1 Sakai (Hirofumi) Group

Research Subjects: Experimental studies of quantum optics and atomic/molecular 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) Controlling quantum processes in atoms and molecules using shaped ultrafast laser fields. (3) High-intensity laser physics typified by high-order nonlinear processes (ex. multiphoton ionization and high-order harmonic generation). (4) Ultrafast phenomena in atoms and molecules in the attosecond time scale. A part of our recent research activities is as follows:

(1) Laser-field-free molecular orientation [1]

We demonstrate laser-field-free molecular orientation with the combination of a weak electrostatic field and an intense nonresonant rapidly turn-off laser field, which can be shaped with the plasma shutter technique. We use OCS molecules as a sample. Molecular orientation is adiabatically created in the rising part of the laser pulse, and it is found to revive at around the rotational period of an OCS molecule with the same degree of orientation as that at the peak of the laser pulse in the virtually laser-field-free condition. This accomplishment means that a new class of molecular sample has become available for various applications.

(2) Field-free molecular orientation by an intense nonresonant two-color laser field with a slow turn on and rapid turn off [2]

We propose a practical and versatile technique to achieve completely field-free molecular orientation with an intense, nonresonant, two-color laser field with a slow turn on and rapid turn off. The technique is based on the combined effects of both anisotropic polarizability interaction and anisotropic hyperpolarizability interaction. Using a FCN molecule as a sample, we show that the orientation achieved adiabatically by the peak of the laser pulse can be successfully revived at the rotational period of the molecule with the same degree of orientation. The crucial importance of the sufficiently slow turn on of the laser pulse is emphasized to achieve the highest possible degree of orientation.

(3) Retrieving photorecombination cross sections of atoms from high-order harmonic spectra [3]

We observe high-order harmonic spectra generated from a thin atomic medium, Ar, Kr, and Xe, by intense 800-nm and 1300-nm femtosecond pulses. A clear signature of a single-atom response is observed in the harmonic spectra. Especially in the case of Ar, a Cooper minimum, reflecting the electronic structure of the atom, is observed in the harmonic spectra. We successfully extract the photorecombination cross sections of the atoms in the field-free condition with the help of an accurate recolliding electron wave packet. The present protocol paves the way for exploring ultrafast imaging of molecular dynamics with attosecond resolution. This work is the collaboration with Drs. Toshihito Umegaki, Toru Morishita, and Shinichi Watanabe from University of Electro-Communications, and Dr. Anh-Thu Le from Kansas State University.

(4) Alignment dependence of the structural deformation of CO_2 molecules in an intense femtosecond laser field [4]

Alignment dependence of structural deformation in the production process of multiply charged CO_2 molecules in an intense femtosecond laser field has been revealed by using aligned sample molecules. Our properly ordered observations clarify that the structural change takes place in the charge state of CO_2^{2+}. The bending angle decreases monotonically from the maximum value of 24° with the laser polarization parallel to the molecular axis to the minimum value of 16° with the polarization perpendicular to the molecular axis. The alignment dependence is discussed in terms of the field-induced nonadiabatic transition between the lowest two adiabatic states formed by the coupling between the electronically excited and the ground states of CO_2^{2+} ions.

[1] A. Goban, S. Minemoto, and H. Sakai, Phys. Rev. Lett. **101**, 013001 (2008).
[2] M. Muramatsu, M. Hita, S. Minemoto, and H. Sakai, Phys. Rev. A **79**, 011403(R) (2009).
[3] S. Minemoto, T. Umegaki, Y. Oguchi, T. Morishita, A.-T. Le, S. Watanabe, and H. Sakai, Phys. Rev. A **78**, 061402(R) (2008).
[4] S. Minemoto, T. Kanai, and H. Sakai, Phys. Rev. A **77**, 041401(R) (2008).