Master Physique — Condensed Matter and Nanophysics

Academic year 2019-2020

Topological nanophotonics in the strong coupling regime

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The utility of topology in quantum materials has been proven by the revolutions in the understanding of a range of phenomena, including the integer and anomalous quantum Hall effects, and the quantum spin-liquid states of antiferromagnets. Recently, a rapidly growing research field known as *topological nanophotonics* has emerged [1], which seeks to harness the power of topological physics in a new generation of highly controllable light-based structures and devices. It is envisaged that this topic will lead to a deeper understanding of light-matter interactions at a fundamental level, as well as novel applications including chiral lasers, robust integrated quantum optical circuits, and nonlinear light generators.

The prototypical one-dimensional (1D) model exhibiting nontrivial topology is the Su-Schrieffer-Heeger (SSH) chain. At its most fundamental level, this model is a tight-binding Hamiltonian with nearest neighbor hopping in a dimerized 1D lattice geometry. In its topologically nontrivial phase, which is associated with a Zak phase of π (the equivalent of a Berry phase in 1D), it hosts edge states at the ends of the chain. This accordance between the Zak phase and the presence of edge states is known as the *bulk-edge correspondence principle*. The SSH model has recently been exploited to great effect in a series of theoretical works, including in photonics, plasmonics, polaritonics, superconducting circuits, and waveguide QED. Cutting edge experiments have already begun to report some of the remarkable topological properties of so-called extended SSH models in these active research fields.

Very recently [2], we considered a physically rich extension of the SSH model, staged by polariton excitations inside a cavity waveguide. We looked at how the intrinsic topology of the SSH model, whose role is played by collective excitations coupled throughout a dimerized dipolar chain, is changed in novel and unexpected directions due to strong light-matter coupling inside the cavity. In particular, we demonstrated the breakdown of the bulk-edge correspondence for a certain parameter range. This is a highly nontrivial result, which has profound consequences for the topological phases of the system.

The goal of this internship is to ask the following question: does the bulk-edge correspondence holds or breaks for a two-dimensional artificial graphene honeycomb array of dipolar resonators (which can be plasmonic or dielectric nanoparticles, microwave resonators, magnonic microspheres, cold atoms, etc.) in the strong light-matter coupling regime. We have already studied [3] how the latter gives rise to a very rich band structure, hosting tunable type-I and type-II Dirac points. However, the question of the nature of the topologically-protected edge states of a graphene-like system under strong coupling remain unexplored, and will be studied in this internship.

The student will work in the Mesoscopic Quantum Physics Team at IPCMS (R. Jalabert, G. Weick, and D. Weinmann). For more information, please contact G. Weick (email: guillaume.weick@ipcms.unistra.fr).

[1] T. Ozawa *et al.*, Rev. Mod. Phys. **91**, 015006 (2019)
[2] C.A. Downing, T.J. Sturges, G. Weick, M. Stobinska, L. Martin Moreno, arXiv:1907.02013
[3] C.R. Mann, T.J. Sturges, G. Weick, W.L. Barnes, E. Mariani, Nature Comm. 9, 2194 (2018)