



## 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**

**Laboratory : Attoscience and Ultrafast Optics**  
**Institution: ICFO – The Institute of Photonic Sciences**  
**City, Country : Castelldefels (Barcelona), Spain**

**Title of the master thesis: Quantum Spectroscopy of Attosecond Dynamics**

**Name of the master thesis supervisor: Prof. Dr. Jens Biegert**

Email address : jens.biegert@icfo.eu

Phone number : +34 93 553 4059

Mail address : Av. Carl Friedrich Gauss 3, 08860 Castelldefels (Barcelona), Spain

**Keywords: Quantum Spectroscopy, High Harmonic Generation, Attosecond, Materials**

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

Have you ever wondered what light can tell us about the *quantum world* inside materials? In this project, you'll dive into the frontier of **quantum harmonic spectroscopy** — where **ultrafast lasers** generate extreme bursts of light (high harmonics) that carry direct information about **how electrons interact, move, and even change phase** inside solids.

You will explore how the *quantum nature of light itself* — not just its intensity or color — can be used as a **precision tool to probe complex materials**. This approach opens a completely new window into **many-body physics, superconductivity, and quantum phase transitions**.

Your work will build on recent breakthroughs such as:

- Discovery of quantum phase transitions through high-harmonic light in superconductors (PNAS 2022)
- First evidence that high-harmonic light is *quantum* in nature (PRX Quantum 2024)
- Revealing hidden anisotropies in a Mott–charge-density-wave transition (Commun. Mater. 2025)

This project is ideal for students who are curious, hands-on, and excited about **bridging quantum optics, ultrafast science, and condensed matter physics**. You'll have the chance to work with



cutting-edge laser technology and participate in experiments that challenge our understanding of light–matter interaction at its most fundamental level.

## 2. Objectives (maximum 1 page):

- **Generate and characterize high-harmonic light from quantum materials.**

Develop and optimize high-harmonic generation (HHG) in selected correlated solids (e.g. superconductors or charge-density-wave materials). Measure the spectral, temporal, and polarization properties of the emitted harmonics under controlled excitation conditions.

- **Implement quantum metrology techniques to probe light–matter correlations.**

Apply quantum optical diagnostics — such as intensity noise analysis, photon correlation, or spectral interferometry — to reveal nonclassical features in the high-harmonic emission. Quantify how these properties reflect the microscopic electron dynamics and many-body correlations in the material.

- **Correlate harmonic signatures with material phase transitions and anisotropies.**

Investigate how the harmonic spectrum, coherence, and quantum statistics evolve across temperature- or field-induced phase transitions. Use these observables to identify experimental fingerprints of quantum critical behavior, electron–phonon coupling, or symmetry breaking.

## Required and Desired Skills

- **Strong curiosity and enthusiasm** for experimental quantum physics, ultrafast optics, and materials science.
- **Diligent and reliable work ethic**, with attention to detail in both laboratory work and data analysis.
- **Basic knowledge of optics and laser physics**, ideally from prior coursework or lab projects.
- **Hands-on experimental skills**, such as optical alignment, vacuum systems, or electronic instrumentation (training will be provided).
- **Familiarity with data acquisition and analysis tools**, e.g. Python, MATLAB, or LabVIEW.
- **Ability to work carefully and safely** with high-power laser systems and precision optical setups.
- **Good communication and teamwork skills**, and willingness to collaborate within an interdisciplinary research group.
- **Motivation to learn new techniques** and engage with cutting-edge research at the interface of quantum optics and condensed matter physics.