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Abstract: We present a critical investigation of the equivalence of attosecond streaking and the reconstruction of attosecond beating by interference of two-photon transitions (RABBITT) for measuring photoemission delays and the reliability of the underlying extraction methods.

Currently, the most common techniques to investigate the single-photon photoemission time delay are based on either the attosecond energy streaking[1,2] or the reconstruction of attosecond beating by interference of two-photon transitions (RABBITT)[3,4]. Both techniques employ a scheme, where an extreme-ultraviolet (XUV) pump pulse initiates electron dynamics and an infrared (IR) probe pulse interrogates the temporal evolution as the delay between pump and probe is varied. While the RABBITT technique uses an attosecond pulse train (APT) in combination with a relatively weak and long IR pulse, attosecond streaking uses a single attosecond pulse (SAP) as a pump and an intense few-cycle IR pulse as a probe. Naturally, the question arises whether the two methods give the same photoemission timing information.

We present a complete comparison, supported by both experiments and simulations, of these two techniques when the photoemission time delay difference between valence electrons emitted from the Ne2p and Ar3p ground states is investigated, as shown in Fig. 1[5].

In particular, we highlight the differences and the similarities between the two techniques, but also critically investigate the robustness and reliability of the procedure used to extract the timing information.

We observed that both techniques lead to very similar results, although both techniques use different approaches to extract atomic delays: the RABBITT technique, in fact, appears to be more robust against the presence of chirp on the XUV pulses but is intrinsically limited through its coarse energy-sampling resolution that is fixed at $2\omega_{IR}$.

Conversely, attosecond streaking requires a reconstruction process that is highly influenced by the chirp of the XUV pulse [6]. In fact, the chirp modifies the spectrogram features in such a way that the FROG-CRAB algorithms based on the central momentum approximation (CMA) cannot correctly retrieve the spectral phase. Most recently, Keathley *et al.*[7] published an algorithm, which does not rely on the CMA and could therefore overcome this limitation.

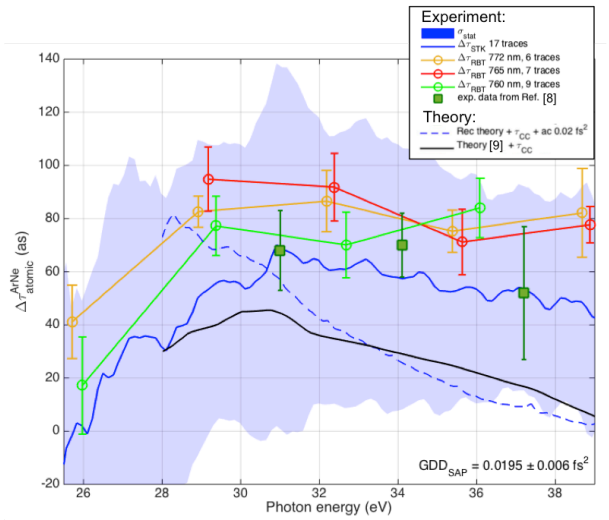

Fig. 1. Comparison between experiments and theory: average group delay difference $\Delta\tau^{ArNe}$ between Ar and Ne as retrieved by FROG-CRAB from experimental streaking traces (blue solid curve, shaded blue area represents the standard deviation) and by RABBITT (colored circles) compared to the theoretical prediction (solid black curve[9]). Additionally, the reconstructed Ar-Ne group delay difference from a simulated streaking trace with an XUV attochirp of 0.02 fs^2 (dashed blue curve), and the experimental data points published in Ref. 8 (dark green scattered squares) are shown.

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REFERENCES

1. J. ITATANI, F. QUÉRÉ, G. L. YUDIN et al., *Phys. Rev. Lett.,* **88**, 173903 (2002).
2. M. HENTSCHEL, R. KIENBERGER, C. SPIELMANN et al., *Nature,* **414**, 509–513 (2001).
3. P. M. PAUL, E. S. TOMA, P. BREGER et al., *Science,* **292**(5522), 1689–1692 (2001).
4. H. G. MULLER, *Appl. Phys. B,* **74**, S17–S21 (2002).
5. L. CATTANEO, J. VOS, M. LUCCHINI et al., *Optics Express*, **24**, 29060-29076 (2016).
6. H. WEI, T. MORISHITA AND C. D. LIN, *Phys. Rev. A* 93, 053412 (2016).
7. P. D. KEATHLEY, S. BHARDWAJ, J. MOSES et al., *New J. Phys.,* **18**(7), 073009 (2016).
8. D. GUENOT, D. KROON, E. BALOGH et al., *J. Phys. B,* **47**(24), 245602 (2014).
9. A. S. KHEIFETS, *Phys. Rev. A,* **87**, 063404 (2013).