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# 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 rescat-\*E-mail: m.okunishi@tohoku.ac.jp

tering 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

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