Aix*Marseille université
Initiative d'excellence

Faculté des Sciences
Aix*Marseille Université

Master Thesis Project

Laboratoire: CINaM

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Floquet theory of high-harmonic generation

A decade ago, it was demonstrated experimentally that when a crystal is illuminated by a strong laser pulse, it generates an electromagnetic radiation at very high harmonics[1]. This high harmonic generation can be used to conceive attosecond laser as well as for band structure reconstruction. Considerable effort has been paid over the past decade to determine the proper description of the underlying physics of high-harmonic generation in solids[2]. What became rapidly clear is that the multiband nature of the band structure influences the high-harmonic generation in several intricate manners: The presence of several conduction and valence bands results in multiple plateaus[3,4], and the Berry curvature[5,6] associated with the orbital and spin chiralities of the bands can give rise to distinct polarizations of the harmonics. The need for a realistic description of the band structure involved in high-harmonic generation in solids combined with the technical difficulties inherent to the theory and numerical simulations of ultrafast processes represent a major challenge for the proper application of high-harmonic generation to electronic band structure characterization.

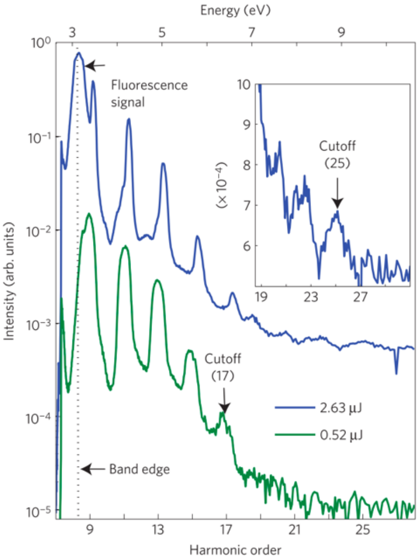

Figure 1 : High-harmonic generation in the strong coupling regime in ZnO

We have recently launched a collaborative project with our experimental colleagues at CINaM as well as at CEA/LIDYL to demonstrate the control of high-harmonic generation in heterostructures. The goal of this internship is to theoretical investigate high-harmonic generation in heterostructures using Floquet theory implemented on tight-binding models. Floquet theorem is the time counterpart of Bloch theorem: under a periodically oscillating excitation, the electron wave packet is represented by the so-called Floquet-Bloch state, which can be used to model high-harmonic generation. The student will first investigate a simple two-dimensional gas with inversion symmetry breaking to determine its influence on high-harmonic generation features. Extension to heterostructures involving multiferroic materials will be considered in a second step.

1. Ghimire, *et al.* Observation of high-order harmonic generation in a bulk crystal. *Nat. Phys.* **7**, 138 (2011).
2. Ortmann, *High-harmonic generation in solids*. *Advances in Atomic, Molecular and Opt. Physics* 70 (2021).
3. Du et al., Enhanced high-order harmonic generation from periodic potentials in inhomogeneous laser fields. *Phys. Rev. A* **94**, 023419 (2016).
4. Ndabashimiye *et al.* Solid-state harmonics beyond the atomic limit. *Nature* **534**, 520 (2016).
5. Liu, H. *et al.* High-harmonic generation from an atomically thin semiconductor. *Nat. Phys.* **13**, 262 (2017).
6. Baykusheva *et al.* Strong-field physics in 3D topological insulators. *Phys. Rev. A* **103**, 23101 (2021).