Thermal rectification through a nonlinear quantum resonator

Bibek Bhandari[1], Paolo Andrea Erdman[1], Rosario Fazio[2], Elisabetta Paladino[3], and Fabio Taddei[4]

[1]*NEST, Scuola Normale Superiore and Istituto Nanoscienze-CNR, I-56126 Pisa, Italy*
[2]*The Abdus Salam International Centre for Theoretical Physics, Strada Costiera 11, I-34151 Trieste, Italy and Dipartimento di Fisica, Università di Napoli "Federico II", Monte S. Angelo, I-80126 Napoli, Italy*
[3]*DFA University of Catania; CNR-IMM UOS Catania (Università), INFN Catania, Via Santa Sofia 64, Catania, Italy*
[4]*NEST, Istituto Nanoscienze-CNR and Scuola Normale Superiore, I-56126 Pisa, Italy*

We present a systematic study of thermal rectification in a prototypical low-dimensional quantum system - a nonlinear resonator: we identify necessary conditions to observe thermal rectification and we discuss strategies to maximize it. In the strongly anharmonic regime where the system reduces to a qubit, we derive general upper bounds on rectification in the weak system-bath coupling regime, and we show how the Lamb shift can be exploited to enhance rectification. We then go beyond the weak-coupling regime by employing different methods: (i) including cotunneling processes, (ii) using the nonequilibrium Green's function formalism, and (iii) using the Feynman-Vernon path integral approach. We find that the strong coupling regime allows us to violate the bounds derived in the weak-coupling regime, providing clear signatures of high-order coherent processes visible in the thermal rectification. In the general case, where many levels participate to the dynamics, heat rectification is calculated with the equation of motion method and with a mean-field approximation. We find that the former method predicts, for a small or intermediate anharmonicity, a larger rectification coefficient.

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