Quasi-monoenergetic GeV positron bunch generation by twisted laser fields

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Dense ultra-short positron bunches with high brilliance and narrow energy spread have many potential applications in laboratory astrophysics, high energy physics, nuclear and particle physics[1]-[2]. Although the generation of high-energy-density positrons are possible with multi-petawatt (PW) lasers in some newly proposed schemes in the past decade[3], the energy spread, duration and collimation of positron beams are barely able to meet the requirements of potential applications mentioned above. Especially, the generation of isolated dense attosecond monoenergetic positron beams is extremely challenging, which is yet to be explored. Moreover, an all-optical approach for coupling the generation and follow-up manipulation of positrons is of tremendous interest to high-field physics community.

To address these problems, we present an all-optical scheme for the generation, acceleration and compression of positrons to form dense ultra-short (680 attoseconds) quasi-monoenergetic (energy spread of 11.2%) GeV positron bunches by using a twisted drive laser.

The schematic diagram is shown in Figure 1, and the scheme can be divided into three stages. At the first stage, a relativistic Laguerre-Gaussian (LG) laser pulse is focused onto a cylindrical near critical density (NCD) plasma with a parabolic transverse density gradient, which can accelerate electrons directly from the background plasma to form sub-femtosecond electron bunches with energy up to several GeV. Then these energetic electrons collide head-on with a high-intensity scattering Gaussian laser field in the second stage, emitting abundant γ-photons via the nonlinear Compton scattering (NCS) process. At the final stage, the multi-photon Breit-Wheeler (BW) process is triggered and copious numbers of positrons are generated. Due to the unique structure of LG laser fields, these positrons are compressed by the radial electric field and suffer phase-locked-acceleration (PLA) by the longitudinal electric field. As a result, dense sub-femtosecond quasi-monoenergetic GeV positron bunches are generated, which can be further accelerated in vacuum.

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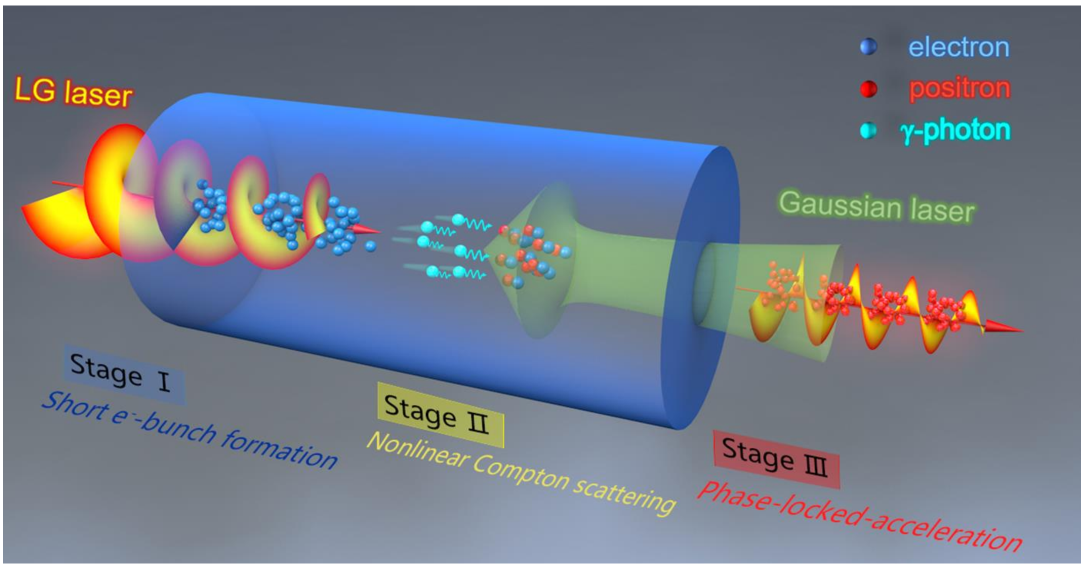

Figure 1. Schematic diagram of quasi-monoenergetic positron bunches generation by twisted lasers in NCD plasma.