Research Internship – 2020-2021 - Master 1 & 2

Laboratory: Laboratoire Charles Coulomb (L2C), Université Montpellier
Address: Bat. 11, Place Eugène Bataillon, 34090 Montpellier
Head of the laboratory: P. Lefebvre

Advisor: Adrien Noury
Email: adrien.noury@umontpellier.fr

Carbon nanotube electro-mechanical sensor: fundamentals limits to sensing, application to nanofluidics

Context

Recent progresses in the field of nanotechnologies have allowed to open up new research routes to investigate mechanical resonators at the nanoscale. Among the most interesting objects for mechanics at this scale is the carbon nanotube, a truly 1D object that is extremely light – probably the lightest mechanical oscillator. This makes carbon nanotubes exceptional for probing their environment, for instance as mass sensors: they can sense added masses as small as a single proton [1].

Achieving such exquisite sensitivity is of great interest for studying other branches of physics. In particular, water confined inside carbon nanotubes shows surprising, counter-intuitive behavior, such as superlubricity [2]. Yet, understanding of the mechanisms at play suffers from a lack of experimental evidences, due to the poor sensitivity of usual measurement methods.

Scientific and technical work

1 - Exploring the limits of mass sensing with carbon nanotube mechanical resonator

The objective will be to understand the fundamental limitations of inertial sensing (mass sensing) with a single nanotube mechanical oscillator. For this purpose, the internship student will experimentally probe the different contributions to the motion of a nanotube harmonic oscillator [3]. More precisely, the internship will perform homodyne detection of the Brownian motion of the resonator while varying the sources of noise: temperature of the resonator, temperature fluctuations, adsorption/desorption from the residual gas in the environment, etc.

2 – Sensing in 'real' conditions using a Phase Locked Loop

In a first step, the internship student will build up on the previously acquired knowledge to perform mass sensing with a carbon nanotube. The novelty here is to use the resonator as a sensor of the matter confined inside the nanotube, instead of probing its external environment. Thus, the internship student will inject matter inside the nanotube (liquid or gas) to experimentally measure the response of the oscillator. It will then be possible to quantify the experimental sensitivity of the resonator as well as to study the additional noise sources related to the presence of matter confined inside the nanotube.

In a second step, the student will design and implement a method to measure flow rates, based on the time-of-flight of tracers (confined molecules) chosen for their mass.

Ultimately, this original approach will allow to study the transport of water inside a carbon nanotube with an unprecedented resolution, providing new insights on nanofluidics in extreme confinement [4].

The work is experimental and very polyvalent. Depending of the student, the work can include:

- Fabrication of samples in clean room
- Optical (Raman scattering) and electrical (probe station) pre-characterization

- Setting of low-noise, high-speed electronics
- Nanomechanical measurements under vacuum
- Nanofluidics

Profile

Students with a background in Physics (condensed matter physics, soft matter, material science, nanoscience or electrical engineering). Prior knowledge of carbon nanotube science is not necessary. Strong taste for experimental work is compulsory.
Extension of the work to a PhD thesis is possible.

Additional information

Length of the internship: 3 to 6 months
Starting date: flexible, to be defined with the candidate
The student will receive a grant of ~ 500€/month

Host team

We are a group with background in condensed matter physics, working on projects at the interface with material science and soft matter. More information can be found at the nanomechanics team website: www.nanomechanics.fr

Bibliography

[1] J. Chaste et al., Nature Nanotechnology **7**, 301-304 (2012)
[2] K. Falk et al., Nano Letters **10**, 4067 (2011)
[3] K. Ekinci et al., Journal of Applied Physics **95**, 5 (2004)
[4] L. Bocquet et al., Chemical Society Reviews **39**, 1073-1095 (2010)