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

Group: *Many-body Quantum Physics with Atoms and Light* (ManboQu)
Institution: Physics Faculty, Universitat de Barcelona (UB)
City, Country: Barcelona, Spain

Title of the master thesis: Quantum Parameter Estimation of Squeezed Light via Atom–Field Interactions

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Keywords: Quantum sensing, Atom-light interactions, Theory

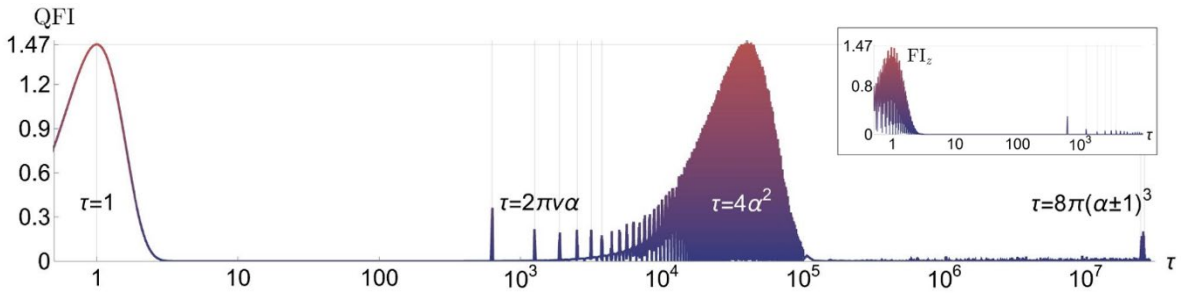
1. **Summary of the subject:**

Quantum sensing is a burgeoning field in which quantum properties are used to enhance precision. It has been used in a lot of different areas and experiments: LIGO, atomic clocks, and NV centers, to name a few. Within optical setups, people are generally interested in estimating the amplitude of a field. In optical platforms, the most common sensing task is the estimation of a field amplitude. Traditionally, this is approached semiclassically by quantizing matter while treating the field as classical.

In our recent work (https://arxiv.org/pdf/2509.22361), the Jaynes–Cummings model was used to fully quantize both the atom and the light field, showing how the amplitude of a coherent state can be inferred through measurements performed only on the atom. This thesis aims to extend that approach to **nonclassical states of light**, specifically **squeezed states**. The goal is to determine how well atomic measurements can be used to estimate key squeezing parameters - such as the squeezing strength r or the squeezing angle ϕ, and to explore how the non-classicality of squeezed light influences achievable precision.

This direction is both natural and timely: squeezed states are more intrinsically quantum than coherent states and are central to state-of-the-art sensing platforms (e.g. LIGO). Understanding how their properties propagate through atom-field dynamics may reveal new quantum-enhanced sensing

strategies.



The picture is taken from https://arxiv.org/pdf/2509.22361, and it is depicted to show how non-trivial the JC is when the initial state of it is a coherent state of high amplitude. All the behaviour of this picture has been predicted by analytical calculations.

2. Objectives:

The exact goals of the project will be adapted according to the interest and skills of the student, but mostly include:

1. **Develop and analyze the Jaynes–Cummings model** where the field is prepared in a squeezed state, characterizing how the squeezing parameters influence the atomic dynamics.

2. **Determine how to estimate squeezing parameters from measurements on the atom alone**, and evaluate the achievable precision using tools such as the Quantum Fisher Information.

3. **Compare the sensing performance to the coherent-state case**, identifying regimes where squeezed states provide enhanced sensitivity or qualitatively new behavior.

4. **Robustness**: Study the role of decoherence, finite detector resolution, or imperfect state preparation. Evaluate feasibility for implementation in cavity-QED or circuit-QED platforms.

Additional information:
* Advised skills (not mandatory):

- Undergrad knowledge of quantum physics, quantum optics or quantum information.

* Miscellaneous:

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

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