PhD PROPOSAL

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Nano-imaging of non-Fourier heat flow

Efficient heat management is critical for the optimal performance and energy consumption of modern-day electronics. While Fourier's macroscopic model for heat diffusion has been a valuable tool for homogeneous solids at room temperature, it falls short in describing heat propagation accurately in particular on short time and length scales. This PhD project aims to quantitatively investigate scenarios where the Fourier model breaks down and work towards developing a more physically satisfying model of heat propagation at the nanoscale.

This project will focus on the phonon viscous hydrodynamic transport regime that has recently attracted considerable interest in the scientific community. It is a many-body phenomena that is neither ballistic nor diffusive and emerges when quasi-particles interact strongly with each other without loosing momentum. It appears at low temperatures in very pure material.

The goal of this PhD will be to build a very sensitive and local thermometer to study this effect. This probe is a superconducting quantum interference device (SQUID) deposited at the end of a sharp tip and has already proven to be one of the most sensitive thermometers and magnetometer in a cryogenic environment. By navigating this tip above a surface, one can reconstruct spatial temperature (or magnetic) profiles, gain access to local sources of dissipation and study directly the effect of disorder at the atomic level. It is a very powerful and versatile tool (unique in France) to study quantum circuits and low dimensionality materials. The goal is to use it to map the temperature distribution at a few tens of nm to look for signatures of the non-Fourier behavior.

During this PhD, you will construct the SQUID-on-tip microscope and use it to image the viscous flow of phonons. You will master various condensed matter experimental techniques such as: vacuum generation, cryogenics, metal deposition, electronic microscopy, electric measurements of superconductors and Josephson junctions but also heat transport in quantum materials. Enthusiasm for instrumentation is a necessity.

Background in one or more of the following is a plus: Josephson effect, heat transport, phonons, electronic measurements, metal deposition, instrument interfacing (Python, Matlab, labview…), cryogenics, high-vacuum, large data management and analysis.

References:
-Halbertal, D. et al. Nanoscale thermal imaging of dissipation in quantum systems. Nature 539, 407–410 (2016). https://doi.org/10.1038/nature19843
-Chen, G. Non-Fourier phonon heat conduction at the microscale and nanoscale. Nat Rev Phys 3, 555–569 (2021). https://doi.org/10.1038/s42254-021-00334-1
-K. Ghosh, *et al.*, Phonon hydrodynamics in crystalline materials, Journal of Physics: Condensed Matter (2022), doi:10.1088/1361-648X/AC718A