The mechanism of high-harmonic generation from solids under intense laser pulses

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Synopsis We present numerical investigation of high-harmonic generation from a solid structure driven by intense laser pulses. Including the full bands, we solve the time-dependent Schrödinger equation (TDSE) numerically using Bloch states. The harmonic spectra have extra plateaus which show the linear dependence on the laser field strength. The trajectories of electron are obtained after convert the wavefunction into x-space. Then the dynamics of electrons is investigated in two-band model by numerically solving semiconductor Bloch equations (SBEs). Based on the temporal dynamics of electrons, the Bloch oscillation can be observed and makes an primary contribution to the second plateau.

As the thriving development of the strong-field physics in past decades, the light-matter interaction regime is expanding from traditional gaseous media: atoms and molecules to solids [1, 2, 3]. Due to the high density, the HHG from solids also shows a high efficiency. In addition, the harmonic spectrum can be used to probe the complicated periodic structure of the solid. Basically speaking, HHG from solids opens the way to study the ultrafast dynamics of electrons in condensed matter phase[1].

Firstly, we present the results obtained using the TDSE method. The involved structure bands are obtained by solving the single electron schrödinger equation using periodical pseudo potential, $V(x) = -0.37[1+\cos(2\pi x/a_0)]$, where $a_0 = 8\ a.u.$ is the lattice constant. The harmonic spectrum shows several plateaus due to the electron dynamics between the highest valence band and the high-lying conduction bands. The trajectories of electron in Fig. 1(a) are obtained after convert the wavefunction into x-space, which shows that the initial localized electrons can migrate in the crystal potential wells arranged like Wannier-Stark ladder.

Secondly, the dynamics of electrons is investigated in two-band model by numerically solving SBEs, we present the temporal population of electrons in Fig. 1(b) and the time-frequency analysis in Fig. 1(c). Based on these analysis, we conclude that the harmonics of the first plateau is contributed by the recombination of electron-hole pair. The harmonics beyond the first plateau is contributed by Bloch oscillations in k-space, and the cutoff energy proportional to Bloch frequency ω_B, linearly depending on the laser field strength. An alternative description of Bloch oscillation in k-space is Wannier-Stark ladder in x-space, which shows that the electron moving among the lattice sites contribute the second harmonic plateau.

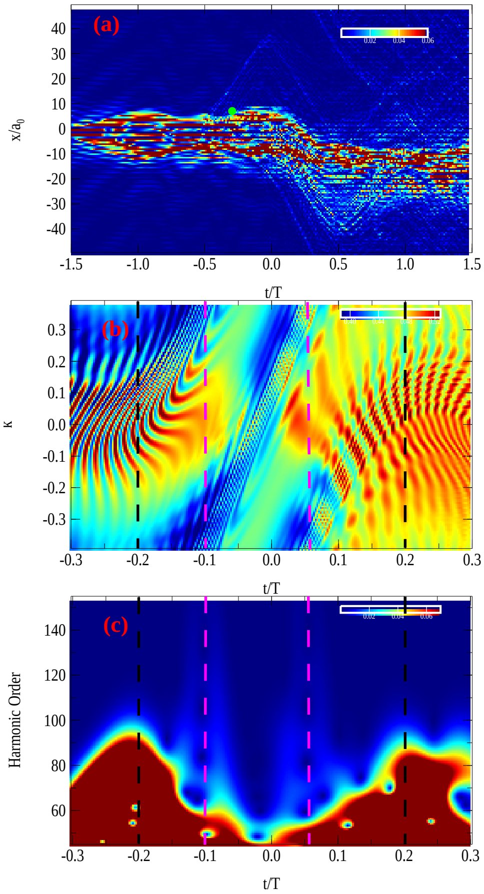

Figure 1. (a) The trajectories of electrons in x-space from TDSE. (b) The temporal population of electrons in conduction band in k-space. (c) The time-frequency analysis of harmonic spectrum.

References

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