Heat transport across a Josephson junction

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In heat transport through nanostructures, quantum effects play an important role. There, intriguing phenomena can emerge from the properties of a quantum system and heat baths. For instance, in 1983, Pendry predicted the quantization of thermal conductance [1] and then it has been observed in various systems involving phonons and photons. As triggered by this seminal work, quantum heat transport serves as a tool for understanding fundamental physics as well as applications for quantum thermal devices.

The superconducting quantum circuit is an ideal platform for the observation of controllable heat current at extremely low temperatures (sub-kelvin temperature range). The Josephson junction is the main building block of the superconducting circuits, and its non-linearity induces the nontrivial transport property. Although the properties of an isolated Josephson junction have been understood well, when it is coupled to a dissipative environment, its properties change drastically. Schmid predicted that the Josephson junction shunted by a resistor undergoes a quantum phase transition at zero temperature [2]. When the shunted resistance is smaller than the resistance quantum, $R_{\mathrm{Q}} = h/(2e)^2 \approx 6.45$ kΩ, the Josephson junction behaves superconducting. In contrast, when the resistance exceeds the critical value, the Josephson junction becomes insulating. Recently, thanks to the technological development of superconducting circuits, the Schmid transition has been investigated from the viewpoint of heat transport and questioned for the existence of the insulating phase [3].

In this poster, we present our recent theoretical work on heat transport across the Josephson junction, which exhibits the Schmid transition [4]. We first derive the relation between the linear thermal conductance and the admittance of the superconducting circuit at finite frequency and temperature. After that, we evaluate the thermal conductance in the context of the Schmid transition. Our non-perturbative results provide a signature of the Schmid transition in the temperature dependence of the thermal conductance both in the superconducting and insulating sides.

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