Photonic heat transport and the Schmid transition in Josephson junctions

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The Josephson junction is a building block of quantum circuits. Its behavior, well understood when treated as an isolated entity, is strongly affected by coupling to an electromagnetic environment. In 1983 Schmid [1] predicted that a Josephson junction shunted by a resistance exceeding the resistance quantum RQ = h/4e2 ≈ 6.45 kΩ for Cooper pairs would become insulating since the phase fluctuations would destroy the coherent Josephson coupling. Such transition is nowadays a matter of big experimental and theoretical debate [2,3].

In spite of this intense activity little is known regarding this system properties beyond dc charge transport. Motivated by recent experiments [4] in this work we analyze photonic heat transport through a Josephson junction in a dissipative environment. For this purpose we derive the general expressions for the heat current in terms of non-equilibrium Green functions for the junction coupled in series or in parallel with two environmental impedances at different temperatures. We show that even on the insulating side of the Schmid transition the heat current is sensitive to the Josephson coupling exhibiting an opposite behavior for the series and parallel connection and in qualitative agreement with experiments. We also predict that this device should exhibit heat rectification properties and provide simple expressions to account for them in terms of the system parameters. .

References

[1] A. Schmid, Diffusion and localization in a dissipative quantum system. Phys. Rev. Lett. 51, 1506 (1983).
[2] A. Murani et al. Absence of a dissipative quantum phase transition in Josephson junctions. Phys. Rev. X. 10, 021003 (2020).
[3] Kuzmin, R.et al. Observation of the Schmid-Bulgadaev dissipative quantum phase transition. arXiv:2304.05806 (2023).
[4] D. Subero et. al., Bolometric detection of Josephson inductance in a highly resistive environment, Nature Comm. 14, 7924 (2023)