Amplitude and phase spectroscopy of attosecond electron wave packets

Kyung Taec Kim[*,†,1], Dong Hyuk Ko[†], Juyun Park[†], Chang Hee Nam[†] and Jongmin Lee[*]

[*]Advanced Photonics Research Institute and Center for Femto-Atto Science and Technology, GIST, Gwangju, Korea
[†]Department of Physics and Coherent X-ray Research Center, KAIST, Daejeon, Korea

Synopsis: The interference of attosecond electron wavepackets, created by high harmonic and femtosecond laser pulses, is measured. The first electron wavepacket is generated by direct ionization of He, and the second one by the two step process of resonant excitation by the attosecond high harmonic pulse and subsequent ionization by the laser pulse. The amplitude and phase retrieved from the interferogram show the ionization dynamics of He.

An interferogram generated by the superposition of two coherent waves is quite functional in analyzing an unknown system. Since the coherence of a light source is transferred to an ionized electron, The interferogram of electron wavepackets may provide the information on the electron dynamics in atoms and molecules [1]. In this work, we present the interferogram of the electron wave packets created from He ionized by attosecond high harmonic and laser pulses, which shows the ionization dynamics of the atom.

The interference of electron wave packets can be generated by creating two coherent waves in the continuum with attosecond high-harmonic and femtosecond laser pulses. The attosecond harmonic pulses are generated from Ar gas by focusing intense femtosecond laser pulse, and the probe pulse is obtained by splitting a part of the femtosecond laser pulse. The first electron wave packet, directly ionized by the attosecond harmonic pulse from the ground-state helium atom to the continuum, plays a role of the reference pulse. The attosecond harmonic pulse also initiates the resonant excitation to the 1s3p state of He. The excited electron is, then, ionized by the probe laser pulse, creating the second electron wave packet in the continuum. Since two coherent electron wavepackets are superposed with a time delay τ, the interferogram is generated in the frequency domain.

Figure 1 shows the photoelectron spectra obtained by the attosecond pulses generated from an Ar cell with an intensity of $2.0\text{x}10^{14}$ W/cm^2. The amplitude and phase of the probed electron wave packets can be obtained by extracting the oscillating signal contained in the photoelectron spectra. The result shows the different behavior depending on the ionization process of the electron. When the the probe laser pulse is overlapped with the attosecond harmonic pulse, the interferogram is quite similar to that appearing in continuum-continuum transitions

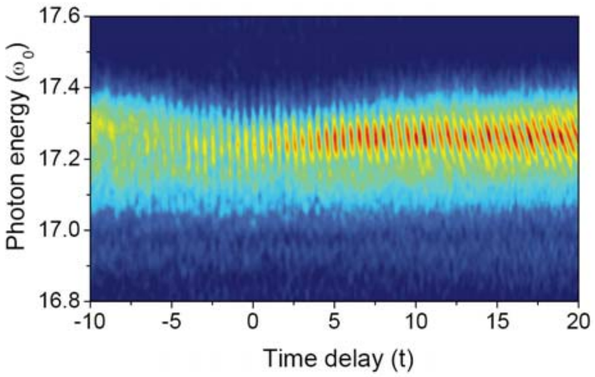

Fig. 1. Photoelectron spectra obtained by the attosecond pulses generated from an Ar cell at an intensity of $2\text{x}10^{14}$W/cm^2 in the presence of a probe laser pulse.

[2]. However, the signal is very similar to that of spectral interferometry when the probe laser pulse is temporally separated from the attosecond pulse [3]. This allows monitoring the time-dependent amplitude and phase of the second electron wavepacket.

In summary, the interference of electron wavepackets, separated in time, is measured. The phase of the electron wavepacket shows the electron dynamics in the ionization process. At a long time delay, the signal is similar to that of the spectral interferometry, which can be used for the characterization of the time-dependent amplitude and phase of the ionized electron after resonant excitation.

References

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[1]E-mail: kyungtaec@gist.ac.kr