New avenues for quantum optical simulators

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Abstract

Quantum optical simulators are systems in which ensembles of quantum emitters (e.g., neutral atoms, ions, or excitons) interact with photons propagating either in free space (like in atomic arrays) or confined in an optical cavity or a dielectric material (such as photonic crystals, see Figure 1). Such systems offer the possibility to exploit cooperative and topological effects to improve the scalability of future quantum devices [1, 2].

In this contribution I will first introduce a quantum neural network architecture in the spirit of [3] consisting on an array of single-mode cavities coupled to quantum emitters, where the nonlinearity is provided by the light-matter interactions. I will show how this can be applied to a variety of problems in quantum metrology, such as producing states that maximize the quantum Fisher information while simultaneously reducing their vulnerability to noise.

Next, I will discuss the possibility to couple bosonic atoms to the boundaries of a two-dimensional topological photonic crystal, which act as a multimode topological waveguide [4] (see Figure 2). Under incoherent driving, driven-dissipative topological phase transitions leading to topological amplification can be observed. Our goal is to assess the impact of interactions between the atoms in such a system.

References

[1] Chang et al., RMP 90, 031002 (2018).
[2] Tabares et al., arXiv:2302.01922 (2023).
[3] Steinbrecher et al., npj Quantum Information 5, 60 (2019).
[4] Vega et al., arXiv:2207.02090 (2022).

Figures

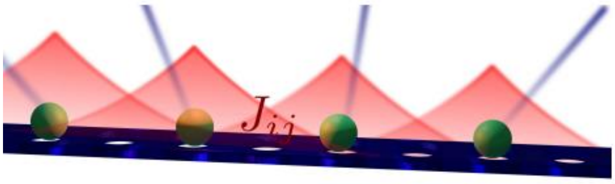

Figure 1: An example of quantum optical simulator: quantum emitters (atoms) are addressed by lasers and coupled to a nanophotonic crystal waveguide (see [2]).

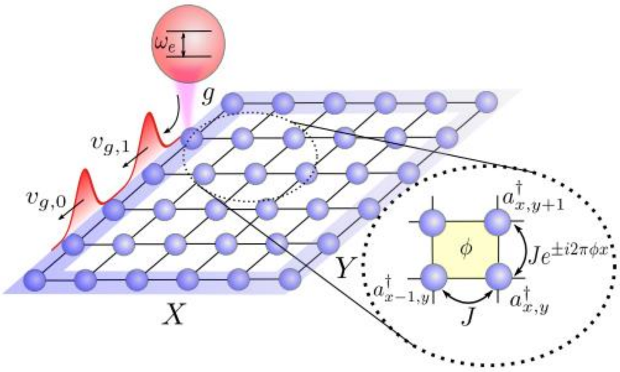

Figure 2: Two-dimensional square photonic crystal subject to an effective magnetic flux (i.e., a Harper-Hofstadter lattice). Quantum emitters are coupled to the topological edge modes of the lattice (figure taken from [4]).