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: Molecular Nanophotonics group (led by Prof. Niek van Hulst)
Institution: ICFO - The Institute of Photonic Sciences
City, Country: Castelldefels (Barcelona), Spain

Title of the master thesis: Event-by-Event Spatiotemporal Microscopy with a 32×32 SPAD Camera: Bayesian Inference of Exciton Diffusion and Annihilation under Structured-Light Excitation

Name and affiliation of the master thesis supervisor: Dr. Luca Bolzonello (supervisor), ICFO
Name and affiliation of the co-supervisor (if any): Dr. Robin Camphausen, Prof. Dr. Niek van Hulst
(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: SPAD array; single-photon time tags; Bayesian online inference; exciton diffusion; exciton–exciton annihilation; ballistic transport; structured illumination (Bessel, lattice, gratings); spatiotemporal microscopy.

1. **Summary of the subject:**
   Spatiotemporal microscopy (SPTM) enables direct visualization of exciton transport phenomena by tracking the space–time evolution of photoexcited quasiparticles such as excitons. Event-resolved single-photon detection with SPAD arrays now allows operating far below the perturbative regime while preserving high temporal fidelity.
   This project proposes a compact SPTM platform built around a 32×32 single-photon avalanche diode (SPAD) camera with per-photon time tags. We will use structured-light

excitation to generate an initial carrier distributions such as Bessel beams or interference gratings/lattices, to interrogate different physical responses. In particular, we aim to separate normal diffusion from ballistic or non-linear effects, i.e. exciton–exciton annihilation (EEA) by leveraging the distinct spatiotemporal fingerprints produced by different excitation symmetries and length scales.

Methodologically, we will develop an event-by-event Bayesian framework in which each detected photon updates the posterior over transport and reaction parameters in real time.

2. References:

[1] Diana Dall'Aglio, Guillermo D. Brinatti Vazquez, Luca Bolzonello, Iris Cusini, Robin Camphausen, and Niek F. van Hulst, ACS Photonics **2025** 12 (3), 1291-1299

3. Objectives:

- Build and calibrate a SPTM platform coupling a 32×32 SPAD array to a high-NA microscope with structured illumination excitation.
- Derive an event-likelihood function (space × time) and realize an online Bayesian estimator.
- Design illumination patterns (Bessel beams, interference gratings/lattices, Airy/Bessel–Gaussian, and Gaussian references) to maximize sensitivity to specific parameters (D, ballistic velocity, annihilation rate).
- Validate on calibrated diffusive media and thin-film semiconductors.

Additional information (if needed):

Required skills:

- Familiarity with programming using Python programming language (common scientific computing libraries such as NumPy etc)
- Previous experience with optics laboratory setups would be a bonus