Hybrid light-matter states in topological superconductors coupled to cavity photons

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Using photonic cavities to control properties of the materials is a novel research direction of condensed matter physics. Topological materials play particularly important role in this direction due to their robustness and their possible application in quantum technologies. Among topological materials, topological superconductors hosting zero-energy Majorana bound states hold a specially interesting place for their potential of being used as building blocks for a fault-tolerant topological quantum computer. The prototype system for topological superconductivity is the Kitaev chain model describing a one-dimensional p-wave superconductor with Majorana bound states emerging at its opposite ends, while semiconducting-superconducting nanowire is one of the most promising platforms for implementing Majorana bound states in the lab. However, their observation caused much controversy since one of their key signatures − the zero-bias peaks in differential conductance measurements − can be attributed to non-Majorana physics. Previous theoretical works conducted in the weak light-matter coupling regime have explored the idea of using cavities to probe Majorana bound states. However, in these works the cavity played a role of non-invasive spectroscopic tool to probe the signatures of these modes. A different scenario arises in the strong or ultrastrong light-matter coupling regime where electronic and photonic degrees of freedom hybridize resulting in formation of polaritons, which in the case of a topological superconductor could take the form of the Majorana polaritons. In [1], we study a topological superconductor that hosts Majorana bound states strongly coupled to cavity photons. We consider two models for topological behaviour: a Kitaev chain and semiconducting - superconducting nanowire. We find that the cavity photonic spectral function (Figure 1) directly related to polariton spectrum of the hybrid system depends on the parity of the Majorana bound states in the topological phase. Moreover, we demonstrate that the peaks in cavity spectral function appear at different energy scales for the electronic chain in the trivial and topological phases. Therefore, cavity spectral function could be used to probe Majorana bound states in topological superconductors.

References

[1] Olesia Dmytruk and Marco Schirò, arXiv: 2310.01296.

Figures

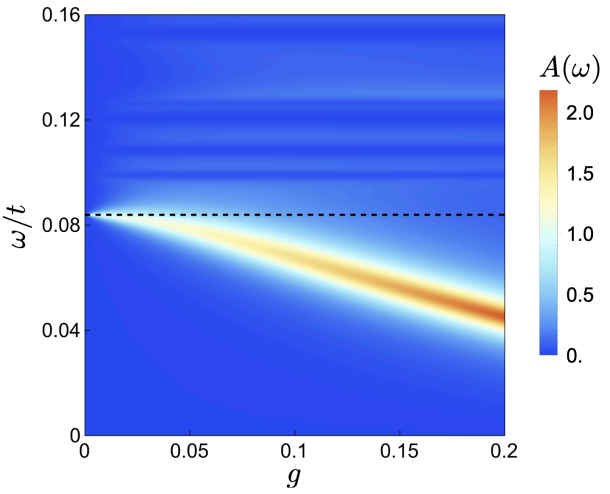

Figure 1: Cavity spectral function of the nanowire as a function of the light-matter coupling and frequency.