Chirality Dependent Photon Transport and Helical Superradiance

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Chirality, or handedness, is a geometrical property denoting a lack of mirror symmetry. Chirality is ubiquitous in nature and is associated with the non-reciprocal interactions observed in complex systems ranging from biomolecules to topological materials. Here, we demonstrate that chiral arrangements of dipole-coupled atoms or molecules can facilitate the unidirectional transport of helical photonic excitations without breaking time-reversal symmetry. We show that such helicity dependent transport stems from an emergent spin-orbit coupling induced by the chiral geometry, which results in nontrivial topological properties. We also examine the effects of collective dissipation and find that many-body coherences lead to helicity dependent photon emission: an effect we call helical superradiance. Our results demonstrate an intimate connection between chirality, topology, and photon helicity that may contribute to molecular photodynamics in nature and could be probed with near-term quantum simulators [1].

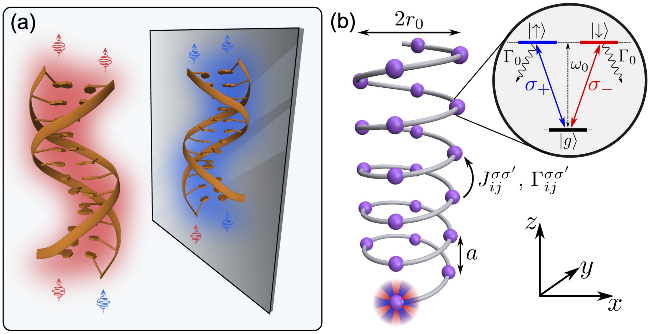

Fig. 1: (a) Illustration of the main results of this work. Photons with a given helicity (red or blue) are preferentially transported through structures of a given chirality, leading to helical superradiance. (b) The model used to describe the transport dynamics. Purple spheres denote emitters with a V-type level structure and spontaneous emission rate Γ_0 (inset). The lattice geometry is a helix with radius r_0, pitch a, and $\mathscr{N}$ atoms per 2π turn. Emitters are coupled with coherent ($J_{ij}^{\sigma\sigma'}$) and dissipative ($\Gamma_{ij}^{\sigma\sigma'}$) hopping rates. The multicolored halo denotes initialization in an unpolarized mixed state.

References

[1] J.S. Peter, S. Ostermann, S.F. Yelin, Phys. Rev. Let. (submitted, 2023)

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