Electron-phonon cooling power significantly suppressed in mesoscopic circuits

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This electron-phonon cooling channel is of vital interest for recent experimental efforts to construct a single-photon detector, important for the future development of nanotechnology. Namely, the knowledge of the electron-phonon cooling effect can provide an ultimate bound of a detectable portion of energy. At the same time, there was an indication that superconducting proximity systems can be suitable candidates for such a device.

When brought in good contact with a superconductor, a piece of a normal metal drastically modifies its electronic properties, and this effect is known as the proximity effect. This remarkable phenomenon is a cornerstone for numerous technological applications such as quantum information processing, quantum sensing, and quantum thermodynamics, to mention a few. From a scientific point of view, it reflects itself through many interesting observations, among them, a spontaneous current flow through the superconductor-normal-metal interface (Josephson effect) and the appearance of a minigap in the normal metal's spectrum. Considering the impact of the proximity effect on the electron-phonon energy relaxation, we obtained a general formula for the thermal conductance function that can apply to an arbitrary electronic system. Our findings demonstrate that the electronic cooling power is getting substantially suppressed when the normal metal is proximitized reducing the energy-current fluctuations in the system. This scenario implies that superconductor-normal-metal proximity systems can be utilized as a single-phonon detector. Furthermore, due to its generality, our theory can serve as a benchmark and an optimization tool for future experiments in quantum calorimetry.

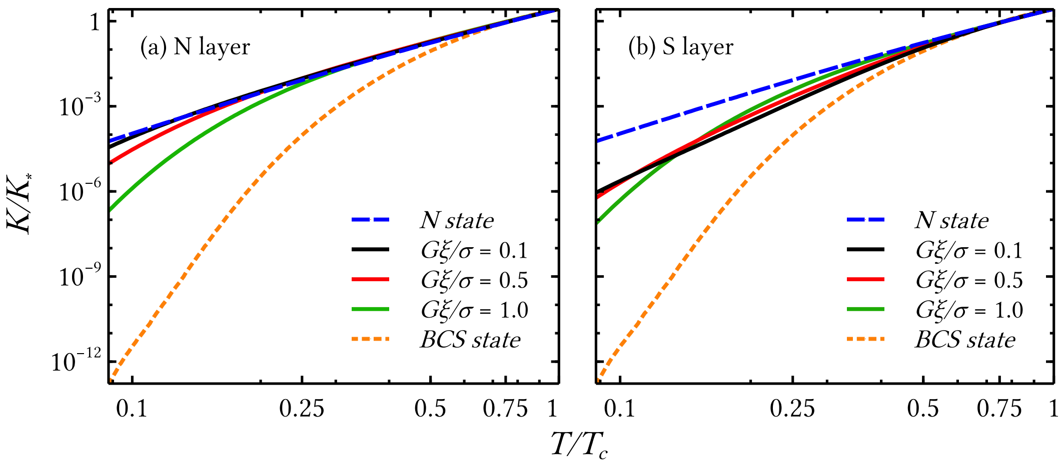

Fig. 1: The electron-phonon thermal conductance K as a function of temperature T for various transparencies of the SN interface in (a) normal side, (b) superconducting side of a thin SN proximity bilayer. At low temperatures, all the curves lie between the bulk normal (the dashed blue line) and the bulk superconducting state (the dotted orange line).