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Generation of high-energy isolated attosecond pulses

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Since the first experimental demonstration of the generation of isolated attosecond pulses, the attosecond technology has become an important branch of ultrafast science [1]. So far, the reported applications of isolated attosecond pulses have been limited by the low photon flux of the available sources. We demonstrate a technique for the generation of isolated attosecond pulses with energy up to 2.1 nJ. The key elements are: (i) the use of few-optical-cycle driving pulses with stable carrier-envelope phase (CEP), linear polarization and peak intensity beyond the saturation intensity of the gas used for HHG; and (ii) the optimization of the interaction geometry in terms of gas pressure, position and thickness of the gas cell.

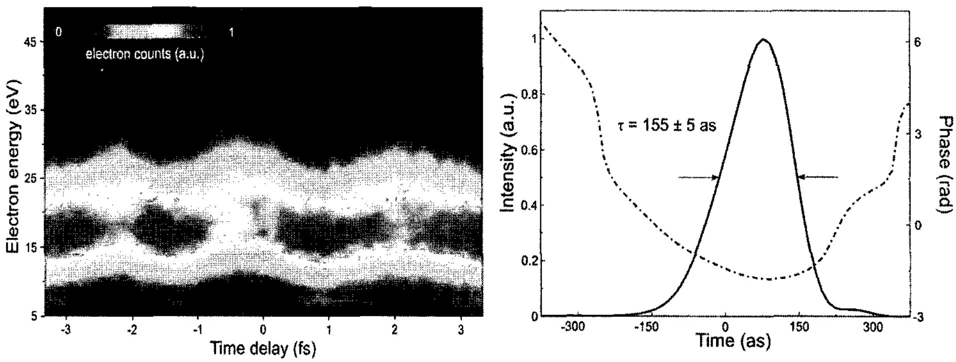

Fig. 1. (a) Portion of a FROG CRAB trace measured as a function of the temporal delay between the attosecond and the IR pulses; (b) reconstruction of the temporal intensity profile and phase of the attosecond pulses

We used 5-fs driving pulses with stable CEP to generate XUV radiation by HHG in a 2.5-mm-long cell filled with xenon at static pressure (2.5-3 torr) at a peak intensity $I=(2.3\pm0.3)\times10^{15}$ W/cm^2. The XUV spectra display an evolution from a continuous behavior to a modulated one by changing the CEP value. The energy of the XUV pulses in the case of continuous spectra was 2.1 nJ, after a 100-nm-thick aluminum filter used to block the fundamental radiation and the low order harmonics. We have also used argon, krypton and neon as generating media: also in such cases clear transition between modulated and continuous XUV spectra were observed upon changing the CEP of the driving pulses. We have measured the temporal characteristics of the attosecond pulses by using the FROG CRAB method [2]. Figure 1a shows a portion of the FROGCRAB trace; in the reconstructed temporal intensity profile of the XUV pulses (see Fig.1b), the pulse duration was 155±5 as (the transform limit was ~120 as).

The physical mechanism at the basis of this method is related to the ionization dynamics in the generating medium. We used a nonadiabatic three-dimensional numerical model [3]. In agreement with experimental results, the calculated XUV spectra display an evolution from a continuous behavior to a modulated one by changing the CEP value. We have then calculated the propagation of the XUV beam from the gas cell to the target position by taking into account the effects of the toroidal mirror and of a 200-μm-diameter pinhole used for spatial filtering of the XUV radiation. With a proper choice of the CEP, isolated attosecond pulses are generated, with a constant pulse duration across the transverse profile of the beam, thus demonstrating the excellent spatial characteristics of the generated attosecond pulses.

References

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