Master in Photonics – "PHOTONICS BCN"
ERASMUS+ "EUROPHOTONICS"

MASTER THESIS PROPOSAL

Dates: April - September 2021

Laboratory: Nanophotonics Theory Group (NPT)
Institution: ICFO – The institute of Photonic Sciences, Castelldefels
Title of the master thesis: Optical applications of graphene nanoribbons

Name of the master thesis supervisor: prof. Javier García de Abajo
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Keywords: Graphene, 2D materials, plasmons, electron-energy loss spectroscopy (EELS), Purcell factor, mode transfer

Summary of the subject:

The synthesis of graphene back in 2004 reached the ultimate limit in the fabrication of nanodevices. Graphene is a tightly compact one-atom-thick layer of carbon atoms arranged in a honeycomb lattice, which exhibits extraordinary properties for opto-electronic applications. Since then many other materials were produced and nowadays the scientific community has at hand a large variety of 2D materials. We can combine monoatomic layers of different nature to obtain desirable properties, and we can also rotate them to add a further degree of tenability (*twistronics*). It is then in this context, that theoretical modelling of their light-matter properties is of primordial importance from which we require fast computational methods able to shed insight into future real experiments.

From the band structure configuration, graphene is a gapless semi-conductor and when adding charges those can move freely, as it happens in metals. Under such circumstances plasmons can be excited – the collective oscillation of conduction electrons –, which are the electromagnetic modes that dominates the optical response. Here we propose the use of graphene nanoribbons, whose sizes are below 100 nm width, to explore their light-matter behaviour from the theoretical viewpoint. We list the following two projects.

Light-matter interaction of graphene nanoribbons:
We propose the use of emitters to couple to the electromagnetic modes of the ribbons to determine their response and study: Purcel factor and electron-energy loss spectroscopy

(EELS). Graphene serves as a platform to improve light-matter interactions and this project aims to seek for suitable configurations for future experimental realizations.

Mode transferring of graphene nanoribbons:
As introduced above, there exists the possibility to stack various layers and play with their spatial configuration, thus we propose the use of two nanoribbons as basic elements for nano-circuitry, to study the transfer of the modes from one to another. Photonic circuits can be benefited from such systems as well as other fields as quantum communications in order to build logic gates.

The student(s) will be hosted in an international group under the supervision of prof. Javier García de Abajo and co-supervised by PhD candidate Álvaro Rodríguez Echarri. S/he will learn the solid-state basis of graphene, which lead to its optical properties, and will be familiar with the theoretical tools to model such nanostructures upon electromagnetic excitations. The student will have to implement their own codes in order to be able to carry out the proposed projects.

We seek for motivated student with background in electromagnetism and photonics, as well as with basic programing skills.