Conditional photonic phase gate in topological waveguide QED

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Topological photonics provides a route to engineer one-way and robust-to-disorder photon flows [1]. An open question in the field is whether it is possible to perform controlled quantum operations between these topologically protected photons, a challenging task due to their non-interacting character [2]. In this work, we provide a positive answer to this question by showing how to engineer a controlled phase gate between two photonic qubits propagating in orthogonal, topologically-protected edge channels appearing in two-dimensional photonic insulators [3]. The only ingredients required are the coupling of several two-level emitters to these channels and a suitable choice of the photonic qubit encoding such that the photons cross as they propagate through the emitters [4,5] (*Figure 1*). We study the fidelity of the conditional gate and its resilience to imperfections by calculating the single and two-photon scattering matrix of the system and demonstrate how it can achieve high fidelities with a moderate number of emitters. Our work paves the way for harnessing topological photonic systems for photonic quantum information processing.

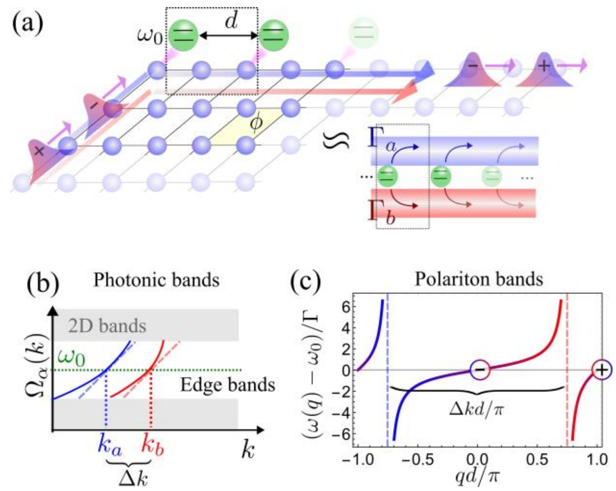

Figure 1: (a) Schematic representation of the setup: a topological photonic insulator hosts two edge modes (a/b) with dispersion represented in (b). The coupling of an array of two-level emitters with frequency ω_0 to the edge of the insulator alters the dispersion (c) via the avoided crossing principle. This is formally equivalent to a two-mode, topological waveguide QED setup. The new resonant excitations (+/-) are orthonormal superpositions of a and b photons, and can be used to encode two photonic qubits with different group velocities. This allows us to achieve a conditional phase gate, exploiting the non-linearities of the emitters, by making the photons cross as they propagate through the array.

References

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