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Injection and acceleration of high-energy polarized positron beam in plasma wakefield

Wei-Yuan Liu[1, *, †], Kun Xue[2, †], Feng Wan[2], Min Chen[1, ‡], Jian-Xing Li[2, ‡], Feng Liu[1], Su-Ming Weng[1], Zheng-Ming Sheng[1, 3] and Jie Zhang[1]

[1] Key Laboratory for Laser Plasmas (MOE) & Collaborative Innovation Center for IFSA, School of Physics and Astronomy, Shanghai Jiao Tong University

[2] Key Laboratory for Nonequilibrium Synthesis and Modulation of Condensed Matter (MOE), School of Science, Xi'an Jiaotong University

[3] SUPA, Department of Physics, University of Strathclyde

[*]e-mail (Speaker): alicelwy@sjtu.edu.cn

[‡]e-mail(Corresponding author): minchen@sjtu.edu.cn, jianxing@xjtu.edu.cn

Over the past decades, rapid development of electron acceleration via plasma-based wakefield accelerators has been achieved [1, 2], which shows the potentials for future compact and economical particle colliders in high-energy physics and many other applications in science and industry [3]. To make an electron-positron collider [4], it is imperative that both electrons and positrons must be highly polarized and highly energetic [5]. In recent years, the communities have reported some studies on positron acceleration through wakefield [6-9], however, few attention has been paid to positron injection schemes, which significantly affects the final beam quality. In addition, it is also a big challenge to make a highly polarized positron beam, which is also necessary for many other applications [10].

To solve these hinders, in this report, we propose a novel scenario for positron polarization, injection and acceleration. An ultra-intense dichromatic laser pulse is used to collide with an initially unpolarized electron beam, resulting in the emission of γ-photons through the nonlinear Compton scattering [11], which further generate electron-positron pairs polarized in the magnetic field direction within the multi-photon Breit-Wheeler process [12]. A relativistic hollow electron beam is used to excite a wakefield which could effectively focus and accelerate the polarized positrons. The polarization of the generated pairs come from the dependence between the particle polarizability and the asymmetry of the laser field. The injection of the polarized positrons is fulfilled during the recovery of the wakefield and the depolarization of the beam has been well suppressed during the acceleration.

Through two dimensional particle in cell simulations with fully-spin-resoved Monte Carlo method developed in [13, 14], we found that 70% of initially polarized positrons can be injected in the front of the wake bubble, such that a positron bunch with transverse polarization above 50%, energy exceeding 1 GeV and angular divergence smaller than 20 mrad is observed in a plasma less than 1 mm. This brings hopes for accelerating highly polarized positrons to the energy level of 100 GeV through multi-stage wakefield accelerators [15, 16].

[†]These authors contributed equally to this work.

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