Strong Laser-Driven Vortex Gamma-Photon Beam and Dense Polarized Positrons

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Vortex γ photons with intrinsic orbital angular momenta (OAM) possess a wealth of applications in various fields, e.g., strong-laser, nuclear, particle and astro-physics, yet their generation remains unsettled. Here, we investigate the generation of vortex γ photons via nonlinear Compton scattering of ultrarelativistic electrons in a circularly polarized laser pulse. We develop a quantum electrodynamics scattering theory that explicitly addresses the multiphoton absorption and the angular momentum conservation. We find that, emitted γ photons possess intrinsic OAM as a consequence of spin-to-orbital angular momentum transfer, and they are in a mixed state of different OAM modes due to the finite pulse shape of the laser. Moreover, the nonlinear Breit-Wheeler scattering of the vortex γ photon in a strong laser can reveal the phase structures of the vortex γ photons. Our findings emphasize the special role played by the intense laser regarding both generation and detection of vortex γ photons, and call for further investigations.

Meanwhile, we also put forward a novel method for producing ultrarelativistic high-density high-polarization positrons through a single-shot interaction of a strong laser with a tilted solid foil. In our method, the driving laser ionizes the target, and the emitted electrons are accelerated and subsequently generate abundant γ photons via the nonlinear Compton scattering, dominated by the laser. These γ photons then generate polarized positrons via the nonlinear Breit-Wheeler process, dominated by a strong self-generated quasi-static magnetic field B_S. We find that placing the foil at an appropriate angle can result in a directional orientation of B_S, thereby polarizing positrons. Manipulating the laser polarization direction can control the angle between the γ photon polarization and B_S, significantly enhancing the positron polarization degree. Moreover, our method is feasible using currently available or upcoming laser facilities and robust with respect to the laser and target parameters. Such high-density high-polarization positrons hold great significance in laboratory astrophysics, high-energy physics and new physics beyond the Standard Model.