiments involving tightly focused pulses and thin foils. However, in this case, finite spot size effects are important and another limiting factor, the transverse expansion of the target, comes into play that may dominate over the group velocity effect. As the laser pulse diffracts after passing the focus, the target expands accordingly due to the transverse intensity profile of the laser. Due to this expansion, the areal density of the target decreases, making it transparent for radiation and effectively terminating the acceleration. The utilization of external guiding may relax the constraints on maximum attainable ion energy. Such guiding can be provided by a composite target, a thin foil followed by a near critical density slab. This slab provides guiding of the laser pulse during the acceleration process. The comparison of a single foil RPA and a composite target RPA shows that, in the latter case, the ions have energy several times larger than in the former case, thus greatly increasing the effectiveness of the RPA regime of laser-driven ion acceleration. In such a configuration, the group velocity effects begin to dominate and determine the maximum achievable ion energy. Work supported by U.S. DOE under Contract No. DE-AC02-05CH11231.