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

MASTER THESIS PROPOSAL

Dates: April 2025 – July or September 2025

Laboratory: Atomic Quantum Optics (Mitchell group)

Institution: ICFO

City, Country: Barcelona, Spain

Title of the master thesis: Atomic Sensors with Operating Beyond the Shot Noise Limit

Name of the master thesis supervisor and co-supervisor: Morgan Mitchell / Aleksandra Sierant

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Keywords: Quantum sensing, atomic physics, quantum optics

Summary of the subject (maximum 1 page):

Optically-pumped magnetometers (OPMs) are sensors that use laser excitation of atomic vapors to make extremely sensitive measurements of magnetic fields. These devices have many applications, ranging from biomedicine (brain imaging) to space exploration (<https://solarsystem.nasa.gov/missions/cassini-hds/mission/spacecraft/cassini-orbiter/magnetometer/>). An intriguing problem is the role of quantum noise (both atomic and optical) in determining the sensitivity of these instruments [1]. Here we study the possibility to operate OPMs beyond the shot noise limit of sensitivity, using *squeezed light* to reduce the optical quantum noise [2,3].

Possible masters projects:

- 1) (experimental) improvements in the vapor control system, to allow experiments with higher vapor densities and thus better sensitivities. Studies of the interaction of optical quantum noise with atomic quantum noise in OPMs for dc and radio-frequency magnetometry.
- 2) (experimental) contributions to the development of a next-generation light squeezer. Nonlinear optics, cavity enhancement, squeezing by parametric amplification.



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Additional information:

* Required skills: Experimental experience is desirable but not absolutely required. Hard working, good knowledge of optics, quantum optics and laser principles.

- [1] M. W. Mitchell and S. Palacios Alvarez, Colloquium: Quantum limits to the energy resolution of magnetic field sensors, *Rev. Mod. Phys.* **92**, 021001 (2020).
- [2] C. Troullinou, R. Jiménez-Martínez, J. Kong, V. G. Lucivero, and M. W. Mitchell, Squeezed-Light Enhancement and Backaction Evasion in a High Sensitivity Optically Pumped Magnetometer, *Phys. Rev. Lett.* **127**, 193601 (2021).
- [3] C. Troullinou, V. G. Lucivero, and M. W. Mitchell, Quantum-Enhanced Magnetometry at Optimal Number Density, *Phys. Rev. Lett.* **131**, 133602 (2023).