1 Sakai (Hirofumi) Group

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

Members: Hirofumi Sakai and Shinichirou Minemoto

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) Laser-field-free three-dimensional molecular orientation [1]

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 turnon and a 150-fs turnoff, 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 turnoff 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.

(2) Structure determination of molecules in an alignment laser field by femtsosecond photoelectron diffraction using an X-ray free-electron laser [2]

We have successfully determined the internuclear distance of I_2 molecules in an alignment laser field by applying our molecular structure determination methodology to an I $2p$ X-ray photoelectron diffraction profile observed with femtosecond X-ray free electron laser pulses. Using this methodology, we have found that the internuclear distance of the sample I_2 molecules in an alignment Nd:YAG laser field of 6×10^{11} W/cm^2 is elongated by from 0.18 to 0.30 Å"in average" relatively to the equilibrium internuclear distance of 2.666 Å. Thus, the present experiment constitutes a critical step towards the goal of femtosecond imaging of chemical reactions and opens a new direction for the study of ultrafast chemical reaction in the gas phase.

This work was done as a collaborative study with researchers from KEK, Ritsumeikan University, National Institutes for Quantum and Radiological Science and Technology, Chiba University, Kyoto University, Japan Synchrotron Radiation Research Institute, and RIKEN SPring-8 Center.

[1] Daisuke Takei, Je Hoi Mun, Shinichirou Minemoto, and Hirofumi Sakai, "Laser-field-free three-dimensional molecular orientation," Phys. Rev. A **94**, 013401 (2016).

[2] Shinichirou Minemoto, Takahiro Teramoto, Hiroshi Akagi, Takashi Fujikawa, Takuya Majima, Kyo Nakajima, Kaori Niki, Shigeki Owada, Hirofumi Sakai, Tadashi Togashi, Kensuke Tono, Shota Tsuru, Ken Wada, Makina Yabashi, Shintaro Yoshida, and Akira Yagishita, "Structure determination of molecules in an alignment laser field by femtosecond photoelectron diffraction using an X-ray free-electron laser," Sci. Rep. **6**, 38654; doi: 10.1038/srep38654 (2016).