Interaction-Induced Topology in Parametrically Driven Resonator Chains

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Abstract: Can nonlocal nonlinear interactions alone drive a topological phase transition? We address this question in a chain of parametrically driven resonators coupled via cross-Kerr interactions, and discuss perspectives for condensed matter and topological photonics systems.

A central question in quantum many-body physics concerns the interplay between interactions and topology. Traditionally, quadratic Hamiltonians are known to generate topological band structures, and nonlinear interactions give rise to phenomena such as localization and superconductivity that often compete with or modify topological effects.

In this talk, I show that nonlocal nonlinear interactions can by themselves drive a topological phase transition. The system under consideration is a chain of parametrically driven quantum resonators coupled exclusively through weak nearest-neighbor cross-Kerr interactions, with no quadratic hopping. When the parametric drive exceeds a critical threshold, the system undergoes a transition from a trivial atomic limit of decoupled oscillators into a symmetry-broken topological phase.

Above the threshold , even a weak nonlinearity is sufficient to stabilize the resonators— a principle well-established in superconducting Kerr qubits and optical systems — and here shown to be the microscopic origin of emergent topological order. These results are relevant to condensed matter and topological photonics, and suggest a new route for engineering and understanding novel topological phases.

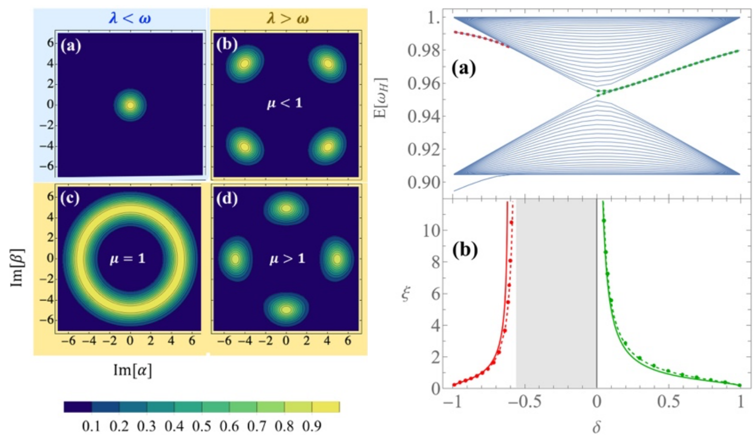

Fig. 1 (Left) Density plot describing the ground-state of a pair of Kerr resonators in phase space (a) thermal Gaussian state (b-c) homogeneous state possibly hosting topological phase (c-d) density wave phase. (Right) Structure of the spectrum in as a. function of the parameter δ tuning the topological gap.

References

[1] A.Coppo, A. Le Boité, S. Felicetti and V. Brosco, Nonlinearity-driven Topology via Spontaneous Symmetry Breaking accepted for publication in Physical Review B (2025)