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## Electron-positron pair production in space-time-dependent colliding laser pulses

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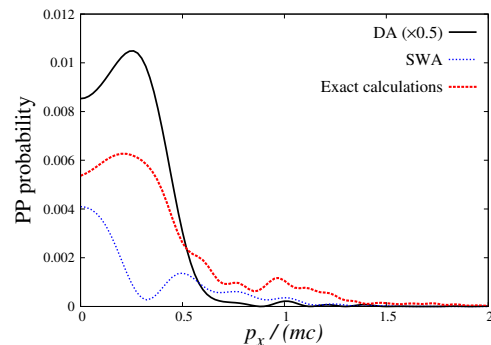
**Synopsis** The Schwinger pair-production process in the presence of two counter-propagating linearly polarised laser pulses is studied by means of a non-perturbative numerical technique. The spatial finiteness of the pulses is taken into account, i.e. the problem is examined beyond the standing-wave approximation.

Electron-positron pair production (PP) from the vacuum in strong external backgrounds is a fundamental non-linear phenomenon predicted by quantum electrodynamics. It is well-known that in a purely electric static field the PP probability is negligible unless the field strength is close to the Schwinger critical value  $E_c = m^2 c^3 / (|e| \hbar) = 1.3 \times 10^{16}$  V/cm. This limit can be effectively lowered if the external field oscillates with time. Let  $E$  and  $\omega$  be the characteristic strength of the external field and its frequency. With the aid of the dimensionless adiabaticity parameter  $\xi = |eE| / (mc\omega)$ , the non-perturbative (tunneling) and the multiphoton regimes can be distinguished by  $\xi \gg 1$  and  $\xi \ll 1$ , respectively. We focus on the intermediate case  $\xi \sim 1$ .

Due to the recent rapid development of laser technologies (ELI, XFEL and other facilities), a substantial interest in non-perturbative PP has been revived. In this context a collision of two counter-propagating laser pulses appears to be a very promising scenario. Most theoretical studies carried out so far approximated the resulting field by a spatially homogeneous background depending solely on time (see [1, 2, 3] and references therein). This approach is called the dipole approximation (DA). However, the influence of the spatial variations of the external field as well as its magnetic component may play a very important role in the PP process [4]. In order to analyse these effects, one can take into consideration the spatial variations of the carrier assuming that the envelope is still homogeneous in space. The resulting field becomes a standing wave oscillating with time.

Within the present study we go beyond the standing-wave approximation (SWA) taking into account the spatial dependence of both carrier and envelope. The patterns established within SWA are strongly modified once the pulses contain a small number of cycles. We provide a numerical analysis based on our non-perturbative technique developed previously [5]. By solving the Dirac equation in the momentum representation, we obtain the PP probabilities and study the spectrum of particles created.

In Figure 1 we present the mean number of electrons produced as a function of the  $x$ -component of their momentum ( $\vec{E} \parallel \vec{e}_x$ ,  $\vec{B} \parallel \vec{e}_y$  and  $z$  is the propagation direction). In these computations  $\xi = 0.5$  for an individual pulse (in the presence of two pulses  $\xi$  effectively equals unity),  $\omega = 0.5 mc^2/\hbar$  and the number of cycles  $N = 2$ . The results were obtained within DA, SWA and beyond these approximations ("exact calculations"). We observe that for the case of a small number of cycles ( $N \sim 1$ ) neither DA nor SWA provides accurate predictions. Within our study this issue is investigated in detail.



**Figure 1.** The PP probability as a function of  $p_x$  (the field parameters are given in the text).

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