MASTER IN PHOTONICS – "PHOTONICS BCN"
ERASMUS+ "EUROPHOTONICS"

MASTER THESIS PROPOSAL

Dates: April - September 2019

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

Title of the master thesis: Engineering superconductivity in twisted bilayer graphene.

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Keywords : Superconductivity, twisted bilayer graphene, quantum electron transport, cryogenics, nanofabrication

Summary of the subject (maximum 1 page) :

Two-dimensional (2D) monolayers have generated a huge research interest in the past years. The discovery of graphene was awarded with the 2010 Nobel Prize in physics. Very recently, it was realised that twisted bilayer graphene represents a promising platform for understanding the elusive properties of unconventional superconductivity [1]. Better understanding high-temperature superconductors may allow physicists to reach superconductivity at room temperature. This would likely have an enormous impact on our society, since it could dramatically reduce energy consumption in many devices and electricity distribution. Here, we propose to explore new types of twisted bilayer graphene devices in order to understand how superconductivity emerges from the strong correlation between electrons.

When two graphene lattices are overlaid and tilted, they can interfere to create a moiré pattern with a long period. At a small angle of about 1.1º, it was showed that the twisted bilayer graphene stack becomes superconducting. At this "magic" angle, the energy dispersion of electrons becomes flat and the electron-electron interaction parameter becomes large. By tuning the carrier density, the twisted bilayer graphene stack becomes a Mott insulator. These properties are similar to those of cuprates and other high-temperature superconductors. Graphene has two key advantages compared to these materials. First, the band structure of monolayer graphene is simple and well understood. Second, the Fermi energy can be tuned by

simply adjusting the voltage applied to the gate electrode in order to characterize the whole phase diagram of electrons. The goal of our research is to fabricate new types of electrical devices based on twisted monolayers in order to understand the physics that leads to superconductivity.

One aspect of the project will be to fabricate ultra-clean twisted bilayer graphene devices. Here the student will have the opportunity to learn how to use an electron beam lithography system, how to produce graphene devices like the Nobel Prize winners, and how to transfer graphene with micrometer precision. The other aspect of the project is to measure superconductivity at low temperature using low-noise electrical measurements.

[1] Y Cao, *et al.*, Nature 556, 43 (2018).

Keywords : Superconductivity, twisted bilayer graphene, cryogenics, nanofabrication, electrical measurements.

Additional information:
* Required skills: We are looking for applicants with a strong background in physics.
* 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.