1 Sakai (Hirofumi) Group

Research Subjects: Experimental studies of atomic, molecular, and optical physics

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Our research interests are as follows: (1) Manipulation of neutral molecules based on the interaction between a strong nonresonant laser field and induced dipole moments of the molecules. (2) High-intensity laser physics typified by high-order nonlinear processes (ex. multiphoton ionization and high-order harmonic generation). (3) Ultrafast phenomena in atoms and molecules in the attosecond time scale. (4) Controlling quantum processes in atoms and molecules using shaped ultrafast laser fields. A part of our recent research activities is as follows:

(1) Photoelectron diffraction from laser-aligned molecules with X-ray free-electron laser pulses [1]

We report on the measurement of deep inner-shell $2p$ X-ray photoelectron diffraction (XPD) patterns from laser-aligned I_2 molecules using X-ray free-electron laser (XFEL) pulses. The XPD patterns of the I_2 molecules, aligned parallel to the polarization vector of the XFEL, were well matched with our theoretical calculations. Further, we propose a criterion for applying our molecular-structure-determination methodology to the experimental XPD data. In turn, we have demonstrated that this approach is a significant step toward the time-resolved imaging of molecular structures.

This work was done as a collaborative study with researchers from KEK, Ritsumeikan University, Japan Atomic Energy Agency, Chiba University, Kyoto University, Riken SPring-8 Center, and Japan Synchrotron Radiation Research Institute.

(2) Laser-field-free three-dimensional molecular orientation [2]

Laser-field-free three-dimensional orientation, corresponding to the complete control of spatial directions of asymmetric top molecules, is achieved with combined weak electrostatic and elliptically polarized laser fields with an 8-ns turn on and a 150-fs turn off, which is shaped by a plasma shutter. Rotationally cold 3,4-dibromothiophene molecules are used as a sample and their lower-lying rotational states are selected by a molecular deflector to increase the degrees of orientation. After the rapid turn off of the pump pulse, higher degrees of orientation are maintained for 5-10 ps, which is long enough for various applications including electronic stereodynamics in molecules with femtosecond pulses. It is found that the dynamics after the rapid turn off of the pump pulse is very sensitive to the intensity of the pump pulse.

[1] Kyo Nakajima, Takahiro Teramoto, Hiroshi Akagi, Takashi Fujikawa, Takuya Majima, Shinichirou Minemoto, Kanade Ogawa, Hirofumi Sakai, Tadashi Togashi, Kensuke Tono, Shota Tsuru, Ken Wada, Makina Yabashi, and Akira Yagishita, "Photoelectron diffraction from laser-aligned molecules with X-ray free-electron laser pulses," Sci. Rep. **5**, 14065; doi: 10.1038/srep14065 (2015).

[2] Daisuke Takei, Je Hoi Mun, Shinichirou Minemoto, and Hirofumi Sakai, "Laser-field-free three-dimensional molecular orientation," to appear in Phys. Rev. A.