# Adiabatic Expressions for the Wave Function of Electron in a Finite-Range Potential and an Intense Low-Frequency Laser Pulse

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There is no doubt that analytical approaches are in demand for a deeper understanding of strong-field phenomena in terms of specific properties of the wave function (WF) in an intense laser field (see, e.g., Refs. [1,2]). In this work, we extend our recently developed adiabatic approach for the description of the above-threshold detachment (ATD) [3] to explore the analytical structure of the WF for an electron interacting with a finite-range potential $U(r)$ and an intense low-frequency infrared (IR) laser pulse [4]. In our analysis, we consider two cases when an electron is initially in a bound (i) or scattering (ii) state of $U(r)$. The obtained closed analytical forms for the WF comprise a sum of the initial bound state for the case (i) or the initial scattering state with the laser-modified (kinematic) momentum for the case (ii) and a rescattering correction, which is a superposition of scattering states of $U(r)$ with time-dependent momenta, whose directions and magnitudes are determined by the classical "rescattering" condition. The time-dependent coefficients in the superposition of scattering states in case (i) are presented as a product of the tunneling exponential (describing the electron appearance in the continuum) and the time-dependent propagation factor, while in case (ii), these coefficients involve the amplitude of electron-core scattering with the energy transfer from the laser pulse instead of the tunneling factor in the case (i).

Based on the analytic expressions for the WFs, including the rescattering corrections, we obtained the parametrizations for transition matrix elements and cross sections for fundamental strong-field processes [i.e., for ATD for high-energy electrons, high-order harmonic generation (HHG), laser-assisted electron scattering, laser-assisted radiative attachment, and laser-assisted bremsstrahlung] in terms of laser and binding-potential parameters with the exact account of effects of $U(r)$ and quasiclassical accuracy for the account of electron-laser interaction. These parameterizations include either tunneling factors or scattering amplitudes and propagation factors involved in the laser-dressed WFs.

In order to describe the laser-dressed state in the presence of an additional weak field, we formulate the perturbative result for the WF in terms of Green's function, whose approximate expression is obtained within the analytic expressions for the adiabatic WFs in the intense IR field [4]. The developed perturbation theory is used to calculate the HHG amplitude in an intense IR field and a weak extreme ultraviolet (XUV) perturbation. We found that the additional perturbative interaction of the XUV field with an atomic system in an intense IR field induces the HHG channels with the absorption of the XUV photons. The interference between different HHG channels carries information about the nonlinear interaction of an atomic system with the laser field in the XUV range, which is of growing interest nowadays due to the increasing intensities of XUV sources.

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