Attosecond Electron Interferometry

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Synopsis: We present two different interferometric pump-probe experiments aiming to access state specific phase information after attosecond pulse excitation. The common idea is that when creating the wave packet we introduce simultaneously a reference that allows us to measure the phase evolution. In the first experiment we use isolated attosecond pulses to characterize ultrafast bound electron dynamics. While in the second we apply attosecond pulse trains in a RABITT measurement to access the phase induced by a resonant bound state in a two-photon-ionization process.

Attosecond science aims to measure electron dynamics on their natural time scale. The pulse durations required are in the range of only a few hundred attoseconds. Both experiments make use of the broad coherent bandwidth linked to theses short pulse durations.

In the first experiment, which was done in Milan in collaboration with AMOLF, LSU, MPQ etc [1], we use an isolated attosecond pulse with sufficient photon energy and bandwidth to simultaneously excite and ionize Helium. As shown in Figure 1 this leads to a coherent excitation of the *p*-states in Helium and a fraction of the continuum, which will act as a reference. The excited bound wave packet is later ionized by a 7 fs infrared (IR) laser field with a locked phase-relation. From the observed interference between the different ionization pathways we show that it is possible to extract the amplitude and phase evolutions and reconstruct the excited bound state wave packet.

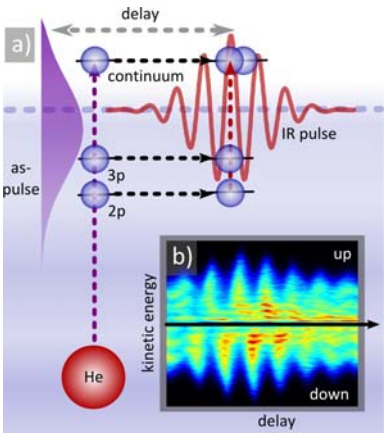

Fig. 1. a) An isolated attosecond pulse is used to excite and ionize Helium; at a later time the trapped portion of the wave packet is ionized by a few cycle IR pulse, which is locked in phase to the attosecond pulse. b) Experimentally observed interference fringes in the photoelectron spectra as a function of delay between the two pulses.

In a second experiment we use an attosecond pulse train for excitation. The photoelectron spectrum consists of a comb of energies, corresponding to the odd harmonics of the fundamental laser field. An additional IR field introduces sidebands through a two-photon process, which allows us to measure the relative phase variation over the harmonic spectrum from a delay-dependent scan (RABITT) [2]. As depicted in Fig. 2 harmonic 15 resonantly excites the 3p state in Helium.

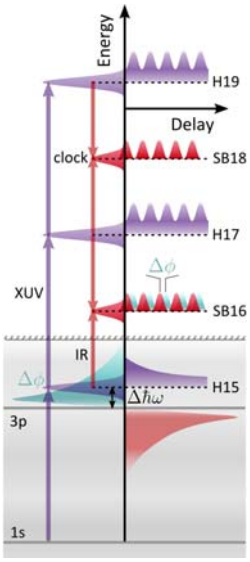

Fig. 2. Influence of a resonant bound state in a RABITT measurement.

The resonance acts as a phase-modulator on the sideband 16 for the two-photon transition, where the phase modulation depends on the detuning of harmonic 15 from the resonance. Referencing SB16 with SB18, we can detect this phase difference. By tuning the laser frequency, we are then able to map out the phase pattern resulting from the presence of the bound state. Having obtained this phase map, we can use it to track the binding energy of the 3p state in Helium when influenced by a strong external laser field (AC-Stark shift).

References

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