Journal of Physics: Conference Series **635** (2015) 112029 doi:10.1088/1742-6596/635/11/112029

Intense near-IR laser induced electron-ion scattering experiment on hydrocarbon molecules

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Synopsis We have measured angle-resolved rescattering photoelectron spectra induced by ultrashort intense near-IR laser pulses at 1200-1650 nm. From the spectra, we have extracted field-free electron-ion differential scattering cross sections and compared them with theoretical calculations.

When atoms or molecules are exposed to linearly-polarized intense near-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. Elastically scattered electrons have structural information of the parent ions. The rescattering process completes within one optical cycle of the laser (about 2.7 fs at 800 nm), which may enable us to observe ultrafast structural changes of molecules with a femtosecond temporal resolution. In our laboratory, we have measured rescattering photoelectron spectra (RPS) of atoms and molecules using laser pulses at 800 nm [1]. Electron-ion differential scattering cross sections (DCSs) extracted from the experimental RPS are well reproduced by theoretical calculations. In the case of 800 nm laser radiation, however, the collision energy of the rescattering electrons is limited due to the depletion of the targets by the strong field ionization. In this study, we measured RPS of C_2H_4 and C_2H_6 molecules using IR laser pulses at longer wavelengths to increase the recolliding momentum of the electrons. Also we have extended the detection range to smaller angles of the rescattering electron emission.

IR laser pulses at 1200-1650 nm are generated by an optical parametric amplifier pumped by Ti:Sapphire laser pulses at 800 nm (100 fs, 1.5 mJ, 1 kHz). The IR pulses are focused onto a sample gas effusively introduced in a vacuum chamber. Angular distributions of photoelectrons are obtained by rotating the polarization direction of the optical fields using a half-wave plate.

Figure 1 shows an angle-resolved RPS of C_2H_4 measured using the laser light at 1650 nm and a comparison between experimental and theoretical DCSs. Rescattering electrons having recolliding momentum around 3.0 a.u. are observed, while only up to 1.0 a.u. in the case of 800 nm. The electron momentum of 3.0 a.u. corresponds to 122 eV in the energy and 1.1 Å in the de Broglie wavelength, which is shorter than 1.34 Å, the C=C bond length of C_2H_4 molecules. In DCSs comparison, we have found that DCSs extracted from several RPS measured with different laser conditions agree well. Additionally, we have obtained fairy good agreement between experimental and theoretical DCSs for the rescattering at higher collision momenta.

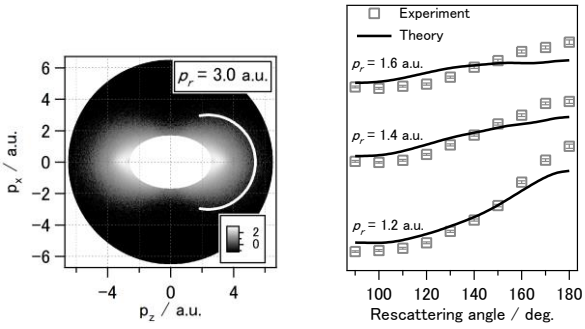

Figure 1. (left) angle-resolved RPS of C_2H_4, (right) comparison between experimental and theoretical DCSs of C_2H_4.

References

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

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