NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2020-2021

Quantum nanophononics at low temperature: towards heat manipulation at the nanoscale

General Scope: Phonons, just like electrons, are known to be quantum particles. In a macroscopic material, this quantum nature of the phonons is hidden by the fact that the typical size of the sample is by far larger than the typical wavelength of the phonons. Just like in optics, in this situation, no spectacular effect of the quantum nature of the phonons can be expected. But if you now reduce the dimensionality of a heat conductor down to the limit of the phonon wavelength, then the quantum nature of the phonons should dominate their behaviour: this is a new field of research in which new concepts are still emerging. In this internship, we will focus on how this confinement changes the phonon behaviour and thus the heat transport in 2D structures (membrane) or 1D (nanowires).
As an example, let us ask what happens when the dimensions of the conductor are comparable with the wavelength of the phonons, how can we describe the *transport* of phonons in such structures? The answer is quite subtle, and is related to the transmission of the wavefunction of the phonons through the structure. The most direct evidence of such a wave-nature of the heat transport in such small systems would thus lie in the appearance of plateaus each time the width of the conductor equals an integer times the wavelength of the phonons. This evidence for the quantum nature of heat transport at low temperature is still not clearly experimentally given.

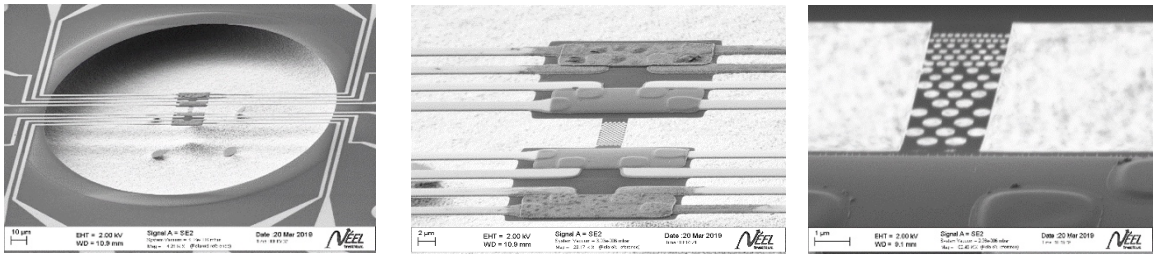

Figure 1 Left: Thermal lab-on-chip sensor composed of two sensing cells for the measurement of thermal conductance of the bridging structure.

Research topic and facilities available: the topic of this thesis holds on phonon transport experiments at very low temperature. These measurements will be carried out in extreme conditions on suspended membranes and nanowires. The experiments will be based on new sensors with sensitivity of the order of Zepto-Joule (10^{-21} Joule), a world record at dilution fridge temperatures (10-50mK).
The goal is to access the quantum regime of phonon transport and thus the quantum regime of heat conduction by optimizing the transmission coefficient. We will demonstrate the potential manipulation of heat flow using non-symmetric nanostructures to evidence thermal rectification. We will manipulate the heat in low dimensionality systems (1D and 2D), a route towards exchange or storage of information using phonon as a carrier.

Possible collaboration and networking: Collaborations with both theoreticians and experimentalists: Natalio Mingo (CEA, Grenoble), David Lacroix (Nancy), Robert Whitney (LPMMC, Grenoble).

Possible extension as a PhD: **The internship could be followed by a PhD**

Required skills: good background in Condensed Matter Physics

Starting date: late winter/early spring

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