Electron-positron pair production by linear Breit-Wheeler process in ultra-short petawatt laser-plasma interaction

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With the advent of ultra-intense petawatt laser system, such as ELI facility, relativistic laser plasma interaction and QED phenomena can be achievable in a laboratory. They have been attractive in fundamental research and technological applications: pair-creation, laboratory astrophysics, and generating γ-rays for radiation therapy and photo-nuclear spectroscopy. In recent years, a lot of numerical and experimental efforts have been devoted for the generation of GeV-energy positron beams and detection of linear Breit-Wheeler (BW) process by using the intense lasers. Our motivation in the current research is to deal with both of them. The linear BW process is one of fundamental QED phenomena, where one electron-positron pair is generated via collision between two high energy photons. Since photons are annihilated in this pair creation, the BW process is supposed to determine opacities for such high energy photons in the universe. However, nobody has observed the linear BW process of real photons in laboratory because of the difficulty to make the events happen enough for the observation caused by its small cross-section (~10^{-26}cm^2). So that, we need to make an efficient photon colliding configuration to detect the process.

In this work, we have demonstrated with a help of particle-in-cell (PIC) simulations with radiations [1,2] that an ultra-short petawatt laser light self-organizes a photon collider in a near critical over-dense plasma and produces positrons with energy of GeV-level via the linear BW process. We have performed 2D PIC simulation by using PICLS code. In the simulations, an ultra-intense petawatt laser is focused on a uniform foam target consisting of carbons. The peak intensity, pulse duration, and wavelength of the incident laser are 3×10^{22} W/cm^2 , 30fs, and 0.8μm respectively. The electron density of the target is $2.8n_c$, where n_c is the non-relativistic critical density of laser light. As radiation processes of electrons, we consider synchrotron radiation and Bremsstrahlung. Such an ultra-intense laser pulse propagates in a over critical plasma by its relativistic transparency with forming a magnetic channel structure inside the pulse and a positive electrostatic field at the pulse front as the result of electron accumulation due to the photon pressure.

In the magnetic channel, the laser light drives relativistic electrons which induce collimated γ -rays (>1MeV) via synchrotron radiation. While at the pulse front electrons are accelerated backward with relativistic energies by an electrostatic field. The relativistic electrons moving backward emit hard X-rays with energies ~100keV via radiative decay when they collide with the laser pulse. These photons then collide with the γ-rays and induce electron-positron pairs via the BW process. We also found that the generated positrons are accelerated by the electrostatic field to energy up to GeV energy level during copropagating with the laser pulse. They come out with a narrow divergence angle of ±10 degrees, so that they have the potential to contribute the detection of linear BW process in experiments. In the talk, we'll report the simulation model and details of the simulation results.

References:

[1] K. Sugimoto *et al*, High Energy Density Phys., **36**, 100816 (2020).
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