INSTITUT NEEL Grenoble

Proposition de stage Master 2 - Année universitaire 2023-2024

Thermal properties and heat transport on suspended 1D and 2D systems

General context :

Thermal transport physics is a major challenge with important fundamental and technological implications for thermal management of electronic nano-components or the conception of new thermoelectric devices. In this context, graphene and other 2D materials exhibit outstanding thermal properties, however they are not yet fully understood. Different experimental techniques have been used such as electronic transport, optical and Raman spectroscopy. Since the contribution of electrons to the thermal conductivity (**κ**) in atomically thin materials has been estimated to be lower than the phonons counterpart, Raman spectroscopy has been widely used as a non-contact thermal probe at the micrometer scale to access the thermal conductivity of graphene (1,2,3). All these works report an extremely high thermal conductivity but a large dispersion of values ranging from 500 to 3000 W/m/K. One important point is that all these experimental values of **κ** are obtained from a setup in which the same laser is used to heat the membrane and to measure its temperature.

Recently, a more insightful approach was developed by Reparaz *et al.* (4) and at NEEL for graphene. This new approach uses two distinct lasers, one as a heater and the second as a non-invasive thermal probe, measuring temperature profiles outside the heated region. The first measurements of suspended graphene membranes using this method has been achieved at NEEL and demonstrated its efficiency to access spatial mapping of temperature within graphene (4). Moreover, temperature profiles show very interesting anomalies which cannot be explained by a simple Fourier model and drive us to develop with our collaborators a multi-linear non-local Fourier model.

Description of the project and facilities:

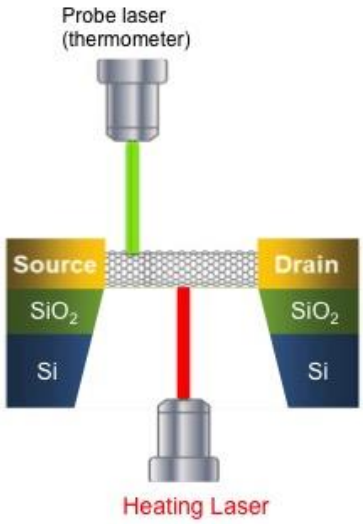

Figure 1: Schematic of the two-laser experiment.

The Master 2 internship aims to find out more about how defects, substrate interactions and environment can change thermal properties. As a start, the simplest circular geometry will be used at room temperature. A two-laser setup will be used to heat the system and measure the optical phonons (see figure). Raman imaging will provide information about spatial distribution of hot phonons and will allow inferring issues on electron-phonon coupling, strain and heating in the system (3,4).

The student will be in charge of the full spectroscopic characterization of the devices. She/He will fabricate the samples and develop the next generation of substrates with electrical wiring. The simultaneous use of Raman spectroscopy and electron transport at this single nano-object level is almost unique and promising compared to conventional methods used separately until now. The setup in ambient conditions is fully operational.

References :

1) A.A. Balandin, S. Ghosh, W. Bao, I. Calizo, D. Tewelde-brhan, F. Miao, and C.N. Lau, Nano Lett. 8, 902-907 (2008).
2) W. Cai, A.L. Moore, Y. Zhu, X. Li, S. Chen, L. Shi, and R.S. Ruoff , Nano Lett. 10, 1645-1651 (2010).
3) C. Faugeras, B. Faugeras, M. Orlita, M. Potemski, R.R. Nair, and A.K. Geim, ACS Nano 4, 1889-1892 (2010).
4) J.S. Reparaz, E. Chavez-Angel, M.R. Wagner, B. Graczykowski, J. Gomis-Bresco, F. Alzina, and C.M. Sotomayor Torres, Rev. Sci. Instr. 85, 034901 (2014).)
5) P. Singh, S. Sarkar, D. Jegouso, L. Del Rey, A. Claudel, B. Fernandez, P. Bouvier, L. Marty, J. Chaste, M. Lazzeri and N. Bendiab, Submitted to PRB.

Interactions and collaborations :

The student will join the Quan2m team gathering experts in materials science, optical spectroscopy, condensed matter physics, mesoscopic transport. Close collaborations outside the lab involve J. Chaste

from C2N for nanofabrication and optical measurements, Michele Lazzeri from IMPMC for Ab initio calculations and Konstantinos Termentzidis from INSA Lyon for Monte Carlo computing.

Required skills :
A master 2 in Condensed Matter Physics or Nanosciences is required along with motivation for experimental work.

Start date : February/March 2024
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