Floquet physics: an outline

Jinyuan Wu

November 14, 2023

Abstract

In crystal systems, the periodic, strong atomic potential breaks the continuous translational symmetry to a discrete one, and hence well-defined momenta for electron eigenstates, but a crystal momentum in the first Brillouin zone still exists for each eigenstate. Similarly, when a system is under periodic (usually optical) driving, the time-dependent Hamiltonian no longer has stationary states, but quasi-stationary states with "quasi-energies" exist. This driven, out-of-equilibrium state of matter is known as Floquet state and is known to host exotic physics. This project will first cover the foundational concepts and theory of the Floquet formalism, and then turn to the theory of Floquet state under angle-resolved photoemission spectroscopy. We then review topological band engineering with Floquet driving, and secondary Floquet effect caused by optical excitations instead of the pump pulse itself.

Contents

- Introduction: Floquet theory leads to Bloch theorem for spatial periodic potential and Floquet state for temporal periodic driving; recent investigations of Floquet state of matter; common experimental platforms.
- Basic formalism of Floquet physics: quasienergies, quasi-stationary Floquet states [1], relation within the generic framework of non-equilibrium physics [2].
- Floquet effect in spectroscopy, time- and angle-resolved photoemission spectroscopy: generic ARPES theory based on lesser Green function, and specifically Fermi golden rule for probing [1, 3].
- Floquet effect caused by exciton induced by light, instead of light itself [4].
- Floquet topological band theory [3, 5, 6].
- Conclusion: possible future developments, like experimental observations predicted but not clearly seen, and probably generalized theory [7].

References

[1] Mark S Rudner and Netanel H Lindner. "The Floquet Engineer's Handbook". In: *arXiv preprint arXiv:2003.08252* (2020).

[2] Andreas Lubatsch and Regine Frank. "Evolution of Floquet topological quantum states in driven semiconductors". In: *The European Physical Journal B* 92 (2019), pp. 1–9.

[3] Michael Schüler and Samuel Beaulieu. "Probing topological Floquet states in WSe_2 using circular dichroism in time-and angle-resolved photoemission spectroscopy". In: *Communications Physics* 5.1 (2022), p. 164.

[4] Y-H Chan et al. "Giant self-driven exciton-Floquet signatures in time-resolved photoemission spectroscopy of WS_2 from time-dependent GW approach". In: *arXiv preprint arXiv:2302.01719* (2023).

[5] Changhua Bao et al. "Light-induced emergent phenomena in 2D materials and topological materials". In: *Nature Reviews Physics* 4.1 (2022), pp. 33–48.

[6] Hang Liu, Haijun Cao, and Sheng Meng. "Floquet engineering of topological states in realistic quantum materials via light-matter interactions". In: *Progress in Surface Science* (2023), p. 100705.

[7] Fabio L Traversa, Massimiliano Di Ventra, and Fabrizio Bonani. “Generalized Floquet theory: Application to dynamical systems with memory and Bloch’s theorem for nonlocal potentials”. In: *Physical Review Letters* 110.17 (2013), p. 170602.