



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: Cooperative Quantum Optics with Atomic Arrays (Theory)

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Keywords: Quantum optics, atomic physics, collective phenomena, theory

1. Summary of the subject:

The development of **novel light-matter** platforms can play a key role for many applications of quantum science. Atomic arrays, made up of individual atoms arranged either in optical lattices or tweezers, display novel features emerging from **cooperative light-matter** interactions. In such arrays, collective radiative effects lead to qualitatively new optical properties: the spontaneous emission of an excited atom can be strongly modified by the presence of neighboring atoms, giving rise to cooperative phenomena.

Notably, subwavelength atomic arrays support **subradiant collective modes**, in which excitations decay extremely slowly, enabling long-lived storage and coherent control of optical excitations [1]. Additionally, two-dimensional arrays can act as **near-perfect mirrors** for resonant photons, demonstrating highly efficient, coherent light-matter interfaces [2].

Thus far, however, most theoretical studies of these cooperative effects assume a simplified **two-level atomic model**, which does not capture the rich structure of real atoms. This project aims to go beyond this approximation by exploring collective radiative effects in arrays of **multilevel atoms**, focusing on cesium. In very recent experiments, the cesium “forbidden transition” ($6s_{1/2} \rightarrow 5d_{5/2}$, 685 nm) has been harnessed for free-space laser cooling, background-free qubit detection and sideband cooling [3]. This transition could offer novel opportunities for quantum optics in atomic arrays given that

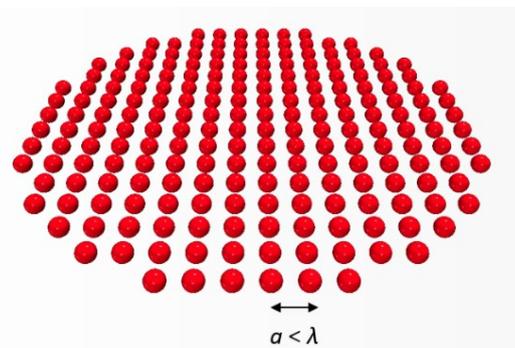


Figure 1. A square atomic array with subwavelength spacing

such narrow-line transitions have essentially not been explored in alkali species. It also offers ways of detecting the ground state spin with high fidelity, and has been proposed as an optical frequency reference.

This project will involve close interaction between theory and possible experimental implementations, with opportunities to collaborate with ongoing and future experimental efforts.

[1] A. Asenjo-Garcia, M. Moreno-Cardoner, A. Albrecht, H. J. Kimble, and D. E. Chang, *Phys. Rev. X* **7**, 031024 (2017).

[2] M. T. Manzoni, M. Moreno-Cardoner, A. Asenjo-Garcia, J. V. Porto, A. V. Gorshkov, D. E. Chang, *New Journal of Physics* **20**, 083048 (2018).

[3] K. N. Blodgett, S. S. Phatak, M. R. Chen, D. Peana, C. Pritts, and J. D. Hood, *Phys. Rev. A* **112**, 043109 (2025).

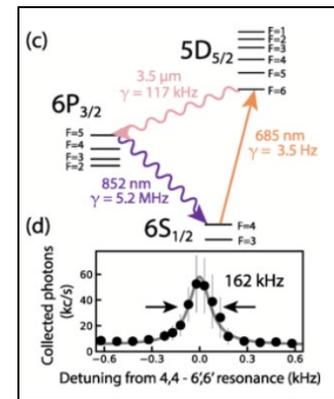


Figure 2. Electric quadrupole transition of Cs at 685 nm, extracted from Blodgett et al. *PRA* 112, 043109 (2025)

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:

- Developing a theoretical model of collective atom-light interactions incorporating the relevant multilevel structure of cesium.
- Analyzing collective radiative modes (including cooperative decay rates and level shifts) in sub-wavelength arrays, using a combination of analytical and numerical tools.
- Studying the quantum many-body dynamics and entanglement generation in driven-dissipative cesium arrays.
- Designing experimental detection schemes for observing driven-dissipative phases, using either far-field emission or in-situ state-resolved atom measurements.
- Assessing the feasibility of quantum-optics protocols based on the electric quadrupole transition of cesium (e.g. preparation of strongly subradiant steady states).

Additional information:

* Advised skills (not mandatory):

- Undergrad knowledge of atomic and quantum many-body physics.

* 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.