Unraveling nonadiabatic ionization and Coulomb potential effect in strong-field photoelectron holography

Guangluo Shi*[1], Cheng Lin*[2], Xiaohong Song*[3], Zhihao Sheng*[4], Jing Chen*†[5], Weifeng Yang*[6],

* Department of Physics, Shantou University, Guangdong 515063, China
† Center for Applied Physics and Technology, Peking University, Beijing 100084, China
‡ Institute of Applied Physics and Computational Mathematics, P. O. Box 8009,Beijing100088,China

Synopsis Strong field photoelectron holography has been proposed as a means for interrogating the spatial and temporal information of electrons and ions in a dynamic system. After ionization, part of the electron wave packet may directly go to the detector (the reference wave), while another part may be driven back and scatters off the ion(the signal wave). The interference hologram of the two waves may be used to extract target information embedded in the collision process. Unlike conventional optical holography, however, propagation of the electron wave packet is affected by the Coulomb potential as well as by the laser field. In addition, electrons are emitted over the whole laser pulse duration, thus multiple interferences may occur. In this work, we used a generalized quantum-trajectory Monte Carlo method to investigate the effect of Coulomb potential and the nonadiabatic subcycle ionization on the photoelectron hologram. We showed that photoelectron hologram can be well described only when the effect of nonadiabatic ionization is accounted for, and Coulomb potential can be neglected only in the tunnel ionization regime.Our results help paving the way for establishing photoelectron holography for probing spatial and dynamic properties of atoms and molecules.

Since above-threshold ionization(ATI) was firstly observed more than thirty years ago, through experimental observations and theoretical efforts our understanding of the underlying physics of laser and high resolution electron spectrometer, photoelectron spectra from some recent experiments have revealed a number of surprises. Besides the familiar ATI peaks, new additional "peaks or fringes" have been observed in the two-dimensional electron momentum spectra. These new features ,usually are called by some new acronyms or simply by "structures", appear to be quite general, as they are nearly independent of the target atoms or molecules, but they are dependent on the laser wavelength, intensity and sometimes also on the pulse duration. Among these photoelectrons are the so-called "low-energy structures"(LES) at a few or sub-eV's or the "very low-energy structure"(VLES) at a few meV's above the ionization threshold. in most cases the widely used strong field approximation(SFA) is incapable of interpreti9ng these observations. For such low-energy electrons, it is intuitively clear that a quantitative theory would require the incorporation of Coulomb potential from the ion core. On the other hand, there are higher energy features that lie close to the so-called $2U_p$ cutoff(U_p is the ponderomotive energy or the averaged quiver energy of a free electron in the laser field, $U_p = \frac{I}{4\omega^2}$) where I is the laser intensity and ω the angular frequency). Among them we will focus on the so-called "side lobes" observed in the photoelectron momentum distribution(PMD).

[1]E-mail: 16glshi@stu.edu.cn
[2]E-mail: 14clin@stu.edu.cn
[3]E-mail: songxh@stu.edu.cn
[4]E-mail: 12zhsheng@stu.edu.cn
[5]E-mail: chenjing@iapcm.ac.cn
[6]E-mail: wfyang@stu.edu.cn

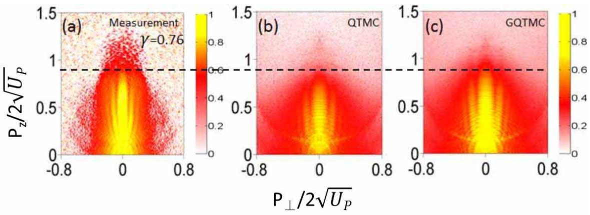

Figure 1. (Color online) Comparison of experimental two-dimensional photoelectron momentum distributions with calculations, for the metastable 6s state($I_p = 0.14a.u.$) of xeon atom by lasers of wavelength of 7000nm[from ref. 1]. (a)Experimental data from ref.2 at $I = 7.1\times10^{11}$ W/cm^2 ;(b)QTMC simulation, the laser pulse envelope is half-trapezoidal, constant for the first four cycles and ramped off linearly within the last two cycles, and the peak intensity is $I = 9.1\times10^{11}$ W/cm^2; (c) same as (b) but for GQTMC. The horizontal dashed line is the cutoff energy of the side lobe. The simulations included laser intensity distributions in the focused volume.

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