Coherent Control of Electron Emission Direction Through Doubly Excited States in Helium with SASE FEL

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Extreme-ultraviolet (XUV) free-electron lasers (FELs) can be used for nonlinear multiphoton excitation or ionization of atoms and molecules. Interfering pathways of the second harmonic of the FEL pulses can be used for coherent control experiments, however their spectral content is typically not measured, which is particularly important for stochastic FEL pulses with spectral fluctuations from shot to shot. We present a novel XUV photon spectrometer capable of simultaneously measuring fundamental (ω) and second harmonic (2ω) of FEL spectra. The spectrometer is installed at FLASH, Hamburg, and operates at a repetition rate of 100 kHz. We use phosphor screens and out-of-vacuum imaging onto two GOTTHARD detectors, allowing us to resolve the intrinsic spectral pulse structure of both ω and 2ω FEL pulses. Using a reaction microscope we measured the three-dimensional momentum distributions of helium recoil ions by tuning FLASH in the vicinity of intermediate singly excited states.