

GW-scale 216-as soft-x ray isolated attosecond pulse created by a fully stabilized 50-mJ three-channel optical waveform synthesizer

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Previously, we achieved a stable high-flux continuum high-order harmonic generation (HHG) in the soft x-ray region by demonstrating a fully stabilized 50-mJ three-channel parallel waveform synthesizer [1] operating a 10 Hz. In this work, we perform a frequency-resolved optical gating for complete reconstruction of attosecond bursts (FROG-CRAB) measurement to experimentally characterizing the GW-scale isolated attosecond pulse (IAP) for the first time.

The sub-microjoule IAP pulse is generated by driving pulse of three-channel parallel waveform synthesizer. Two Brewster-angled beam splitters (BS) [2] with NbN coating on Si substrate are introduced for reducing the energy of polarization-managed synthesizer beam. With another 100-nm thickness aluminum filter, therefore, the synthesizer pulse is totally removed and then the separated IAP is focused by a Mo/Si mirror with 300-mm focal length. The gating pulse (streak field) is position-optimized to overlap the IAP with the same polarization at the electron time of flight (e-TOF) device entrance to meet with the neon gas jet. Thanks to the generated intense attosecond pulses, the e-TOF signal can be directly observed through a simple oscilloscope.

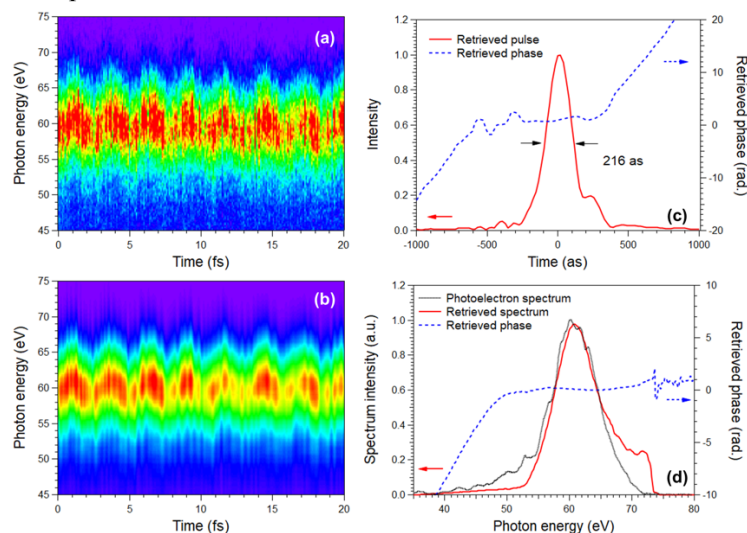


Fig. 1. Experimental FROG-CRAB trace (a) and retrieved trace (b) by PCGPA, the retrieved FROG error is 8%; retrieved attosecond pulse duration and its phase (c); e-TOF obtained photoelectron spectrum and retrieved spectrum (d). PCGPA: Principal component generalized projections algorithm.

The fully stabilized three-channel optical waveform synthesizer generates the intense IAP with 0.24- μ J pulse energy. The measured photoelectron spectrum ionized by the IAP is shown in Fig. 1 (d), its spectrum bandwidth supports a 166-as duration. The experimentally measured FROG-CRAB trace with delay scan of the IR gating pulse is shown in Fig.1(a). For each scan step, the delay time separation is 100 as and collected 100 shots. The retrieved FROG-CRAB trace using the PCGPA is shown in Fig.1(b). According to the retrieved result (Fig.1(c) and (d)), the IAP indicates 216-as duration at FWHM. Consequently, the a fully stabilized three-channel optical waveform synthesizer can generate the GW-IAP in soft x-ray region (with 0.24- μ J pulse energy and 216-as duration), which will pave the way for IAP pump-IAP probe nonlinear spectroscopy and single-shot IAP microscopy.

Reference:

- [1] B. Xue, Y. Tamaru, Y. Fu, *et al.*, *Sci. Adv.* **6**, 16, eay2802 (2020)
- [2] Y. Nagata, Y. Nabekawa, and K. Midorikawa, *Opt. Lett.* **31**, 1316-1318 (2006)