WKB Electron Wave Functions in a Tightly Focused Laser Beam

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Available laser technology is opening the possibility of testing QED experimentally in the so-called strong-field regime. This calls for developing theoretical tools to investigate strong-field QED processes in electromagnetic fields of complex spacetime structure. Here, we propose a scheme to compute electron wave functions in tightly focused laser beams by taking into account exactly the complex spacetime structure of the fields. The scheme is solely based on the validity of the Wentzel-Kramers-Brillouin (WKB) approximation, and the resulting wave functions, unlike previously proposed ones [1], do not rely on approximations on the classical electron trajectory. Moreover, a consistent procedure is indicated to take into account higher-order quantum effects within the WKB approach depending on higher-and-higher powers of the Planck constant. In the case of a plane-wave background field, the found wave functions exactly reduce to the Volkov states, which are then written in a new and fully quasiclassical form. Finally, by using the leading-order WKB wave functions to compute the probabilities of nonlinear Compton scattering and nonlinear Breit-Wheeler pair production, it is explicitly shown that, if additionally, the energies of the charges are sufficiently large that the latter are not significantly deflected by the field, the corresponding Baier's formulas are exactly reproduced for an otherwise arbitrary classical electron/positron trajectory.

References

[1] A Di Piazza, Phys. Rev. Lett. **113**, 040402 (2014)