Fourier-Limited Few-Cycle Attosecond Pulses from High-Order Harmonic Generation Assisted by an Ultraintense Ultrafast Magnetic Field

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Attosecond (*as*) pulse generation is temporally constrained by the attochirp inherent to the high-order harmonic generation (HHG) process. In the extreme ultraviolet, near Fourier-limited *as*-pulses are obtained compensating the attochirp using dispersive materials like metallic filters. The shortest *as*-pulse record used a Zr-filter to compress the pulse down to just 43 *as* [1]. However, at the soft x-rays regime, chirp compensation optics is inefficient and the generation of near Fourier-limited pulses has become a great challenge. We identify a promising scenario to suppress the attochirp assisting HHG with a strong fast oscillating magnetic field (B-field), up to tens of kT, than can be obtained from structured beams or stationary configurations of state-of-the-art Petawatt laser systems. [2]

We spot a situation where a strong B-field assists the HHG process creating a transverse harmonic oscillator-like potential acting as an energy reservoir and as a confinement of the free electron wavepacket after the ionization step. Whereas HHG driven by a circularly-polarized (CP) laser is not efficient by the ineffective recollision with the parent ion [3], this no longer holds if assisted by a B-field in a configuration like in Fig. 1 (a). We numerically show how CP drivers not only result in a broad spectra beyond the classical limit, but also form near Fourier-limited *as*-pulses. In Fig. 1 (b), we compare the HHG spectra, driven by a $|E_0|^2 = 1.6 \times 10^{14}$ W/cm^2 laser at $0.8\,\mu$m, with the standard scheme of HHG (blue line, linearly-polarized (LP) driver and no B-field), and our proposed configuration (orange line, CP driver assisted by a 2.8×10^4 T B-field at $1.6\,\mu$m). In the new setup, the spectrum is extended to 310 eV, hundreds of harmonic orders above the cutoff energy (black arrow). Remarkably, the radiation arises as a few-cycle near Fourier-limited 27 *as* full-width half maximum pulse (Fig. 1 (c)). To understand the intrinsic physics, we develop a unidimensional model for the transverse component of the free wavepacket (Fig. 1 (d)). From the interplay between the trapping potential and the transverse component of the CP driver, the wavepacket follows a quivering trajectory together with a lateral breathing cycle. If the maximum wavepacket compression is synchronized with the ion recollision, the effective rescattering time is minimized leading to a chirp-free emission. We foresee a new scenario where Petawatt lasers may be vital in an attochirp-free x-ray HHG process, paving the way to the generation of few-cycle Fourier-limited *as*-pulses. [4]

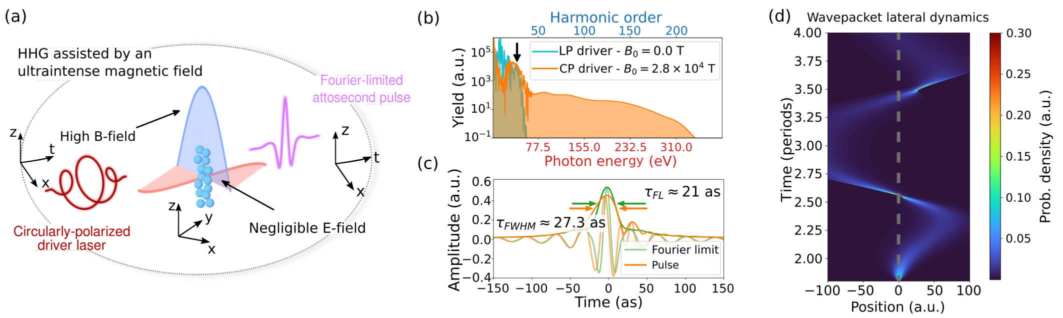

Fig. 1: (a) The proposed scheme for the HHG assisted by a strong fast oscillating B-field. The B-field results from two counter-propagating Petawatt laser beams. (b) Comparison between the HHG spectra with the standard scheme (orange) with a LP driver and no B-field, and in the proposed scheme with a CP driver and a 2.8×10^4 T B-field at $1.6\,\mu$m. The driver intensity in both cases is $|E_0|^2 = 1.6 \times 10^{14}$ W/cm^2 at $0.8\,\mu$m. (c) Pulse obtained filtering out harmonics below 108 eV for the orange spectrum in (b). The pulse exhibits 27 *as* full-width half maximum (FWHM) duration, near the Fourier limit (FL). (d) Lateral breathing dynamics for the free wavepacket from the interplay between the trapping potential and the transverse component of the CP driver.

References

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