Heat transport in the quantum Rabi model: Universality and ultrastrong coupling effects

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Heat transport in the quantum Rabi model at weak interaction with the heat baths displays various regimes upon acting on the qubit-oscillator coupling g, which essentially controls the conduction properties. In this work, we evaluate the linear conductance of the quantum Rabi model employing a diagrammatic approach based on a master equation formalism in Liouville space [1]. Universality of the linear conductance versus the temperature is found in the low-to-intermediate temperature regime, when quantities are scaled with a coupling-dependent Kondo-like temperature $T_K(g)$. At low temperatures, coherent heat transfer via virtual processes yields a $(T/T_K)^3$ behavior in the linear conductance modulated by a prefactor which is determined by the junction parameters and unravels its multi-level nature. Destructive interference arises in the presence of quasi-degeneracies in the spectrum. As the temperature increases, incoherent emission and absorption dominate. Upon increasing g, the conductance transitions from a resonant to a broadened, zero-bias peak regime in the presence of a bias on the qubit. Similarities with the heat transfer in a qubit highlight how the internal qubit-oscillator coupling plays the role of the qubit-bath coupling in the spin-boson model [2].

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[1] L. Magazzù, E. Paladino, M. Grifoni "A unified diagrammatic approach in Liouville space to quantum transport for bosonic and fermionic reservoirs", arXiv:2403.06923.

[2] L. Magazzù, E. Paladino, M. Grifoni "Heat transport in the quantum Rabi model: Universality and ultrastrong coupling effects" arXiv:2403.06909.