Adiabatic Theory for Strong Field Ionization of Atoms

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Synopsis We present the adiabatic theory of ionization of atoms by intense few-cycle laser pulses. We discuss a *trilobite*-like structure in a photoelectron spectrum generated by a pulse of overbarrier intensity.

The Keldysh theory [1] and its extensions [2], commonly called the strong field approximation, in contradiction to the latter name are known [3] to apply only to weak in atomic scale laser fields whose amplitude satisfies $F_0 \ll \alpha^3$, $\alpha=(2I_p)^{1/2}$. Considering ionization from the ground state of neutral atoms by near-IR pulses with $\lambda \sim 800$ nm, this approximation is only qualitatively correct for $F_0 \sim 0.1$ a.u. ($I \sim 10^{14}$ W/cm^2) and completely fails in the overbarrier regime $F_0 \sim 1$ a.u. ($I \sim 10^{16}$ W/cm^2). Thus a reliable theory capable of treating the interaction of atoms with truly intense laser pulses of current interest is needed.

Such a theory can be developed on the basis of adiabatic approximation. The problem is characterized by two dimensionless parameters – the ratios of the atomic and laser time $\varepsilon=\omega/\alpha^2$ and energy $\xi= F_0/\alpha^3$ scales, respectively; their ratio gives the Keldysh parameter γ. The adiabatic theory is a uniform with respect to ξ asymptotics for $\varepsilon \to 0$, i.e., it becomes exact in the low-frequency limit for arbitrary intensity of the pulse. Recently, we have developed the adiabatic theory for a model one-dimensional problem [4]. A key object in this theory is the atomic Siegert state in a static electric field equal to the momentary value of the laser field. The advent of a powerful method to calculate such states for realistic atomic potentials [5] has made the extension of the adiabatic theory [4] to the three-dimensional (3D) case possible. A comparison of adiabatic results with exact numerical solution of the TDSE shows that the adiabatic theory works well already in the mid-UV range ($\lambda \sim 200$ nm) and becomes progressively more accurate as one moves to the mid-IR range ($\lambda \sim 7$ μm), where solving the TDSE becomes prohibitively difficult, thus providing a reliable quantitative theory suitable for treating the variety of current applications of intense laser pulses.

First results of the adiabatic theory in the 3D case will be presented at the conference. As an example, **Fig. 1** shows a *trilobite*-like structure in a photoelectron spectrum generated by a pulse of overbarrier intensity. Similar spectra were recently observed experimentally [6]. The adiabatic theory explains the origin of the horizontal (low-contrast) interference fringes and shows that they bear structural target information on the scattering amplitude of the ionized electron by the parent ion.

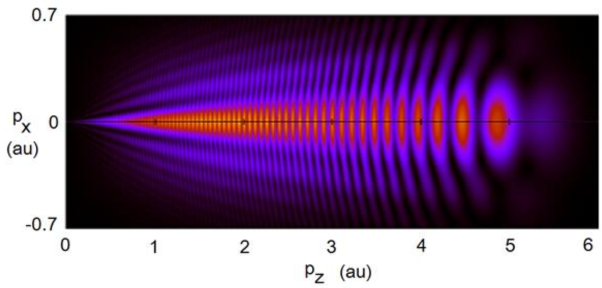

Figure1. Photoelectron spectrum generated by a one-cycle laser pulse with λ=800 nm and F_0=0.5 a.u..

References

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