



## Congratulations to New ICFO PhD Graduate

Dr Carles Urgell Flores graduated with a thesis entitled "New Phenomena in High-Quality Suspended Nanotube Devices"

March 30, 2021

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We congratulate Dr Carles Urgell Flores who defended his thesis today in ICFO's auditorium with online participations due to social distancing to contain the Coronavirus pandemic.

Dr Urgell Flores received his MSc in Nanoscience and Nanotechnology from the UAB, Barcelona. He joined the Quantum NanoMechanics research group led by Prof Dr Adrian Bachtold to carry out his PhD studies on mechanical vibrations coupled to electron spin. Dr Urgell Flores' thesis entitled "New Phenomena in High-Quality Suspended Nanotube Devices" was supervised by Prof Dr Adrian Bachtold

### **ABSTRACT:**

Carbon nanotubes (CNTs) have attracted the attention of the scientific community since their discovery in the 90s. They are an excellent material for the development of research fields as diverse as nanomechanics or quantum transport. Nanotube mechanical resonators are endowed with exceptional properties, including extremely small mass, ultra narrow

crosssection, and operation over a large frequency range from 10 kHz to 10 GHz. They are also fantastic sensors of both mass adsorption and forces. Its electric transport properties are remarkably the long ballistic transport of charge carriers, strong electron-electron interaction, and the important role of the spin and valley degrees of freedom. It is possible to observe a wide range of quantum transport phenomena ranging from single-electron tunneling to Kondo physics and Fabry-Perot interference. It should be noted that the electrical transport and mechanical motion of suspended nanotubes can be coupled by a large amount. In the first part of this thesis, we present an advanced ultra-sensitive fabrication method that allows us to build and functionalize a nanotube cantilever for optical measurements. We grow a platinum particle at the end of the nanotube in order to increase laser reflection. For this, we track the material deposition on the cantilever through the electromechanical coupling with the electron beam during the process. Next, we show electron transport measurements in high-quality devices with high transmission. While high-temperature measurements indicate electron-electron correlations, low-temperature transport characteristics point towards singleparticle Fabry-Perot interference. We observe this effect both by modifying the temperature and by tuning the source-drain voltage. This effect is attributed to the interplay between fluctuations and quantum interactions in a correlated Fabry-Perot regime. In the last part, we show that it is possible to couple the mechanical movement of the CNT to the electron transport. By applying an electron current through the system, we can either cool or amplify the mechanical motion of the eigenmode. We cooled the nanoresonator down to  $4.6 \pm 2.0$  quanta of vibration. The instabilities present in electron transport measurements are attributed to self-oscillation induced by the backaction amplification. These effects have an electrothermal origin. This method can be used in the future to cool NEMS into the quantum regime.

**Thesis Committee:**

Prof Dr Takis Kontos, Laboratoire Pierre Aigrain - CNRS

Prof Dr Darrick Chang, ICFO

Dr Gary Steele, Technische Universiteit Delft