Measurement of angle-resolved rescattering photoelectron spectra and extraction of differential scattering cross sections of polyatomic molecules

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When atoms or molecules are exposed to intense IR laser fields, a part of the electrons released by tunneling ionization will be driven back by the oscillating electric field into recollisions with their parent ions. Elastic scattering electrons have structural information of the parent ions. Therefore it is expected that ultrafast dynamics of molecules can be observed with a femtosecond time resolution. In our laboratory, we have measured rescattering photoelectron spectra of atoms and molecules using laser pulses at 800 nm [1]. Electron-ion differential scattering cross sections (DCSs) extracted from the experiment are well reproduced by theoretical calculations. In the case of 800 nm laser radiation, however, the recollision momentum of the electrons is limited due to the depletion of the targets by the strong field ionization. This problem can be solved by using longer wavelength laser pulses to increase the momentum of the recolliding electron. In this study, we measured rescattering photoelectron spectra of polyatomic molecules using IR laser pulses at 1200-1650 nm.

An optical parametric amplifier pumped by Ti:Sapphire laser pulses at 800 nm (100 fs, 1.5 mJ, 1 kHz) is used to obtain IR laser pulses at 1200-1700 nm. The IR pulses are focused onto a sample gas effusively introduced in a vacuum chamber. Angular distributions of photoelectrons are obtained by continuously rotating the polarization direction of the optical fields using a half wave plate.

Fig. 1 shows an angle-resolved rescattering photoelectron spectrum of C_2H_4 measured using the laser light at different wavelengths. Rescattering electrons having recollision momentum around 3.0 a.u. are observed, while only up to 1.0 a.u. in the case of 800 nm. DCSs extracted from this experiment and theoretical calculations are shown in Fig. 2. We have obtained fairy good agreement between experimental and theoretical DCSs for the rescattering at higher collision momenta.

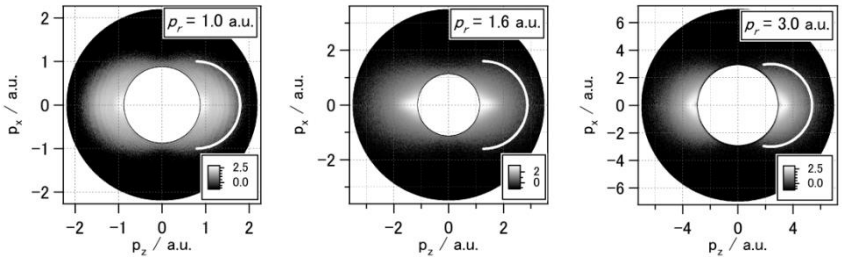

Fig. 1 Angle-resolved rescattering photoelectron spectrum of C_2H_4 measured using the 800 nm, 1300 nm, and 1650 nm laser light from the left.

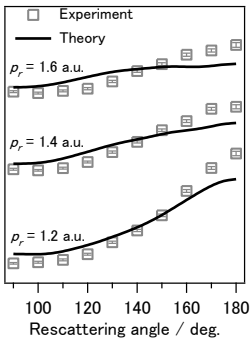

Fig. 2 Experimental and theoretical DCSs of C_2H_4.

[1] M. Okunishi *et al*., Phys. Rev. Lett. **100**, 143001 (2008); M. Okunishi *et al*., Phys. Rev. Lett. **106**, 063001 (2011); C. Wang *et al*., J. Phys. B: At. Mol. Opt. Phys. **45**, 131001 (2012).