Topology and energy dependence of Majorana bound states in a cavity

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Light-matter interaction plays a crucial role in modifying the properties of quantum materials. In this work, we investigate the effect of cavity induced photon fields on a topological superconductor hosting Majorana bound states (MBS). We model the system using a Peierls substitution of the photonic operator in the kinetic and spin-orbit terms and utilize an exact diagonalization of Hamiltonian for a finite number of photons to investigate the coupled system. We find that the MBS persist even in the presence of a cavity field, but appear at finite energy, in contrast to a usual 1D topological superconductor. The MBS energy is shifted by two processes: the cavity photon energy $\hbar\omega(N_{ph} + 0.5)$, where ω is the photon frequency and N_{ph} is the number of photons setting the probed photon sector, and the light-matter interaction strength γ, which causes an additional energy shift, resulting in a *pseudo-dispersion* of the MBS energies. Additionally, we find that the MBS energy oscillations are suppressed with increasing light-matter interaction. Combined, these offer additional tunability and stability of the MBS. Figure 1. shows how MBS energy can be tuned with light-matter coupling γ and magnetic field B.
As a second result, we establish a modified spectral localizer (SL) formalism as an essential tool for topological characterization of matter in a cavity. The SL allows characterization at arbitrary energies, which is needed for probing different photon sectors. However, hybridization between different photon sectors in the low-frequency regime limits a straightforward application of the SL. We resolve this issue by judiciously applying an energy shift to the SL. Our work thus introduces a new avenue for controlling MBS via light–matter coupling and provides a framework for exploring cavity-modified topologies.

Figures

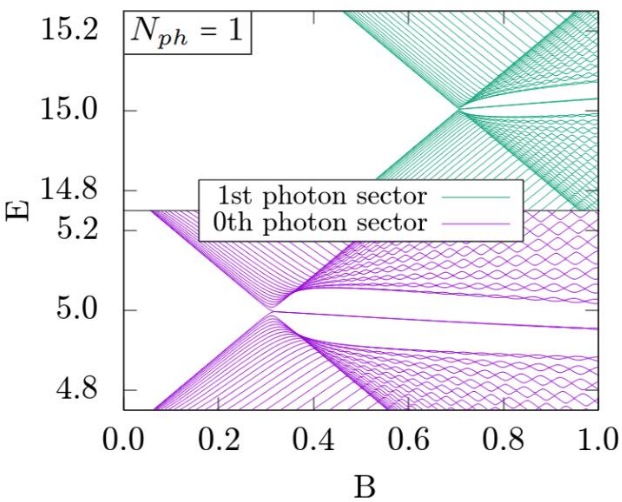

Figure 1: Energy spectrum of the 1D topological superconductor in a light cavity as a function of magnetic field B. If one photon is present in the system, non-zero light-matter coupling γ leads to *pesudo-dispersion* of MBS energy. This energy change if then amplified by magnetic field.