



Master in Photonics – “PHOTONICS BCN” Master ERASMUS Mundus “EuroPhotonics”

MASTER THESIS PROPOSAL

Starting full time from April 2024

Presentation at the end of July or beginning of September 2024

Laboratory: Quantum Nanoelectronics and Nanomechanics group

Institution: ICFO – The Institute of Photonic Sciences

City, Country: Barcelona, Spain

Title of the master thesis: Charge sensing for nano-electromechanical quantum simulator

Name of the master thesis supervisor and co-supervisor:

(for external proposals a co-supervisor from the Master program and a collaboration agreement is needed)

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Keywords:

Summary of the subject (maximum 1 page):

The project aim is to create a *quantum simulator based on a carbon nanotube electromechanical system*.

Electron-phonon interactions lead to a plethora of phenomena in strongly correlated solid-state systems such as superconductivity and charge-density waves. However, the complex dynamics manifesting these phases can be beyond the reach of computational modelling, especially when taking into account electron-electron interaction. Therefore, one of the outstanding challenges in the field of correlated-electron physics is a widely tuneable model system that can mutually couple several electronic and phononic degrees of freedom. To date, no such system has been experimentally realized. While previous efforts have mostly focused on cold-atom configurations,



nano-electromechanical systems are naturally suited to address this challenge. One of the most challenging requirements to engineering such a system is the achievement of ultrastrong electromechanical coupling, which has been recently demonstrated by our research group in a capacitively coupled carbon nanotube. Leveraging this capability, we work to engineer a model system in which electronic degrees of freedom are defined within four quantum dots and coupled to vibrational modes of a carbon nanotube. If successful, the project will enable the first experimental platform for quantum simulation of electron-phonon coupling.

Objectives:

In the short term, the main focus during the time of the Master's project will be to engineer a *carbon nanotube charge sensor*, which is both an essential stepping stone to our long-term goal of realizing a quantum simulator, and a high-impact research goal by itself. The research is carried out under supervision of Prof. Adrian Bachtold and postdoc Stefan Forstner, with training supplied by PhD student Marta Cagetti and Stefan Forstner.

Specific tasks/objectives

- 1) Fabrication of carbon nanotube devices for charge sensors: This task comprises “growing” carbon nanotubes over nanostructure arrays that are supplied by our collaborator D. Czaplewski in Argonne National Labs, IL, USA. This task will be carried out in the *ICFO graphene lab* with training by Marta Cagetti. In this task, Marco will learn the basics of clean-room work and gain some experience in nanofabrication.
- 2) Room-temperature testing of charge sensors: This task includes testing the fabricated carbon nanotubes, and identifying the best candidates for extensive measurements in our dilution fridge – first in a simple electrical setup, and then in a more complex, high-frequency vacuum testing station. Here, Marco will learn the basics of electrical testing- and transport measurements.
- 3) Participation in cryogenic measurements: Ultimately, the charge sensor measurements are carried out at ultra-low temperatures in a dilution fridge. Marco will participate in these measurements (albeit, not do them independently)

Additional information (if needed):

* Required skills:

* Miscellaneous: