

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

MASTER THESIS PROPOSAL

Full time from April 2026 (it can start part time from February 2026)
Presentation date to be chosen: end of July or beginning of September 2026

Laboratory: *Atomic Quantum Science Lab* (UB)
Institution: Physics Faculty, Universitat de Barcelona
City, Country: Barcelona, Spain

Title of the master thesis: Laser Cooling of Cesium Atoms

Name and affiliation of the master thesis supervisor: Antonio Rubio-Abadal
Email address: antonio.rubio@fqa.ub.edu
Phone number: 93 402 90 37
Mail address: Departament de Física Quàntica i Astrofísica, C/ Martí i Franquès, 1
08028 Barcelona - SPAIN

Keywords: Atomic physics, quantum science, laser cooling

1. Summary of the subject:

Neutral atoms find applications in essentially all branches of **quantum science and technology**. Some major examples include atomic clocks, quantum sensors or quantum simulator/computers. A prerequisite for most of these applications is to prepare an atomic cloud to temperatures below few microkelvin. These temperatures are achieved via **laser cooling**¹, a technique where carefully tuned laser light is used to drastically reduce the kinetic energy of atoms.

In our newly established lab at the Universitat de Barcelona (UB), the *Atomic Quantum Science Lab*, we are building the first cold-atom experiment in the city of Barcelona. Our atom of choice is cesium-133, due to its desirable energy level structure and its tunable interaction properties. Among the scientific directions that we want to explore, we include quantum simulation of low-dimensional systems and quantum optics with atomic arrays.

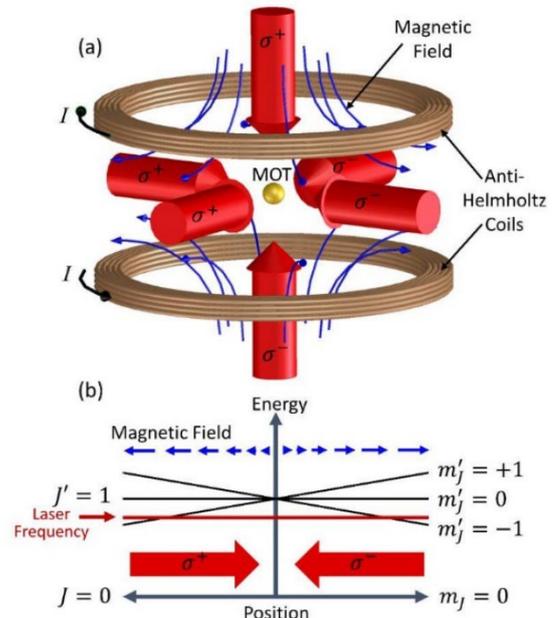


Figure 1 Schematic of a working magneto-optical trap. Extracted from McClelland et al. *Appl. Phys. Rev.* 3 (2016)

In this master project, we offer a unique chance to introduce yourself to the world of cold atoms by designing and building a setup to laser cool ^{133}Cs . The experimental project will revolve around the D_2 transition of cesium, at 852 nm. For this infrared wavelength, tunable laser sources exist based on external-cavity laser diodes, allowing for reliable control. As an optical frequency reference, Cs atomic vapor cells can be operated at room temperature to lock the wavelength of the laser to the suitable transition. In addition, the design of a suitable vacuum chamber and magnetic coils could also be part of this project.

[1] F Schreck and K. van Druten, Nature Physics 17, 1296-1304 (2021)

2. Objectives:

The exact goals of the project will be determined according to the interest and skills of the student, but a suggestive list includes:

- Assembly of a laser module at 852 nm for spectroscopy of atomic cesium and precise frequency locking. This will include the laser source, optics, the atomic vapor cell and suitable electronics.
- Design of a magneto-optical trap for cesium. In particular, the vacuum chamber, the magnetic coils and the photonic layout will be considered.
- Simulate numerically the different laser cooling mechanisms (magneto-optical trapping, optical molasses...) to bring a gas of cesium atoms to microkelvin temperatures.

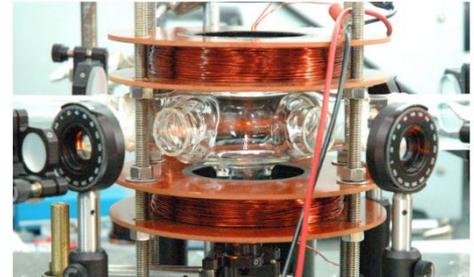


Figure 2. Left: Ampoule with atomic cesium at room temperature. Right: Example of a magneto-optical trap experiment (from BCIT)

Additional information:

* Advised skills (not mandatory):

- Undergrad knowledge of atomic and quantum physics.
- Previous experience in experimental physics, ideally in photonics.
- Experience with electronics or mechanical design.

* Miscellaneous:

The Master project, which will take place at UB, will be aligned with the activities ManboQu team (<https://manboqu.fqa.ub.edu>) and the QComms Lab (<https://quantumcomms.fqa.ub.edu/>).

Opportunities for fellowships might be available through the Màster+UB program.