Ion-Electron Spectroscopy of Nonlinear Atomic Processes in Intense EUV-FEL Fields

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Strong high-frequency light fields from free electron lasers (FEL) make it possible to investigate nonlinear optical phenomena of materials where inner core electrons as well as valence electrons participate. Intensive studies on atoms and molecules as a standard system have revealed that a typical nonlinear response in the extreme ultraviolet (EUV) and X-ray region is multiple ionization induced by simultaneous absorption of the high-frequency photons, and that resonance states play an important role in multiphoton processes.

To investigate such resonance contributions, photoelectron spectroscopy have an advantage over simple ion detection since electron kinetic energies directly reflect electronic states involved in multiphoton processes. In a series of our previous work, we carried out single-shot photoelectron spectroscopy of rare gas atoms in intense EUV-FEL fields. Simultaneous detections of the nonlinear responses of the targets as well as spectral properties of SASE FEL that statistically fluctuate every shot, provide detailed information on resonance effects, as demonstrated for multiphoton ionization [1,2], nonlinear double excitations [3] and two-color multiphoton processes [4,5].

Recently, we have extended the photoelectron studies by introducing an ion detection scheme into a magnetic bottle type electron spectrometer [6] in order for a deeper understanding of nonlinear atomic processes in the EUV region. The high collection efficiency for ejected electrons and that for the counterpart ion allow for extracting electron spectra correlated with higher-order nonlinear ionization from strong electron signals generated in the lower-order processes.

In this report, we will present our recent work on nonlinear atomic processes in the EUV region by using ion-electron spectroscopy. A particular focus is laid on two-photon absorption processes of Xe, in which several competing ionization pathways to the formation of the Xe^{4+} state are clearly identified.

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