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The Heat Generation by Electric Current in Nano-Devices

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Abstract:

Over the past two decades, with the development of micro-machining technology, there has been enormous progress in the operation speed and integrating techniques of the semiconducting electronics. With these advancements, one critical issue arises, namely the dissipation of the conducting electrons (i.e., the thermal generation from electric currents). The dissipation in nano-devices strongly hinders further development of the semiconductor electronics. Thus, it is important to uncover the laws of thermal generation induced by electric currents in nano-devices.

In this work, we study the heat generation in a nano-device with an electric current flowing through. A general formula for the heat generation is derived by using the non-equilibrium Keldysh Green's functions. This formula can be applied in the linear and non-linear transport regions, for time-dependent cases, and with multi-terminal systems. The formula is also valid if the nano-device contains various interactions. As an application of the formula, the heat generation of the device with lead-quantum dot-lead is investigated. The dc and the ac biases are studied in detail. We find several interesting behaviors that are unique to nano-devices, revealing significant difference from heat generation in macroscopic systems.

Host: Zhenyu Zhang