Positron generation and acceleration in a self-organized photon collider driven by ultra-short petawatt laser-plasma interaction

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With the advent of ultra-intense petawatt laser system, such as ELI facilities, relativistic laser plasma interaction and quantum electrodynamics (QED) phenomena will be achievable in lab. In the previous research [1], a scheme has been proposed to validate linear Breit-Wheeler (BW) process [2] by using the relativistic laser-plasma interaction. Although the number of electron-positron pairs generated by the BW process has been evaluated, the dynamics of positrons, such as how the positrons are accelerated by the laser light, have not been clarified. Understanding the dynamics of electron-positron plasmas is essential for detecting the BW processes.

In order to analyze the electron-positron dynamics in the interaction, we have incorporated a positron generation model of the BW process into the PIC code, PICLS[3], which can calculate the radiation process from electrons self-consistently. We have performed 2D PIC simulations where an ultra-intense petawatt laser is focused on a uniform carbon target. The peak intensity, pulse duration, and wavelength of the incident laser are 3×10^{22} W/cm^2, 30 fs, and 0.8 μm, respectively. The electron density of the target is $2.8n_c$, where n_c is the non-relativistic critical density of an electromagnetic wave. A relativistic intense laser pulse can propagate in the dense plasma with density greater than n_c by relativistic transparency. The pulse forms a magnetic channel in the plasma and pushes electrons in front of the pulse by its photon pressure. In the magnetic channel, the laser light accelerates electrons via direct laser acceleration. The relativistic electrons then emit collimated gamma-photons (>1 MeV) along the laser axis via synchrotron radiation. While at the pulse front electrons are accelerated backward by an electrostatic field induced by the electron accumulation. The electrons moving backward emit hard X-photons (100 keV) via radiative decay when they collide with the laser pulse. These photons interact with the gamma-photons and electron-positron pairs are induced via the BW process. We also found that some of the generated positrons are accelerated by the electrostatic field to energy up to GeV during co-propagating with the laser pulse [4].

References

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