Carrier-wave Rabi flopping signatures in high-order harmonic generation

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Synopsis

We present theoretical investigations of carrier-wave Rabi flopping (CWRF) in real atoms by studying high-order harmonic generation in alkali species. We concentrate on the features of the third harmonic of Na and K atoms. For pulse areas of 2\pi and Na atoms, a characteristic unique peak appears, which, after analyzing the ground state population, we correlate it with the conventional Rabi flopping. On the other hand, for larger pulse areas and K atoms, CWRF occurs, and it is associated with a more complex structure in the third harmonic. These new characteristics indicate the breakdown of the area theorem, as was already demonstrated in narrow band gap semiconductors.

When the atom is modeled as a two-level system, the conventional Rabi flopping behavior and carrier-wave Rabi flopping (CWRF) phenomenon features are observed. However, it is well known that the two-level approximation breaks down when strong electric fields are applied, in particular in the CWRF regime. Experiments on narrow band gap semiconductors have shown a clear signature of CWRF, which manifested itself as a split in the third harmonic of the emitted light into the forward direction \cite{1}. An important question emerges as to what extent CWRF could potentially be observed in real atoms \cite{2}. One of the advantages of atoms (relative to semiconductors) is the possibility to employ longer laser pulses and, as a consequence, to explore a broader range of laser parameters. We compute high-order harmonic generation (HHG) spectra in K atoms in which the transition energy between the ground and first excited states is resonant with the driven light. We observe that HHG spectra of K atoms present a drastic change around the third harmonic (see figure 1) as pulse envelope area increases in contrast to the HHG spectra of Na (not resonant), where a single peak is seen in the third harmonic regardless of the envelope pulse area. We use accurate values for the atomic wavefunction of both ground and excited states as well as typical laser parameters, easily achievable with the current laser technology. As a consequence, the experimental confirmation of our results appears straightforward. Moreover, the CWRF phenomenon could emerge as a robust alternative for carrier-envelope phase (CEP) characterization for long pulses.

![Figure 1. HHG spectra in K for the corresponding laser intensities $I = 3.158 \times 10^{11}$ W/cm$^2$ (panel a), $I = 5.614 \times 10^{11}$ W/cm$^2$ (panel b) and $I = 1.108 \times 10^{12}$ W/cm$^2$ (panel c) and an 18 fs (FWHM) driving pulse. Panels (d), (e) and (f) show the HHG in Na for the same laser parameters. The insets of panels (a), (b) and (c) show a zoom of the third harmonic $\omega/\omega_0 = 3$.](image)

References

\begin{enumerate}
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