



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

Note: The main Master Thesis supervisor has to be a professor of the Master in Photonics program. One co-supervisor (internal or external) can be defined. Main Supervisor is responsible for the subject of the proposal and has to give continuous support to the student (research development, Report writing and presentation preparation). For external proposals a co-supervisor from the Master program and a collaboration agreement with UPC are needed. You can find all information about the Master Thesis process in [our webpage](#).

Laboratory: Optoelectronics group (<https://www.icfo.eu/research-group/15/optoelectronics/home/>)

Institution: ICFO - The Institute of Photonic Sciences

City, Country: Castelldefels (Barcelona), Spain

Title of the master thesis: Towards Genuine Spatial Entanglement Certification

Name and affiliation of the master thesis supervisor: Prof. Dr. Valerio Pruneri (supervisor)

Name and affiliation of the co-supervisor (if any): Dr. Jorge Fuenzalida, Dr. Robin Camphausen (for external proposals a co-supervisor chose among the Master Program professors and a collaboration agreement with UPC is needed)

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Keywords: Quantum entanglement, spatial correlations, SPAD camera

1. Summary of the subject (maximum 1 page):

Quantum entanglement is one of the most fascinating features of quantum physics and today is the cornerstone of quantum technologies. Photons can be entangled in different degrees of freedom, such as polarization or spatial modes [1]. The latter has been certified several times [2]; however, these experiments contain an important loophole, namely, the independent measurement of position and momentum. Since the Bell inequality (certification) is linked to the Heisenberg uncertainty principle, these two quantities —position and momentum— must be measured simultaneously in order to close the loophole.

$$\Delta x \Delta p \geq \frac{h}{4\pi}$$



The project consists on moving towards the measurement of genuine spatial entanglement by closing this loophole. The project will start observing quantum interference in a free-space interferometer, and, if time allows, will follow with the detection of spatial entanglement using single-photon avalanche diode cameras.

The student will be part of the Optoelectronics group at ICFO, led by Prof. Valerio Pruneri, working closely with members of the quantum imaging team in order to take advantage of the group's expertise in quantum optics.

2. References:

- [1] John C. Howell, Ryan S. Bennink, Sean J. Bentley, and R. W. Boyd, "Realization of the Einstein-Podolsky-Rosen Paradox Using Momentum- and Position-Entangled Photons from Spontaneous Parametric Down Conversion, " *Phys. Rev. Lett.* **92**, 210403 (2004).
[2] Baptiste Courme, Chloé Vernière, Peter Svihira, Sylvain Gigan, Andrei Nomerotski, and Hugo Defienne, "Quantifying high-dimensional spatial entanglement with a single-photon-sensitive time-stamping camera," *Opt. Lett.* **48**, 3439-3442 (2023).

3. Objectives (maximum 1 page):

- 1) Understanding of quantum optical experiments, spatial entanglement, and quantum interferometry
- 2) Manipulation of SPAD cameras

Additional information (if needed):

* Required skills:

- Motivation to work and passion for **fundamental** quantum physics

* Miscellaneous:

Stipend: yes, for details please enquire when applying