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) Laser-field-free orientation of state-selected asymmetric top molecules [1]

With combined electrostatic and shaped laser fields with a slow turn on and rapid turn off, laser-field-free orientation of asymmetric top iodobenzene molecules with higher degrees of orientation has been achieved for the first time. In order to further increase the degrees of orientation, state-selected molecules are used as a sample. It is confirmed that higher degrees of orientation is maintained in the laser-field-free condition for 5–10 ps, which is long enough to study femtosecond-attosecond dynamics in molecules, after the rapid turn off of the laser pulse. The observation of the slow dephasing time of 5–10 ps ensures future prospects in molecular orientation techniques. This accomplishment means not only that a unique molecular sample has become available in various applications but also that the present technique can be used as a new spectroscopic technique to investigate ultrafast rotational dynamics of molecules.

(2) Phase differences of near-threshold high-order harmonics generated in atoms and molecules [2]

We present the observations of the phase differences $\Delta\phi_{\mathrm{HH}}^{(2n)}$ between adjacent high-order harmonics generated from Ar and N_2 at the near-threshold region. The $\Delta\phi_{\mathrm{HH}}^{(2n)}$'s are extracted from the photoelectron signals resulting from two-color two-photon ionization of rare-gas atoms, which are produced by high-order harmonics to be measured and a part of the fundamental pulse for probing. An analysis method is employed to remove the inevitable modulations in high-order harmonic intensities based on the underlying mechanism of the production of photoelectrons. We find a significant difference in the $\Delta\phi_{\mathrm{HH}}^{(2n)}$ at the nearest-threshold order between Ar and N_2. This difference cannot be reproduced by the model calculation by using the saddle-point method within the strong-field approximation. To elucidate the origin of the difference between the $\Delta\phi_{\mathrm{HH}}^{(2n)}$ for Ar and that for N_2, we note the fact that the phase difference $\Delta\phi_{\mathrm{HH}}^{(2n)}$ contains information both on the recombination time t_r of the freed electron and on the phase of the recombination dipole moment d^*. With the help of some numerical calculations, we discuss the effect of the potential created by the parent ion on t_r and d^* which are neglected in the strong-field approximation.

[1] Je Hoi Mun, Daisuke Takei, Shinichirou Minemoto, and Hirofumi Sakai, "Laser-field-free orientation of state-selected asymmetric top molecules," Physical Review A **89**, 051402(R) (5 pages) (2014).

[2] Kosaku Kato, Shinichirou Minemoto, Yusuke Sakemi, and Hirofumi Sakai, "Phase differences of near-threshold high-order harmonics generated in atoms and molecules," Physical Review A **90**, 063403 (10 pages) (2014).