Efficient generation of extremely dense gamma-rays and polarized lepton beams in plasmas

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Significant advances in the multi-petawatt laser technology have opened the door to the study of light-matter interactions in unexplored high-field regimes. Under such extreme conditions, strong-field quantum electrodynamics (QED) effects dominate and play a key role in collective plasma physics effects, resulting in a new class of QED plasmas [1, 2]. During the interaction, a large amount of electron energy can be converted into high-energy photons, which in turn decay further into electron-positron pairs. In this talk, we will present our recent work on efficient generation of extremely dense gamma-rays and polarized lepton beams in plasmas [3-5].

For example, recently we discovered an efficient scheme for generating high-energy polarized positrons simply based upon electron-beam-solid interactions, as shown schematically in Fig. 1. In this scheme, the electron beam needs to be focused to a density close to a solid target density by use of a properly designed hollow cone in order to trigger QED processes during the beam interaction with a solid target, since modern accelerators cannot yet produce beams with such a high density. When such a focused dense beam impinges on a solid target along its surface, asymmetric intense magnetic fields are induced near the target surface due to the large plasma electron backflows. The fields are high enough to trigger the multiphoton Breit-Wheeler process, leading to the generation of copious energetic positrons inside the target near the surface. Because the probability of spin-resolved pair production is intrinsically asymmetric and there are asymmetric field effects, most positrons are polarized via radiative spin flips. The polarized positrons can be created with an unprecedented high efficiency up to 10^8 positrons/J and the yield of about 0.3 e^+/e^-, which cannot be achieved by other methods in the prior art.

Since the induced magnetic fields experienced by the positrons are naturally asymmetric, the spin polarization mechanism is robust, making it feasible to create polarized positrons in realistic beam-solid interactions. In addition, by increasing the charge and/or energy of the driving beam, more high-energy polarized positrons can be produced, which is desirable for applications such as electron-positron colliders. Such polarized dense positron sources may open the door to many research frontiers.

References

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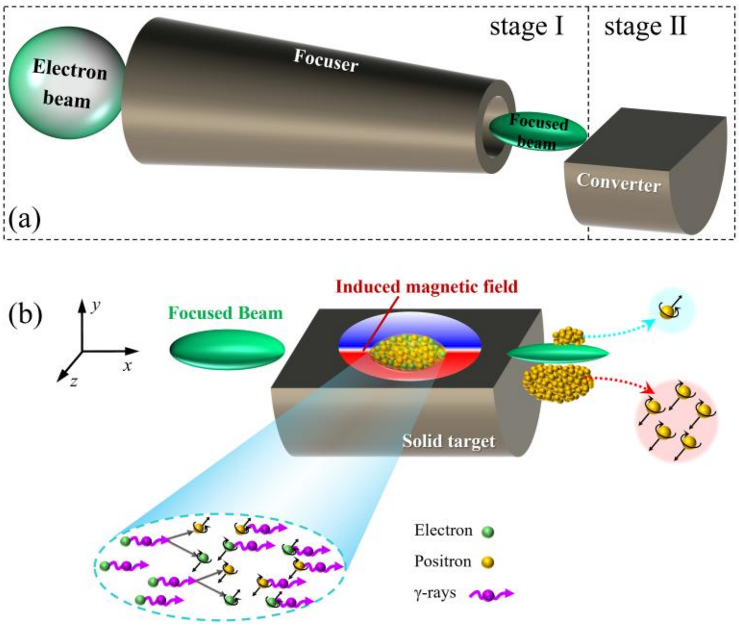

Figure 1. Schematic illustration. (a) This scheme involves two stages, i.e., a relativistic electron beam is first focused by passing through a hollow cone target (the focuser) in the first stage, and, subsequently, the focused beam impinges the surface of a solid target (the converter) for positron generation in the second stage. (b) When such a dense beam hits the solid target surface, it excites asymmetric intense magnetic fields of megatesla magnitude at the target surface, producing a large number of energetic positrons via the multiphoton BW process. Most positrons are polarized in such intense asymmetric fields due to the radiative spin flip effect and split into two parts in space along the *y*-direction due to the Lorentz force.