Comment on “Universality of Returning Electron Wave Packet in High-Order Harmonic Generation with Midinfrared Laser Pulses”

In Ref. [1], Le et al. establish in the long-wavelength limit a universal shape for the returning electron wave packet in high-order harmonic generation (HHG) as a function of the returning electron’s energy. Based on this approach, Le et al. suggest a universal wavelength scaling law, $\propto \lambda^{-4.2}$, for the HHG yield for laser wavelengths in the range $3 \mu m \leq \lambda \leq 6 \mu m$. This scaling law differs from the faster decrease of the HHG yield with increasing $\lambda$, $\propto \lambda^{-5.6}$, predicted earlier [2–5]. Le et al. attribute this difference to the limited interval of wavelengths ($\lambda \leq 2 \mu m$) used to solve the time-dependent Schrödinger equation (TDSE) in Refs. [2,3,5]. Since the HHG yield is a fundamental quantity for practical applications, any new scaling law for $\lambda \gtrsim 3 \mu m$ must be clearly justified owing to its importance for planning experiments involving the generation of extreme ultraviolet radiation by means of HHG using long-wavelength lasers.

The apparent disagreement stems from the use in Ref. [1] of a different definition of the harmonic yield $\Delta Y$ from that used in Refs. [2–5]. As noted in Ref. [5], the $\lambda$-scaling law depends on the precise definition of $\Delta Y$. In Ref. [2], the authors study “the scaling of an average harmonic yield, obtained by integrating the power spectrum over a fixed bandwidth.” (They integrate the HHG power spectrum over harmonic energy intervals of 40–80 eV for He and 20–50 eV for Ar.) In Ref. [4], the definition of harmonic yield from Ref. [2] was adopted for a monochromatic field, defining the yield $\Delta Y$ in terms of the HHG power. For a short-pulse laser field, in Refs. [3,5], a definition of the HHG yield compatible with that in Ref. [2] is used; i.e., $\Delta Y$ is defined as the energy radiated per unit time by the target atom (subjected to a laser pulse of duration $T$) into a fixed harmonic energy range $[\Omega_1, \Omega_2]$:

$$\Delta Y = \frac{1}{T} \int^{(\Omega_2)}_{\Omega_1} \rho(\Omega) d\Omega,$$

where $\rho(\Omega)$ is the spectral density of harmonics with energy $\Omega$. (Although Ref. [3] properly defines the HHG yield in words, the factor $1/T$ was inadvertently omitted in Eq. (2) of Ref. [3]; this omission was corrected in Eq. (3) of Ref. [5].) Since the laser pulse has a fixed number $N$ of optical cycles, $T$ scales linearly with $\lambda$. By inserting the recolliding wave packet results of Ref. [1] into Eq. (1), the scaling $\Delta Y \propto \lambda^{-5.2}$ found in Refs. [2–5] is confirmed.

In conclusion, we have shown that when the same definition for the HHG yield is used [cf. Eq. (1)], the results of Ref. [1] give the same scaling law found earlier in Refs. [2–5] for wavelengths $\lambda \leq 2 \mu m$. We note that this latter scaling law can be obtained analytically by using results of the model developed in Ref. [6] for the description of short-pulse HHG spectra. These analytic results as well as new numerical TDSE results for longer wavelengths, $\lambda \leq 4 \mu m$, will be published elsewhere.

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