I-U Nonlinear Processes Induced by Ultrafast Laser Pulses

Recent technological progress on the generation of intense XUV pulses has opened up a new field on ultrafast and nonlinear optics. Commercial femtosecond Ti:Sapphire laser systems typically produce light pulses with pulse durations of tens of fs around the wavelength of 800 nm. Recalling that the optical cycle of the 800 nm light pulse is 2.7 fs, the pulse duration of tens of fs implies that tens of cycles are contained in a single pulse. When the number of the cycles decreases down to a few-cycle, new phenomena which are dependent on the carrier-envelope phase (absolute phase) emerge. In this project, we have carried out theoretical investigation related to the few-cycle pulse.

I-U-1 Few-Cycle Effects in the Low Intensity Regime

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One of the most fascinating features induced by few-cycle-pulses is that laser-induced dynamics such as ionization and high harmonic generation have a dependence on the carrier-envelope-phase (CEP). Naturally any kinds of CEP effects will be easily smeared out if the CEP is not stabilized on the shot-to-shot basis. Whether and how much CEP effects we can see depends on the number of cycles and pulse intensity, and the dependence is different for different systems even with the same pulse conditions. In the intensity region where tunneling ionization plays a major role, the dynamics can be rather well described using a semi-classical theory, *i.e.*, quasi-static tunneling theory for ionization, with the help of classical mechanics after the electron ejection, and it was shown that photoelectron yields exhibit a clear CEP dependence. In the weaker intensity region, however, tunneling ionization hardly takes place and multiphoton ionization is the dominant process for ionization. It has not yet been clarified whether and how much CEP effects can be seen in the weaker intensity region. We have theoretically studied the CEP effects in this intensity regime and found significant CEP effects in terms of the total ionization yield and the bound state population of atomic systems.

I-V Control of Photoionization Processes Using Lasers

Optical control of various photoexcitation processes are of great interest in recent years, which is termed “coherent control.” In this project, we have theoretically explored the possibility to control spin-polarization and the ejection angle of photoelectrons.

I-V-1 Control of the Spin-Polarization of Photoelectrons/Photoions Using Short Laser Pulses

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Since highly spin-polarized species such as electrons, ions, and nucleus, *etc.*, are very useful in various fields, developing a new method to control the spin degree of freedom is one of the most important issues in modern technology and science. Recently we have theoretically proposed a generic pump-probe scheme to control spin-polarization of photoelectrons/photoions by short laser pulses. The validity of the theoretical treatment, however, has been limited to the weak field in which a very small fraction of atoms are pumped to the excited states. For the maximum production of spin-polarized ions/electrons, it is desired to use strong pump/probe pulses. Based on the Schrödinger equation, we have developed a theory of spin-polarization so that the laser intensities can be arbitrarily strong. By numerically solving the derived equations for the realistic scheme of Mg atom, we have found a intensity-dependent spin-polarization.

I-V-2 Control of Photoelectron Angular Distributions Using a Dressing Laser

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Strong dressing laser field can induce various interesting modification in laser-matter interactions. Among them, an interesting modification is observed in the photoionization spectra in the wavelength region at which two-photon near-resonance is satisfied for the initially occupied state by a probe laser and initially unoccupied state by a dressing laser. This is known as laser-induced continuum structure (LICS). Recently we have reported the theoretical analysis of LICS for the K atom in terms of the modification of photoelectron angular distribution, where the geometry of laser polarization has been limited to the case in which both probe and dressing lasers are linearly polarized and parallel.

We have obtained strong modifications, as a function of the two-photon laser detuning and the dressing laser intensity, in the photoelectron distribution and the branching ratios into different ionization continua.

We have further extended the analysis for the case with a variable polarization angle. Again, a significant polarization-angle dependence has been found in terms of the photoelectron angular distribution and the branching ratios into the different ionization continua.