Long-range Coulomb effect in intense laser-driven photoelectron dynamics

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Synopsis The long-range Coulomb effect (LRCE) is demonstrated experimentally and theoretically by investigating the wavelength, intensity and pulse duration dependence of photoelectron momentum distributions of noble gas atoms subject to intense laser fields. With the semi-classical analysis, we show that LRCE plays an important role in determining photoelectron dynamics after the pulse ends. Furthermore, our experimental evidence show that, with few-cycle laser field at 800 nm, LRCE may be strong enough to influence the photoelectrons with higher energy, i.e., low-energy-structure.

As one of the most fundamental interactions in nature, long-range Coulomb interaction (LRCE) plays an indispensable role in our understanding of atomic structure and dynamics. However, the significant influence of LRCE in strong field atomic physics community has been overlooked for a long time [1, 2]. We demonstrate experimentally and theoretically that the LRCE can be revealed by investigating the wavelength, intensity and pulse duration dependence of photoelectron momentum distributions of noble gas atoms subject to intense laser fields.

With the cold target recoil-ion momentum spectroscopy [3] and a commercial optical parametric amplifier laser system, we perform the experiments for Xe subject to laser field at a series of intensities and wavelengths. Integrated over a small interval (0-0.02 a.u.) of the transverse momentum, the photoelectron momentum distribution exhibits a zero energy structure (ZES) [4] around $p_z=0$, which evolves with respect to the laser intensity and wavelength. The semi-classical analysis [5, 6] indicates that the evolution of ZES versus laser intensity and wavelength can be attributed to the LRCE [7].

Moreover, the LRCE may not totally be confined in the region of ZES. It is found experimentally that the low-energy-structure (LES) [6,8] shows itself as double hump structure (DHS) in momentum distributions for Ne subject to few-cycle and multi-cycle laser fields at 800 nm, as shown in Figure 1. Obviously, the DHS is more prominent for multi-cycle laser field than that for few-cycle case. This result can be reproduced and explained qualitatively with a semi-classcial model and attributed to the paramount role of LRCE [9].

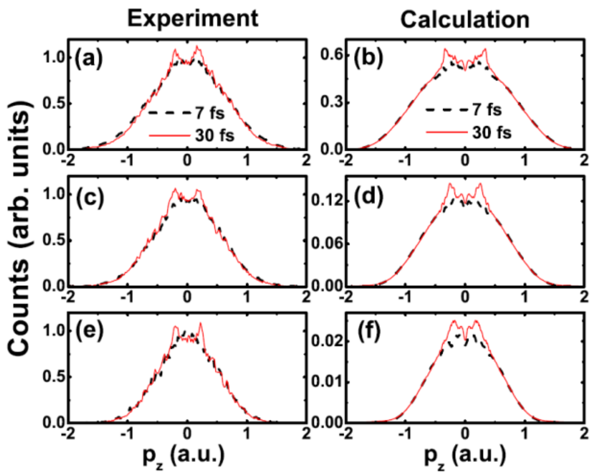

Figure 1. The measured ((a),(c),(e)) and calculated ((b),(d),(f)) longitudinal momentum distributions (LMDs) integrated over the transverse momentum of Ne^+ for the pulse durations of 7 fs (black line) and 30 fs (red line). The laser intensities are 5.0 × 10^{14} W/cm^2 for (a) and (b), 3.8 ×10^{14} W/cm^2 for (c) and (d), 2.9 ×10^{14} W/cm^2 for (e) and (f) [9].

By investigating the wavelength, intensity and pulse duration dependence of ZES and LES for Xe and Ne subject to intense laser fields, we reveal the paramount role of LRCE in determining the photoelectron dynamics after the laser pulse ends..

References

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