INSTITUT NEEL Grenoble

Proposition de stage Master 2 - Année universitaire 2019-2020

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 the conductor down to the limit of the phonon wavelength, then the quantum nature of the phonons should dominate their behaviour in the solid: this is a new field of research in which concepts are still emerging, maybe the last domain in nanosciences which is still untouched. In this internship, we will focus on how this confinement changes the phonon heat exchange mechanisms in 2D structures (membrane) or 1D (nanowires). Two types of materials are particularly interesting: single crystals and amorphous materials and both will be studied.

Another question naturally arises when considering quantum transport: if the dimensions of the conductor is 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 the quantum nature of the heat transport in nanostructures would be to show that it exhibits plateau as a function of the width of the conductor, width being an integer times the wavelength of the phonons. This Landauer approach, which has been successfully applied in the domain of electronic transport, has not been extended to phonons so far.

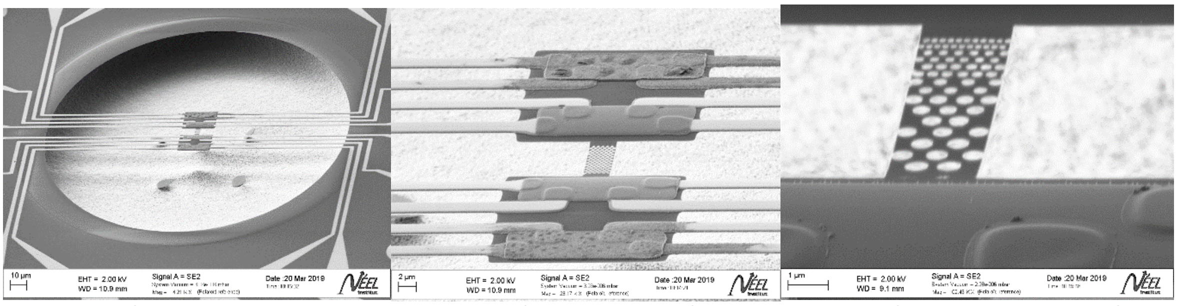

Figure 1 Left: Thermal lab-on-chip sensor composed of two sensing cells for the measurement of thermal conductance of the bridging structure.

Research topic and facilities available: the topic of this thesis holds on phonon transport experiments at very low temperature using ultra-sensitive measurements of heat conduction. These measurements will be carried out in extreme conditions on membranes and nanowires (monocrystalline silicon or silicon nitride (SiN amorphous)). 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 (30-50mK). 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 (see figure). We will manipulate the heat at low dimensions (1D and 2D systems) a route towards exchange or storage of information using phonon as a carrier.

Possible collaboration and networking:

Collaborations with theoreticians and experimentalists: Natalio Mingo CEA-LITEN, David Lacroix (Nancy).

The internship could be followed by a PhD

Formation / Competences : skills and knowledge in cryogenics, microfabrication, fine instrumentation and mesoscopic quantum physics will be widely acquired especially in the field of nanophononics and nanothermics.

Starting date: late winter/early spring

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