# From Landauer limit to application in quantum computing: thermal phonon transport at very low temperature

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The study of heat transfer at the nanoscale is of growing interest due to the general trend toward reducing the size of electronic chip components. Consequently, it becomes essential to understand heat transfer at small length scales by mastering the physical phenomena emerging from this reduction (ballistic or coherent phonon effects, reduction in the mean free path of phonons, confinement effects, etc) [1]. Among all these mechanisms, the thermal quantities of great importance is the thermal resistance that appears at the interface between two solids, known as Thermal Boundary Resistance (TBR). The thermal resistance at an interface can be thought of as an acoustic impedance between two bodies; it arises from the surface or from a nano-contact.

We will illustrate this physics by presenting experimental results in two main cases. One is the SThM (Scanning thermal microscopy) technique probing thermal transport through a small contact at room temperature. The second one is about measurement of phonon heat exchange at very low temperature between two platforms [2,3]. Both methods allow probing phonon heat flow at the nanometer scale.

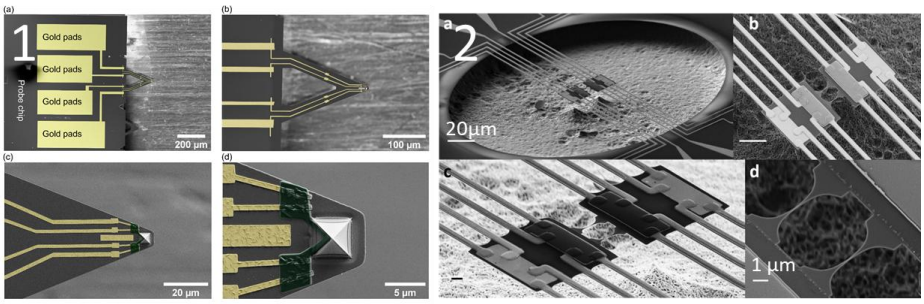


Fig.1. 1-Left, AFM-SThM thermal probe working down to nanoscale at room temperature (see ref [2]). 2-right, double platform for very low temperature measurement of nanostructures (see ref [3]).

We will see that the concepts described above can be applied to numerous domains including quantum computing. Indeed, many problems of decoherence arises from thermal issues. The current techniques will help addressing these problems experimentally: finding hot spots in integrated circuits, and probe heat flow at very small length scale between the qbit stages and their controlling electronics at very low temperature where numerous thermal interfaces are present [4].

[1] O. Bourgeois, D. Tainoff, A. Tavakoli, Y. Liu, M. Boukhari, A. Barski, E. Hadji, *Reduction of phonon mean free path: from low temperature physics to room temperature applications in thermoelectricity*, Comptes Rendus Physique **17**, 1154 (2016).

[2] R. Swami, G. Julié, S. Le-Denmat, D. Singhal, J. Paterson, J. Maire, J.F. Motte, G. Pernot, H. Guillou, S. Gomès, and O. Bourgeois, *Experimental set-up for thermal measurements at the nanoscale using an SThM probe with niobium nitride thermometer*, Rev. Sci. Instrum. **95**, 054904 (2024). arXiv:submit/5457854 DOI10.1063/5.0203890

[3] A. Tavakoli, K. Lulla, T. Purtinen, I. Maasilta, E. Collin, L. Saminadayar, O. Bourgeois, *Specific Heat of Thin Phonon Cavities at Low Temperature Revealed by ZeptoJoule Calorimetry*, Physical Review B **105**, 224313 (2022).

[4] G. Ridgard, J. Prance, M. Thompson, L. Schreckenberg, N. Deshpande, C. Degenhardt, A. Cabrera, O. Bourgeois, and V. Doebele, *Voltage Noise Thermometry in Integrated Circuits at mK Temp.,* J. Appl. Phys. **137**, 245901 (2025).