Evolution of chirality in the electron-positron pair production driven by photons

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Recent years, electron-positron pair production induced by multiple photons has become one of the most promising approaches to investigate the property of electroweak vacuum. However, the production and evolution of chirality, a key topic in the study of the vacuum, has not been thoroughly considered in the context of multiphoton pair production. In this work, as the first step of filling this gap, we used the Dirac-Heisenberg-Wigner formalism to study the production and evolution of chirality in vacuum under the excitation of spatially homogeneous electric and magnetic fields $\boldsymbol{E}(t)$ and $\boldsymbol{B}(t)$ that are parallel to each other and are only nonzero in a short time span $0 < t < \tau$. These fields serve as a simplified model of the laser beams in multiphoton pair production experiments. Based on analytical calculation, we discovered that after the external fields vanish, an oscillation of pseudoscalar condensate $\langle \bar{\psi} i \gamma_5 \psi \rangle$ occurs in the system (ψ is the Dirac field of the electrons and positrons). We found that this oscillation suppresses the chirality of the produced electron-positron pairs. In the same time, the oscillation introduces a peak on the energy spectrum of the chiral charge (see Fig. 1). The energy of the peak is $\epsilon_p = 3m$ (m is the mass of electron). This novel phenomenon could help us identify different types of products in future multiphoton pair production experiments.

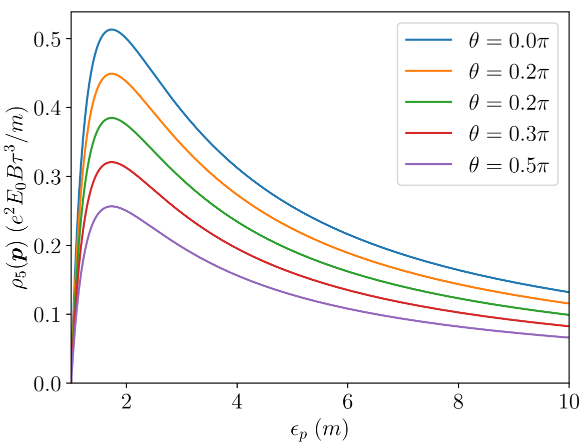

Figure 1: The energy spectrum of chiral charge measured at different outgoing angles θ of electron-positron pairs ($\theta = 0$ is the direction of the electric and magnetic fields). The x axis is the energy of the particle normalized by electron mass m. The y axis is the time-averaged value of the momentum-space chiral charge distribution $\rho_5(\boldsymbol{p})$, normalized by $e^2 E_0 B_0 \tau^3 / m$, with τ as the timescale of the electromagnetic excitation and E_0 and B_0 as the strength of the electric and magnetic field.