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Generation of quasi-monoenergetic proton beams via quantum radiative compression

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Dense high-energy monoenergetic proton beams are vital for wide applications, thus modern laser-plasma-based ion acceleration methods are aiming to obtain high-energy proton beams with energy spread as low as possible. In this work, we put forward a quantum radiative compression method to post-compress a highly accelerated proton beam and convert it to a dense quasi-monoenergetic one. We find that when the relativistic plasma produced by radiation pressure acceleration collides head-on with an ultraintense laser beam, large-amplitude plasma oscillations are excited due to quantum radiation-reaction and the ponderomotive force, which induce compression of the phase space of protons located in its acceleration phase with negative gradient [see the interaction scenario in Fig. 1]. Our three-dimensional spin-resolved QED particle-in-cell simulations [1-3] show that hollow-structure proton beams with a peak energy of about GeV, relative energy spread of few percents and number of 10^{10} can be produced in near future laser facilities, which may fulfill the requirements of important applications, such as, for radiography of ultra-thick dense materials, or as injectors of hadron colliders [4].

References

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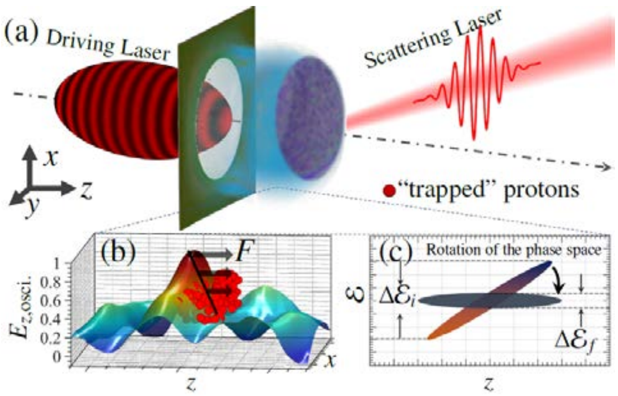

Figure 1. Interaction scenario. (a): The accelerated plasma via light-sail radiation pressure acceleration (RPA) by a circularly-polarized driving laser collides with another linearly-polarized scattering laser after RPA. (b): Protons are trapped and further accelerated by the oscillating longitudinal field $E_{z,osci.}$, induced by quantum radition-reaction effects and the ponderomotive force. The black line and arrows represent the negative gradient of $E_{z,osci.}$ and the acceleration force F, respectively. Longer arrows denote larger F. (c): The energy spread of protons is compressed.