Resolving forward rescattering photoelectron holography of Ar by phase-controlled two-color femtosecond lasers

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Synopsis We perform an experimental study on forward rescattering photoelectron holography of Ar using phase controlled two-color laser fields (800+400 nm). A method is developed to resolve the holography of forward rescattering and direct electrons from the total photoelectron distribution. The obtained hologram provides us a new approach to explore the tunneling ionization and rescattering dynamics for atoms/molecules in strong laser fields.

Tunneling ionization is always considered as the first step during the interaction of a strong laser field with atoms and molecules and a trigger for subsequent dynamic processes such as laser induced electron diffraction, high harmonic generation and Coulomb explosion. Tunneling ionization also produces rich information about the system from interference carpets, electron diffraction and photonelectron holography. The recent developed forward rescattering photoelectron holography (FRPH) is a new method to detect tunneling ionization and rescattering dynamics with attosecond resolution [1]. The FRPH is based on the interference between direct ionization wave and rescattering wave, and these two waves are generated from the same quarter of laser oscillating field. The spider-like distribution is formed in the photoelectron momentum distributions (PEMDs), and the time delay between ionization and rescattering and the rescattering phase can be extracted from the interference fringes.

We have performed an experiment for obtaining the FRPH of Ar using a velocity map imaging and a phase-controlled two-color laser field. A 50 *fs*, 800 nm laser beam was introduced into a β-BBO crystal to obtain 2ω pulses, and the time-delay between ω and 2ω pulses was compensated by a birefringent α-BBO crystal. The relative phase between two color laser beams was controlled by a pair of fused silica wedges. We have measured the PEMDs of Ar in the laser fields by changing the relative phase between two laser beams. The relative-phase contrast (RPC) and a phase of the phase (PP) of each final electron momentum have been extracted by Fourier transformation or curve fitting using $A\cos(\varphi+\phi)$. The obtained RPC (A) is shown in Fig. 1(a) and the PP (ϕ) is shown in Fig. 1(b). It is clear to see the spider structures from the obtained FRPH, as illustrated by black dash lines in these figures. The phase difference between the signal and the reference wave packets from the interference fringes is expressed as

$$\Delta\phi_{AA} = \frac{1}{2} p_r^2 (t_C - t_0^{ref}) + \alpha + O(\varepsilon^1)$$

with a time delay (t_C-t_0^{ref}) between tunneling ionization and rescattering. The rescattering phase (α) can be extracted also from the obtained PEMDs according to the theoretical method proposed in ref. [2]. We find that the time difference in the response of each path is on the order of sub *fs*. In addition, the phase jumps in the PP distribution correspond to the delay of the direct electron and rescattering electron from 2ω field, indicating that the PP distributions provide information on time delay of the tunneling ionization to 2ω field. The experimental method described here provides us an opportunity to further explore the ultrafast electron dynamics of the tunneling ionization for atom and molecule in strong laser field.

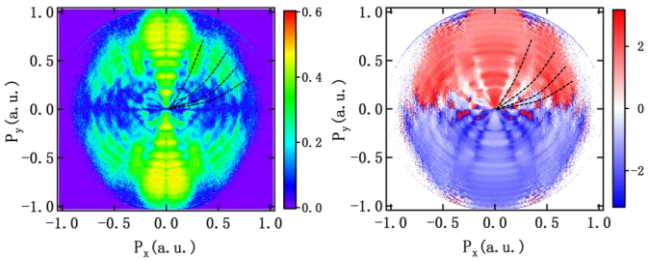

Figure 1. The RPC (a) and PP (b) distributions obtained from two-color laser ionization of Ar.

References

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