Effects of the polarizations of laser fields on pair production

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Abstract

The effects of the polarizations of laser fields on electron-positron pair production are investigated numerically by employing the real-time Dirac-Heisenberg-Wigner (DHW) formalism. It is found that the polarizations will change the momentum spectra and the number density of created particles. For nonperturbative regime, the number density of created pairs decreases with increasing the values of polarizations. For multiphoton process, the relation between the number density and the polarizations of electric fields is very sensitive to the field frequency.

Introduction

A vacuum in the presence of strong fields is unstable and will decay into electron-positron (EP) pairs [1]. This theoretical prediction of quantum electrodynamics has not yet been observed experimentally as the needed strength of external fields should be comparable to Schwinger critical electric field $E_{cr} = m^2c^3/e\hbar \sim 1.32 \times 10^{16}$ V/cm, where m is the electron rest mass and e is the magnitude of electron charge. However, the high-intensity and ultrashort laser facilities under construct, the Extreme Light Infrastructure [2] and the x-ray free electron laser (XFEL), raise the hopes to realize an experimental detection of EP pair production from vacuum [3].

Model and Results

We focus on the EP pair production in a homogeneous and time-dependent electric field with arbitrary polarizations:

$$\mathbf{E}(t) = \frac{E_0}{\sqrt{1+\delta^2}} \exp\left(-\frac{t^2}{2\tau^2}\right) \left[\cos(\omega t), \quad \delta \sin(\omega t), \quad 0\right]^{\mathrm{T}}, \quad (1)$$

where E_0 is the maximal field strength, τ defines the pulse duration, ω is the laser frequency, and $-1 \le \delta \le 1$ represents the polarization.

By employing the DHW formalism [4,5], we calculate the momentum spectra and the number density of created pairs for different polarizations, see Fig. 1 and Fig. 2, respectively.

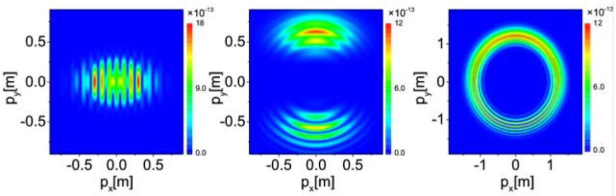

Fig. 1. Momentum spectra in the (p_x, p_y) plane of created pairs for δ=0, 0.5, and 1, from left to right. Other parameters are E_0=0.14E_{cr}, ω=0.1m, and τ=100/m.

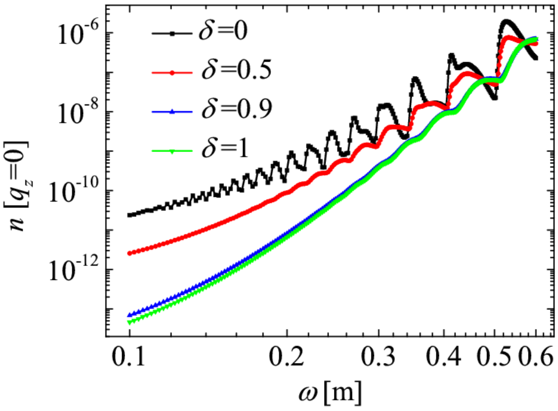

Fig. 2. The number density of created particles n (the momentum component q_z is set to 0) as a function of the field frequency ω for δ=0, 0.5, 0.9, and 1.

Conclusions

By numerically solving the DHW formalism, we have investigated the effects of the polarizations of laser fields on the momentum spectra and the number density of created EP pairs (see Fig. 1 and 2). It is found that a ring structure presents in the momentum spectra for a large value of polarization. The number density of created pairs decreases with increasing polarizations in nonperturbative regime. For multiphoton process, the relation between the number density and the polarizations of electric fields is sensitively dependent on the field frequency. Our results are valuable to deepen the understanding of EP pair production in complex external fields

References

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