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Time-resolved spectroscopy of Xe giant plasmonic resonance by in situ measurement method

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Time-resolved spectroscopy of multi-electron dynamics associated with the Xe giant plasmonic resonance is demonstrated by applying an attosecond *in situ* measurement method. The Xe giant resonance was first noticed through enhanced photoionization around 100 eV using synchrotron X-ray beams. Recently, this was revisited with high harmonic spectroscopy, where enhanced extreme ultraviolet (XUV) emission was measured above the photon energy of 90 eV. Although this is remarkable progress, achieved using a table-top XUV source with excellent coherence, we need phase information to understand electron interactions during the resonant excitation. To measure this, we introduce a weak field to perturb recollision electron trajectories during the XUV generation process. This modulates the emitted XUV beam, allowing us to determine emission times of each XUV frequency. Consequently, we observe a large group delay variation around 84 eV of the XUV spectrum, which coincides with the strong amplitude enhancement at the resonance. This reveals the time-dependent response of the resonance, showing a tail with a decay time of 200 as. Since the emission time is the frequency derivative of the spectral phase, this measurement corresponds to the full characterization of the X-ray pulse influenced by the resonance.

This is an evidence that *in situ* methods can probe multi-electron correlation. Our demonstration to measure the delay of the plasmonic resonance implies that *in situ* methods are a viable alternative to photoelectron streaking utilizing recollision electrons as exquisitely sensitive probes to characterize ultrafast electron dynamics. Although the *in situ* method does not distinguish between the ionization and recombination steps of high harmonic generation, it is still valuable for simple approaches pursuing attosecond science. The application of *in situ* techniques, as demonstrated here in a many-body system, presents a new direction of strong-field attosecond physics where ultrafast many-body dynamics are measured and controlled by all-optical metrologies.

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