Mechanisms of the high-order harmonic generation from solids

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Synopsis Laser-solid interaction was investigated numerically by simulating the Bloch electron wave-packet dynamics in periodic potentials. We introduced a quasi-classical model in the *k* space combined with the energy band structure to reveal the mechanisms of high-order harmonic generation (HHG) processes occurring in a sub-cycle timescale. We also proposed an efficient way to enhance the yield of HHG in inhomogeneous laser fields below the damage threshold.

Recently, high-harmonic generation (HHG) from solids has received particular attention [1]. Two-band [1] and multiband models [2], intra-band [1, 3] and inter-band [4] transitions are used to interpret the mechanisms behind HHG. However, the mechanisms are still much debated. Simple quantitative universal models are required.

We report a quasi-classical model [5] to investigate the electron dynamics in HHG. The cutoff of HHG obtained by this model agrees well the experimental measurement. It reveals the linear dependence of cutoff energies on the amplitude of vector potential A_0 of the laser fields. It can also predict the emission time of HHG, which agree with time-profile analysis of TDSE. It provides a scheme to reconstruct the energy band in Brillouin zone and to control the quantum trajectories of HHG by varying the shape of laser pulses. This model is instructive to control and optimize HHG experimentally from solids.

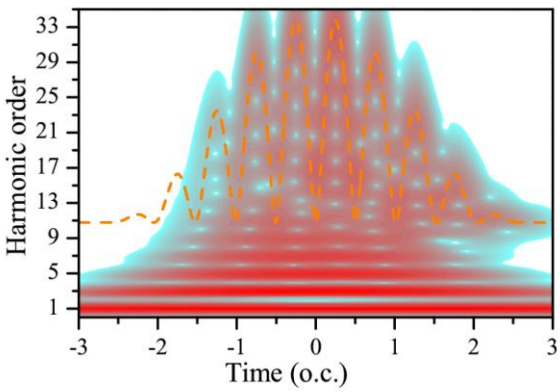

Figure 1. Time-frequency analysis of the first HHG plateau. The colormap is extracted from the quantum TDSE simulations, while the dash curve represents the predictions of emission time of the HHG by the quasi-classical model.

Based on the knowledge of the mechanisms of HHG from solids, we propose that the HHG yield can be greatly enhanced by using inhomogeneous laser fields induced by bow-tie structure growing on the semiconductor substrate below the damage threshold [6]. This is attributed to the bigger transition probabilities to higher conduction bands. The enhancement of the second HHG plateau can be used to generate intense narrow isolated attosecond pulses from solids.

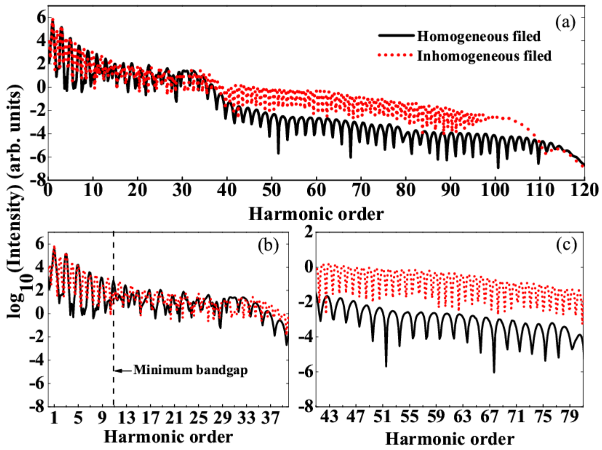

Figure 2. Comparison of HHG spectra between homogeneous and inhomogeneous fields. (a) HHG with full range. (b) The first HHG plateau. (c) The second HHG plateau.

References

[1] S. Ghimire *et al.* 2011 *Nature Phys.* **7** 138-141
[2] G. Vampa *et al.* 2015 *Phys. Rev. B* **91** 064302
[3] P. G. Hawkins *et al.* 2013 *Phys. Rev. A* **87** 063842
[4] C. R. McDonald *et al.* 2015 *Phys. Rev. A* **92** 033845
[5] T. Y. Du and X. B. Bian 2017 *Opt. Express* **25** 151-158
[6] T. Y. Du, Z. Guan, X. X. Zhou and X. B. Bian 2016 *Phys. Rev. A* **94** 023419

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