Rescattering photoelectron spectroscopy of CO_2 molecule with an analytical returning electron wavepacket

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Synopsis Angle-resolved photoelectron momentum distributions of rescattering electron generated by intense infrared laser pulses were measured for CO_2 molecules. It is shown that the measured distributions along the outermost backward rescattering caustic are well reproduced by calculations based on a newly developed factorization formula with the analytical returning photoelectron wave packet.

In the past decade laser-induced electron diffraction (LIED) for simple gas phase molecules, which utilizes the elastically rescattered electrons generated by intense ultrafast laser pulses, was reported for extracting molecular geometry information [1]. The LIED is based on a proposed factorization formula for outermost photoelectron momentum distributions (PEMDs) induced by strong field ionization of the molecules. It states that PEMDs near the high-energy cutoff can be factorized into the differential cross section (DCS) for elastic scattering of a photoelectron on the parent ion and a returning photoelectron wave packet (RWP) [2]. Recently a new factorization formula for PEMDs along the outermost backward rescattering caustic was derived analytically [3], and it was demonstrated for strong-field ionization of NO and CO molecules, in which experimentally extracted PEMDs were compared with the theoretical calculations [4]. In the present study, we extend it to CO_2 to demonstrate the utility of the new formula.

The output of a Ti:Sapphire laser (800 nm, 100 fs, 1.5 mJ, 1 kHz) was injected into an optical parametric amplifier to convert the wavelength to 1300, 1450 and 1650 nm. The laser was introduced in a high vacuum chamber through a half waveplate and focused on CO_2 molecules. A field-free time-of-flight spectrometer was used to get the PEMD with waveplate orientation.

Figure 1 shows the PEMD measured with 1650 nm laser pulses along the outermost rescattered electron caustic, where the electron rescattering momentum is 3.5 atomic units. We compare the experimentally extracted PEMD with theoretical calculations. Three types of calculations are presented here, (i) independent atomic model (IAM) calculation of electron-molecule scattering, (ii) single active electron (SAE) model calculation, and (iii) *ab initio* calculations of electron-ion scattering.

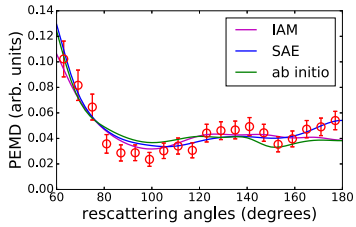

Figure 1. Experimentally extracted and theoretically calculated PEMD along the outermost electron caustic measured with 1650 nm laser pulses.

The SAE and *ab initio* calculations show good agreement with the experimental results for wide range of the rescattering angles, but IAM calculation fail to reproduce the modulation of the PEMD around 140-160 degrees.

References

[1] Ito Y *et al* 2017 *Phys. Rev. A* **96** 053414 and references therein
[2] Morishita T *et al* 2008 *Phys. Rev. Lett.* **100** 013903
[3] Morishita T and Tolstikhin O I 2017 *Phys. Rev. A* **96** 053416
[4] Ito Y *et al* 2018 *Phys. Rev. A* **97** 053411

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