# 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) Recipe for preparing a molecular ensemble with macroscopic threefold symmetry [1]**

We propose how to prepare a molecular ensemble with macroscopic threefold symmetry. By utilizing the special laser electric field trajectory with threefold symmetry, which can be formed by superposing a counterrotating circularly polarized fundamental pulse and its second harmonic pulse, sample molecules with threefold symmetry such as $BX_3$ (X = F, Cl, Br, I) can be aligned with their three arms along (or in between) the laser electric fields with threefold symmetry depending on the sign of the hyperpolarizability of the sample molecule. We show that this method is feasible with practical experimental conditions as for the rotational temperature of the sample molecules and the intensities of the two wavelengths. This method will open up physics of symmetry concerning a molecular ensemble with macroscopic threefold symmetry.

**(2) Orientation of linear molecules in two-color laser fields with perpendicularly crossed polarizations [2]**

Molecular orientation methods based on nonresonant two-color laser pulses having parallel polarizations have been reported theoretically and experimentally. In this work, we demonstrate that perpendicularly polarized two-color laser fields can be used to achieve stronger molecular orientation when nanosecond laser pulses are used. The two-color fields align the molecules to the two-dimensional plane parallel to the field polarization; at the same time, they orient the molecules in the direction of the $2\omega$ polarization. We show that the interplay between the interactions due to the $\omega$- and $2\omega$-laser fields provides stronger molecular orientation than the parallel field configuration. This is due to temporally synchronized generations of alignment and orientation, which reduce the nonadiabatic effects.

**(3) Development of a plasma shutter applicable to 100-mJ-class, 10-ns laser pulses and the characterization of its performance [3]**

For the purpose of preparing a sample of aligned and oriented molecules in the laser-field-free condition, we developed a plasma shutter, which enables laser pulses with 100-mJ-class, 10-ns pulse durations to be rapidly turned off within $\sim$150 fs. In this work, the residual field intensity after the rapid turn off is carefully examined by applying the shaped laser pulse to OCS molecules in the rotational ground state. Based on the comparison between the observation of alignment revivals of the OCS molecules and the results of numerical simulations, we demonstrate that the residual field intensity is actually negligible (below 0.4% of the peak intensity) and, if any, does not influence the alignment and orientation dynamics at all.

[1] Hiroto Nakabayashi, Wataru Komatsubara, and Hirofumi Sakai, "Recipe for preparing a molecular ensemble with macroscopic threefold symmetry," Phys. Rev. A **99**, 043420 (2019) (5 pages).

[2] Je Hoi Mun, Hirofumi Sakai, and Rosario González-Férez, "Orientation of linear molecules in two-color laser fields with perpendicularly crossed polarizations," Phys. Rev. A **99**, 053424 (2019) (10 pages).

[3] Je Hoi Mun, Shinichirou Minemoto, and Hirofumi Sakai, "Development of a plasma shutter applicable to 100-mJ-class, 10-ns laser pulses and the characterization of its performance," Opt. Express **27**, 19130–19140 (2019) (11 pages).