Extracting Electron-Ion Differential Scattering Cross Sections for Partially Aligned Molecules by Laser-induced Rescattering Photoelectron Spectroscopy

Misaki Okunishi[*,1], **Hiromichi Niikura**[*,†,‡], **Robert R. Lucchese**[*,♯], **Toru Morishita**[†,♮], **Kiyoshi Ueda**[*],

[*]Institute of Multidisciplinary Research for Advanced Materials, Tohoku University, Sendai 980-8577, Japan
[†]PRESTO, Japan Science and Technology Agency, Chiyoda-ku, Tokyo 102-0075, Japan
[‡]Department of Applied Physics, Waseda University, Shinjuku-ku, Tokyo 169-8555, Japan
[♯]Department of Chemistry, Texas A & M University, College Station, Texas 77843-3255, USA
[♮]Department of Engineering Science, University of Electro-Communications, Chofu, Tokyo 182-8585, Japan

Synopsis We extract large-angle elastic differential cross sections (DCSs) for electrons scattering from partially aligned O_2^+ and CO_2^+ molecules using rescattering photoelectrons generated by infrared laser pulses. The extracted DCSs are in good agreement with those calculated theoretically, demonstrating that accurate DCSs for electron-ion scattering can be extracted from the laser-induced rescattering spectra.

Rescattering of electrons produced by intense ultrafast laser pulses is of current interest due to the possibility of using the returning electrons for self-imaging the target. Recently, it has been demonstrated that elastic differential cross sections (DCSs) for scattering of *free* electrons from *atomic* ions can be accurately extracted from the momentum distributions of high-energy rescattering photoelectrons. [1] In this report, we demonstrate the extraction of DCSs of partially aligned molecules with a wide range of electron momentum. The spectra are recorded for randomly oriented free molecules. But the highest occupied molecular orbitals of O_2 and CO_2 have π_g symmetry and thus have lobes at $\sim 45°$ relative to the molecular axis. As a result field ionization by the intense laser predominantly occurs for the molecules aligned at $\sim 45°$ relative to the laser polarization vector.

In the experiment we covered a very wide range of laser intensities from 7×10^{13} W/cm^2 to 1.2×10^{15} W/cm^2 using three different pulse widths. At the lowest laser intensities, we used 100 fs laser pulses. For higher laser intensities, shorter pulse durations (35fs and 10fs) are used, in order to reduce the effect of depletion of the sample molecules.

Figure 1 shows the experimentally extracted and theoretically calculated elastic DCSs for scattering of free electrons from partially aligned O_2^+ and CO_2^+. [2] We extract the angular distribution of the cross section for each momentum at the time of recollision from the experimental electron momentum distributions by following the procedure proposed by Chen *et al.* [3] The experimental DCSs are normalized to the theoretical ones at a fixed angle ($\theta_r = 160°$). The extracted DCSs are in good agreement with *ab initio* results, confirming the validity of the extraction procedure. The work supported in part by JST, JSPS, MEXT, IMRAM, Matsuo foundation, DOE, and Welch foundation.

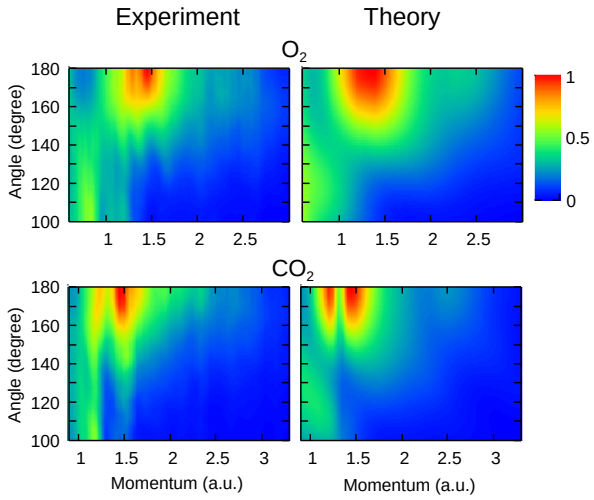

Figure 1. Experimental and theoretical elastic DCSs for scattering of free electrons from partially aligned O_2^+ and CO_2^+. The theoretical results were obtained by a convolution with MO-ADK angle-dependent ionization rates.

References

[1] T. Morishita *et al.*, J. Phys. B: At. Mol. Opt. Phys. **42**, 105205 (2009), and references therein.

[2] M. Okunishi *et al.*, Phys. Rev. Lett. **106**, 063001 (2011),

[3] Z. Chen *et al.*, Phys. Rev. A **79**, 033409 (2009).

[1]E-mail: okunishi@tagen.tohoku.ac.jp