EUROPHOTONICS-POESII MASTER COURSE

PROPOSAL FOR A MASTER THESIS

Dates: April 1st, 2016 – September 30th, 2016

Laboratory/Institution: ICFO
City, Country: Castelldefels (Barcelona), Spain

Title of the master thesis: Nano-Optomechanical Sensing with Carbon Nanotubes

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Summary of the subject (maximum 1 page) :
Single-wall carbon nanotubes (SWCNT) have been shown to be the most robust and sensitive nanomechanical transducers, breaking the limits of zeptonewton force sensitivity [1] and single-proton resolution mass spectroscopy [2,3], while more recently their real-time dynamical behavior has been studied [4]. However, these performances remain confined to cryogenic temperatures, where their exquisite nanomechanical properties are typically 4 to 5 orders of magnitude better than in ambient conditions [5]. This project proposes to explore the fundamental dissipation mechanisms involved in the dynamics of SWCNT, and to control them in order to recover their exceptional mechanical response behavior at room temperature. It is based on the development of a non-invasive, ultra-sensitive nano-optomechanical detection method [6] which is used in order to detect and subsequently remove the massive excess of noise observed at room temperature [7,8]. This project opens a path towards generalizing the use of SWCNT to the more versatile ambient conditions, with major consequences for ultra-sensitive measurement applications at room temperature.

The applicant is sought to contribute to several important and interdisciplinary aspects of the experimental apparatus. She/he will develop a positioning interface enabling to address and stabilize the static position of SWNTs with a sub-nanometer accuracy. She/he will subsequently characterize and quantify both short and long term stability of the nanotubes in order to calibrate the sensing potential of the SWNTs at room temperature.

Keywords : Optomechanics, Carbon nanotube, Low-noise optical measurements, Nanofabrication

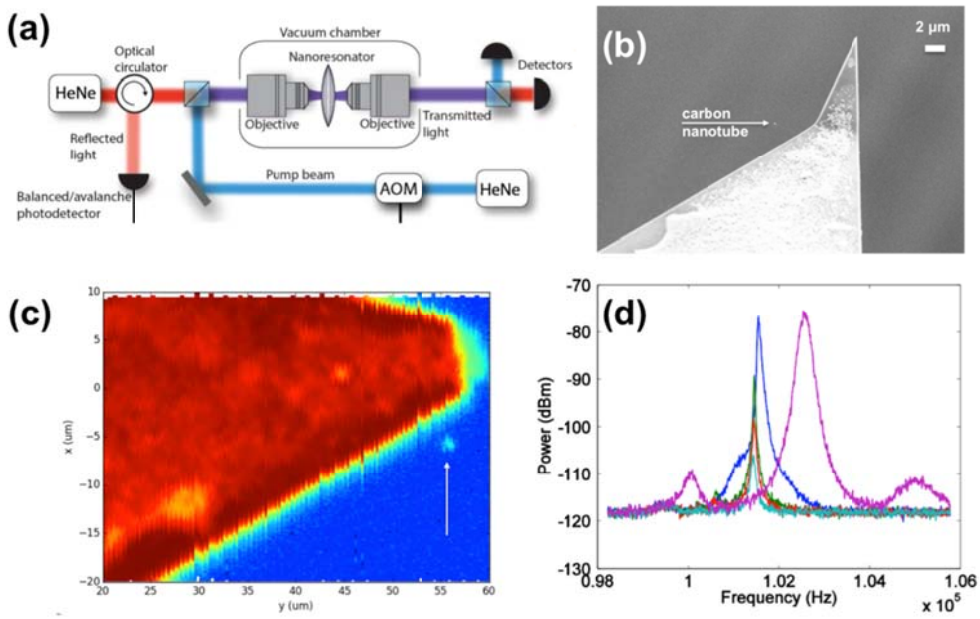

Figure: Nano-optomechanical sensing of carbon nanotubes. (a) Principle of the experiment. A strongly focused laser beam is sent onto a SWNT. The optical response of the latter is collected using a high NA objective and further sent onto a ultra-sensitive avalanche photodetector or a balanced detector. (b) SEM micrograph of a 4-μm long carbon nanotube. (c) Imaging of the carbon nanotube using the experimental setup. (d) Brownian motion spectra of a carbon nanotube at room temperature.

[1] Moser, J. et al. Ultrasensitive force detection with a nanotube mechanical resonator. Nature nanotechnology 8, 493-496 (2013).
[2] Chaste, J. et al. A nanomechanical mass sensor with yoctogram resolution. Nature nanotechnology 7, 301-304 (2012).
[3] Tavernarakis, A. et al. Atomic monolayer deposition on the surface of nanotube mechanical resonators. Physical review letters 112, 196103 (2014).
[4] Moser, J., Eichler, A., Güttinger, J., Dykman, M. & Bachtold, A. Nanotube mechanical resonators with quality factors of up to 5 million. Nature nanotechnology (2014).
[5] Tsioutsios I., Tavernarakis A., Osmond J., Verlot P. & Bachtold A. Brownian motion of a carbon nanotube using an electron beam. in preparation (2015).
[6] Gloppe, A. et al. Bidimensional nano-optomechanics and topological backaction in a non-conservative radiation force field. Nat Nano 9, 920-926, doi:10.1038/nnano.2014.189 (2014).
[7] Gavartin, E., Verlot, P. & Kippenberg, T. A hybrid on-chip optomechanical transducer for ultrasensitive force measurements. Nature nanotechnology 7, 509-514 (2012).
[8] Gavartin, E., Verlot, P. & Kippenberg, T. J. Stabilization of a linear nanomechanical oscillator to its thermodynamic limit. Nat Commun 4, (2013).

Additional information:

* Required skills: We are looking for applicants with a strong background in physics. Solid bases in statistical and quantum physics are appreciated.
* Acquired Skills: The applicant will acquire a strong experience in ultra-sensitive nano-optomechanical measurements, including ultra-low noise; high-frequency optical detection; fiber-optics; phase-sensitive, real-time feedback schemes; nano-scale imaging techniques; nano-fabrication; etc…
* Amount of the monthly allowance (if it is the case): up to 600 euros/month
* Miscellaneous: We have the funding to pay the master thesis as well as to continue the work with a PhD.