Master 2 internship proposal

Subject: Heat transfer in nano-circuits as a bosonic scattering problem
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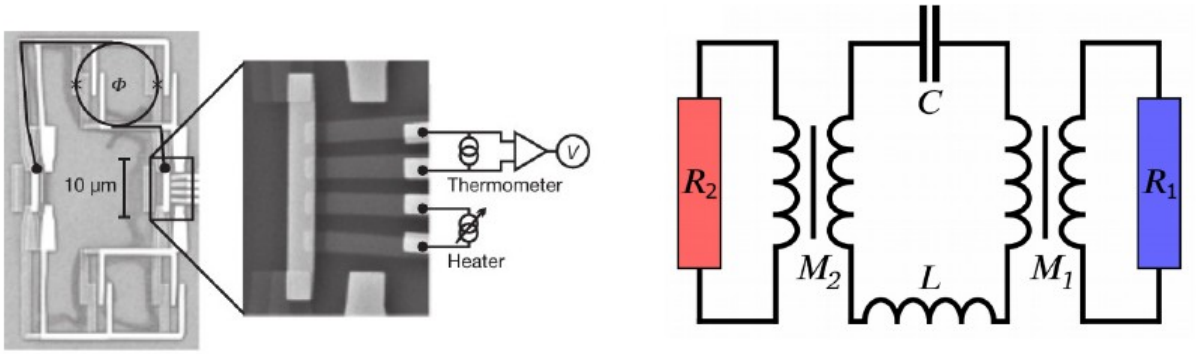
We will study heat transfer in a simple model system consisting of two small metal islands kept at two different temperatures and coupled by a single photon mode. Such a system was realized in [1], where the photon mode was represented by a superconducting resonator (left figure). At sub-Kelvin temperatures, heat transfer by phonons or electron quasiparticles is inefficient. Then, the photonic mechanism is dominant: the electrons in the hot island emit photons into the resonator, which are absorbed by the electrons in the cold island.



This system can be modeled by an effective electric circuit (right figure), where the metallic islands are represented by resistors R_1, R_2, the superconducting resonator by an LC contour, coupled to each other by mutual inductances M_1, M_2. Average heat current in this circuit has been calculated using the semiclassical approach of fluctuating electrodynamics [2].

In this internship, we will represent each resistor as a bath of quantum harmonic oscillators and reformulate the heat transfer problem as a scattering problem for the bosonic excitations of the baths. This approach should enable us to calculate not only the average heat current, but also its fluctuations (and all statistical properties) which are a useful tool to characterize the heat transfer mechanisms [3].

The specific goals of the internship are:

1. Construct the scattering matrix for the bath excitations
2. Express the heat current and its fluctuations in terms of the scattering matrix.

This internship work can be continued as Ph.D.

Necessary background: quantum mechanics, scattering theory, second quantization

Bibliography: [1] M. Meschke, W. Guichard, and J. P. Pekola, *"Single-mode heat conduction by photons"*, Nature **444**, 187 (2006).
[2] L. M. A. Pascal, H. Courtois, and F. W. J. Hekking, *"Circuit approach to photonic heat transport"*, Phys. Rev. B **83**, 125113 (2011).
[3] J. L. Wise, N. Roubinowitz, W. Belzig, and D. M. Basko, *"Signature of resonant modes in radiative heat current noise spectrum"*, Phys. Rev. B **106**, 165407 (2022).