Light-matter correlations in Quantum Floquet Engineering

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Since the earliest studies to understand the nature of light, harnessing light-matter interactions has been a persistent goal in condensed matter physics and, more recently, in quantum technologies. A well-known example is the use of classical driving fields as external knobs to alter and control the properties of materials, in what is now widely known as Floquet engineering [1].

An avenue currently being explored known as Quantum Floquet engineering [2,] involves the use of quantum fields rather than classical ones. Theoretically, this regime entails some difficulties. It was recently revealed that a gauge-invariant description of this interaction requires including the photonic field operators to arbitrary order in the Hamiltonian [3]. Unfortunately, such Hamiltonians are extremely non-linear and complex to simulate. This makes it important to develop effective models which can describe the system over a wide range of coupling regimes, being also simple enough to capture the main mechanisms governing the physics.

In this work [4], we present a framework to obtain simple effective Hamiltonians by means of a disentangling technique. It allows us to find a non-perturbative, polynomial expansion of the full, gauge-invariant Hamiltonian, which can be truncated to low order and provides accurate results for arbitrary coupling strength.

Within this framework, we study the paradigmatic case of a Su-Schrieffer-Heeger (SSH) chain [5] coupled to a single mode cavity, and show that their interaction can produce topological phase transitions. Interestingly, each photonic band exhibits its own topological phase transitions, which allows the control of the topological properties of the fermionic system through the number of cavity photons.

Furthermore, we find that light-matter correlations are crucial as they can spontaneously break chiral symmetry, severely affecting the topology even when the cavity frequency is far detuned from the electronic system. With these results in mind, we address the important differences between classical and quantum Floquet engineering in the high frequency regime. Finally, we discuss how the spectroscopy of the photons can be used to detect all our findings and the possibility to use the cavity to externally control the state transfer between topological edge states.

References

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