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) 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) Generation of high-order sum and difference frequencies by adding an intense parallel- and perpendicular-polarized infrared laser field [1]

We demonstrate both efficient control of polarization and high tunability of high-order sum and difference frequencies generated by adding an intense parallel- and perpendicular-polarized infrared laser field. When 805 nm pulses from a Ti:sapphire laser system and 1300 nm pulses from an optical parametric amplifier (OPA) are combined with perpendicular polarizations, the sum frequencies with two or four OPA photons are generated stronger than those with one or three OPA photons. This observation directly reflects the difference in their polarizations of the generated sum frequencies. Sum frequencies absorbing up to eight OPA photons are also observed for the parallel polarizations. Our observations are successfully reproduced by the theoretical calculations with the Lewenstein model including a weighting factor.

(2) All-optical molecular orientation [2]

We report clear evidence of all optical orientation of OCS molecules with an intense nonresonant two-color laser field in the adiabatic regime. The technique relies on the combined effects of anisotropic hyperpolarizability interaction as well as anisotropic polarizability interaction and does not rely on the permanent dipole interaction with an electrostatic field. It is demonstrated that the molecular orientation can be controlled simply by changing the relative phase between the two wavelength fields. The present technique brings researchers a new steering tool of gaseous molecules and will be quite useful in various fields such as electronic stereodynamics in molecules, ultrafast molecular imaging and so on.

(3) Effect of nuclear motion observed in high-order harmonic generation from D_2 / H_2 molecules with intense multi-cycle 1300-nm and 800-nm pulses [3]

We investigate high-order harmonic generation from D_2/H_2 molecules with intense multi-cycle pulses centered both at 1300 nm (60 fs) and at 800 nm (50 fs) together with that from N_2/Ar as reference. The experimental observations with 1300-nm pulses are different from those with 800-nm pulses both in spectral shapes and in intensity ratios I_{D_2}/I_{H_2}. The effect of nuclear motion in D_2 and H_2 are more distinctive for 1300-nm pulses than for 800-nm pulses. With multi-cycle pulses of 50–60 fs, the intensity ratios I_{D_2}/I_{H_2} are found to be more enhanced for both 800-nm and 1300-nm pulses than those with few-cycle pulses of 8 fs, which is attributed partly to the contribution of the coupling between the $1s\sigma_g$ and $2p\sigma_u$ states in D_2^+ and H_2^+ molecular ions during the higher-order returns of the electron wave packets.

(4) Dependence of the generation efficiency of high-order sum and difference frequencies in the xuv region on the wavelength of an added tunable laser field [4]

We investigate the dependence of the generation efficiency of sum and difference frequencies in the xuv region on the wavelength of an added tunable laser field. The wavelength of the added field ranges from 600 nm to 1500 nm. The generation efficiency of sum and difference frequencies is dramatically enhanced when the wavelength of the added field is longer than that of the fundamental field for pure harmonics. The discussions are held to the added field with perturbative intensity first, and they are further extended to that with nonpertubative intensity.

[1] Yuichiro Oguchi, Shinichirou Minemoto, and Hirofumi Sakai, Phys. Rev. A. **80**, 021804(R) (2009).
[2] Keita Oda, Masafumi Hita, Shinichirou Minemoto, and Hirofumi Sakai, submitted.
[3] Hiroki Mizutani, Shinichirou Minemoto, Yuichiro Oguchi, and Hirofumi Sakai, submitted.
[4] Yuichiro Oguchi, Shinichirou Minemoto, and Hirofumi Sakai, submitted.