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

### **MASTER THESIS PROPOSAL**

**Dates: April 2023 – July or September 2023**

**Laboratory: Ultracold Quantum Gases**

**Institution: ICFO**

**City, Country: Castelldefels (Barcelona), Spain**

**Title of the master thesis: Exploring supersolidity in a spin-orbit coupled mixture of potassium Bose-Einstein condensates**

**Name of the master thesis supervisor and co-supervisor: Leticia Tarruell; Ramón Ramos**

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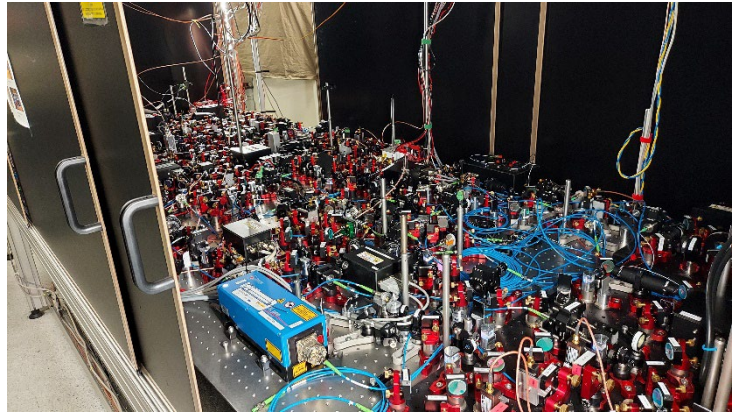
**Keywords:** ultracold quantum gases, quantum simulation, Bose-Einstein condensates, degenerate Fermi gases, spin-orbit coupling, supersolidity.

### **Summary of the subject (maximum 1 page):**

Ultracold atomic gases have become an ideal platform for exploring novel quantum phases of matter thanks to the excellent control that they provide over the system. This allows one to engineer complex quantum many-body systems described by Hamiltonians that are perfectly well defined, and whose parameters (interatomic interactions, dispersion relation of the particles, system geometry, etc.) can be tuned experimentally almost at will. One intriguing phase that has fascinated physicist for decades is the supersolid: a counterintuitive quantum state of matter that spontaneously breaks translational invariance, developing crystalline structure like a solid, while simultaneously displaying frictionless flow like a superfluid.



Our group at ICFO is currently attempting to realize this phase in one of its laboratories. The idea is to use a mixture of Bose-Einstein condensates, where interactions can be broadly tuned by controlling the external magnetic field, and subject them to a synthetic spin-orbit coupling obtained by dressing the atoms with light. Supersolidity has been predicted in this system for a certain range of parameters, but a complete characterization of the phase and of its intriguing excitation spectrum is still lacking.



The goal of this project will be to support the observation and characterization of supersolidity in our experiment. The master student will integrate into the potassium team and will actively participate in the main experiment. Depending on the experimental circumstances, the student will develop subprojects such as magnetic field monitoring and stabilization, the development of an improved laser source for Raman dressing, the correction of aberrations in the imaging system, or the contribution to the operation of the experiment and the analysis of the data. During this time, the student will develop experimental and theoretical skills in laser cooling, atomic physics, laser sources, optics and electronics.

### **Objectives:**

Integrate in the potassium team of our group, and assist in the investigation of the supersolid phase in potassium Bose-Einstein condensates. Depending on the advancement of the experiment, and the challenges that arise, this might range from magnetic field monitoring and stabilization, to the development of a new Raman coupling laser system, the implementation of a scheme to correct aberrations in the optical system or the development of an optical setup to generate arbitrary potentials on the Bose-Einstein condensates and to probe its excitation spectrum using Bragg scattering.

### **Additional information (if needed):**

\* Required skills: We are looking for candidates with a good background in quantum optics and atomic physics, and a strong motivation for setting up and conducting challenging experiments in a team of three to four people. We offer training in a broad range of cutting-edge experimental techniques (from optics, electronics, ultra-high vacuum technology and computer control to the engineering of quantum many-body states), as well as in theoretical atomic, quantum, statistical, and condensed matter physics.

\* Miscellaneous: The Master project is funded. More details can be found in [jobs.icfo.eu](http://jobs.icfo.eu)