



## **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: beginning of September 2026**

**Laboratory:** Optics group

**Institution:** UAB

**City, Country:** Bellaterra, Spain

**Title of the master thesis:** Experimental entangled two-photon absorption in the human retina

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**Keywords:** Light-matter interaction, nonlinear optics, entanglement generation

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

Two-photon absorption (TPA) is a nonlinear optical process of major relevance in imaging and biophotonics. Conventionally, TPA requires high-intensity pulsed lasers due to the low simultaneous photon absorption probability. However, entangled two-photon absorption (eTPA) can significantly enhance this process by exploiting quantum correlations between photon pairs, enabling nonlinear interactions even at much lower photon fluxes [1].

The aim of this project is to demonstrate eTPA using the human retina as a biological detector. This will involve building a bright, pulsed spontaneous parametric down-conversion (SPDC) source tailored to emit entangled photon pairs in a spectral range compatible with retinal two-photon sensitivity.

The student will contribute to the development of the SPDC source, optimize its brightness and temporal correlations [2], and participate in designing the delivery optics. A critical part of the work involves implementing quantum delay lines and coupling systems to ensure high-purity photon delivery to the retina. The system will be aligned and tested using single-photon detectors and coincidence electronics.

The project will be carried out in collaboration with nonlinear optics experts in ICFO and vision science experts from the University of Murcia, who will oversee psychophysical testing and assist in



interpreting visual response data. This interdisciplinary research lies at the intersection of quantum optics and neuroscience and may contribute to new methods in quantum bioimaging, visual stimulation, and the fundamental understanding of nonlinear light-matter interactions in biology [3,4].

## 2. Objectives:

- Review the state-of-the-art in entangled two-photon absorption and its biological applications.
- Design and implement a pulsed SPDC source optimized for retinal sensitivity, in the 900–1100 nm range.
- Implement filtering, mode coupling, and entanglement control techniques to maximize photon-pair brightness and indistinguishability.
- Simulate the optical and temporal profile of the entangled beam at the eye and assess safety constraints.
- Analyse experimental results and compare perceptual thresholds against classical and quantum TPA models.

### Additional information:

It is desirable that the student has basic knowledge of experimental optics, LabView and Python programming.

### References

- [1] B. E. A. Saleh, B. M. Jost, H. B. Fei, and M. C. Teich, “Entangled-Photon Virtual-State Spectroscopy,” *Phys. Rev. Lett.* 80, 3483–3486 (1998).
- [2] B. Dayan, A. Pe’er, A. A. Friesem, and Y. Silberberg, “Two Photon Absorption and Coherent Control with Broadband Down-Converted Light,” *Phys. Rev. Lett.* 94, 043602 (2005).
- [3] T. B. Pittman, Y. H. Shih, D. V. Strekalov, and A. V. Sergienko, “Optical imaging by means of two-photon quantum entanglement,” *Phys. Rev. A* 52, R3429 (1995).
- [4] A. Roorda, F. Romero-Borja, W. J. Donnelly III, H. Queener, T. J. Hebert, and M. C. W. Campbell, “Adaptive optics scanning laser ophthalmoscopy,” *Opt. Express* 10, 405–412 (2002).