Local dissipation in a quantum dot junction

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Characterization of quantum devices relies primarily on electrical properties. It is usually assumed that all parts of the device remain at the same temperature, but the inevitable presence of local dissipation can lead to significant deviations and degrade device performance [1].

Here, we present simultaneous measurement of the electrical current through a quantum dot (QD) junction, as well as the dissipation generated by the same. To this end, we thermally isolate the drain contact of an epitaxially defined QD in an InAs nanowire. The electron temperature is measured via the zero-bias conductance of a Josephson junction [2].

We map out the electron temperature as a function of gate and bias voltages and highlight key aspects of heat generation through a single quantum level, as compared to charge transport.

Further, we find that most of the dissipated heat is evacuated in the InAs section between the QD and the thermometer, implying a substantial temperature gradient in the immediate vicinity of the QD.

Based on the experimental results, we discuss strategies to mitigate detrimental heating effects in similar devices.

The presented techniques can be readily adapted to different semiconductor materials and contribute to proper thermal management upon large-scale integration of quantum materials.

References

[1] Philips, S.G.J. et al., Nature 609, (2022) 919-924
[2] Karimi, B & Pekola, J.P., Phys. Rev. Applied 10, (2018) 054048

Figures

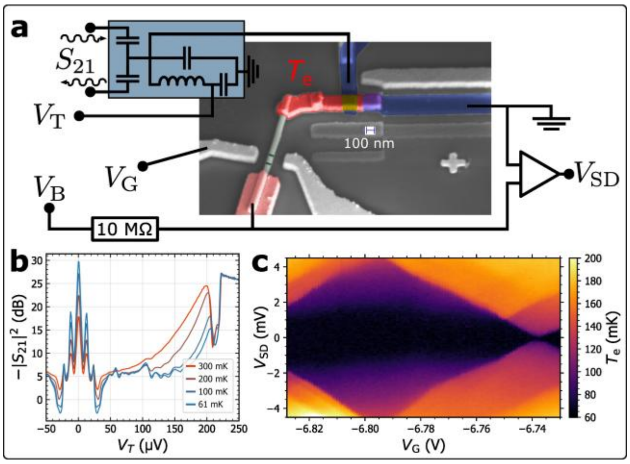

Figure 1: (a) The metallic island (dark red) acts as the drain reservoir of the QD within the InAs nanowire. Superconducting contacts (blue) provide thermal isolation. (b) Tunnel spectra of the Josephson junction at different cryostat temperatures. The zero-bias signal is used as a sensitive electron thermometer. (c) Electronic temperature of the metallic island as a function of V_G and V_{SD} at cryostat temperature of 64 mK.

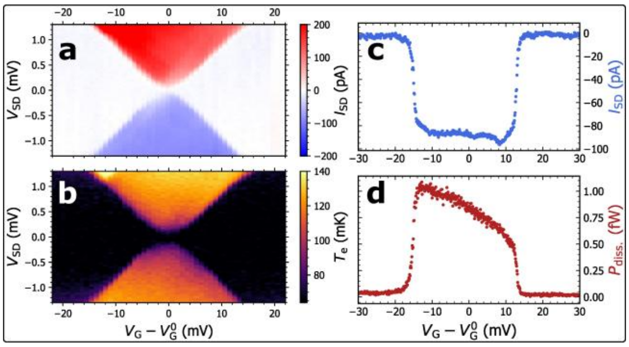

Figure 2: Current trough a single quantum dot level (a) and temperature of the metallic island (b) as function of V_G and V_{SD}. (c) Line cut of (a) at V_{SD}=-1.25 mV and (d) heat dissipated in the metallic island in the same sweep.