2025

Master internship and PhD proposal

Campus Pierre et Marie Curie
Tower 23 – 3rd floor – 23-22
Director: Massimiliano Marangolo

Title: Manipulating the Quantum Photon-Avalanche Process with Plasmonic Nano-Antennas

Keywords: Avalanche behavior, highly nonlinear processes, plasmonic nano-antennas, light-matter interactions, quantum optics

Scientific description:

Phenomena such as earthquakes, landslides, forest fires, species extinctions, stock market crashes, and wars are all examples of self-organized criticality in nature, exhibiting avalanche-like behavior (YouTube link). In optics, a similar behavior is observed in the photon emission from certain rare-earth-doped nanoparticles, specifically those doped with thulium ions (Tm^{3+}). This highly nonlinear phenomenon is known as the **photon avalanche** (PA).

The emission from these Avalanching Nanoparticles (ANPs) exhibits a nonlinear response to the excitation source (see Figure 1), making them promising probes for applications such as super-resolution biological imaging.

Building on our team's expertise in manipulating electric and magnetic light-matter interactions at the nanoscale, we propose to study the influence of plasmonic nano-antennas (see Figure 2) on the internal physical mechanisms of the photon avalanche.

As part of this fundamental research project, we will employ experimental techniques such as Scanning Near-field Optical Microscopy (SNOM), power-dependent measurements, and spectroscopic analysis to characterize the exotic behavior of ANPs.

Collaborating with the University of California, Berkeley, and Columbia University, this experimental project is at the forefront of a new field of research with high potential for significant scientific publications and technological applications.

Position Description:

We are seeking a motivated student to join our research team for an internship focused on this cutting-edge project. The internship could lead to an ERC-funded PhD.

Responsibilities:

- Participate in the design and execution of experiments to study photon-avalanche phenomena in ANPs.
- Utilize advanced optical techniques, including SNOM.
- Perform power-dependent and spectroscopic measurements.
- Analyze experimental data and contribute to interpreting results.
- Collaborate closely with team members and international partners.
- Predict the ANP phenomena by analytically calculating the differential rate equations.

Candidate Profile:

- Currently enrolled in a Master's program in physics, optics, nanotechnology, or a related field.
- Strong interest in experimental quantum optics and nanophotonics.
- Experience with optical instrumentation and data analysis is a plus.
- Good communication skills and the ability to work effectively in a team.

What We Offer:

- Opportunity to work on groundbreaking research with international collaborators.
- Hands-on experience with advanced optical techniques and nanofabrication methods.
- A stimulating research environment within a dynamic and supportive team, , including Benoît Reynier (PhD Student) and Eric Charron (Research Engineer), among others
- Potential to contribute to high-impact scientific publications.

Application Procedure:

Interested candidates should submit the following:

- A detailed CV
- A cover letter explaining your motivation and relevant experience
- Academic transcripts

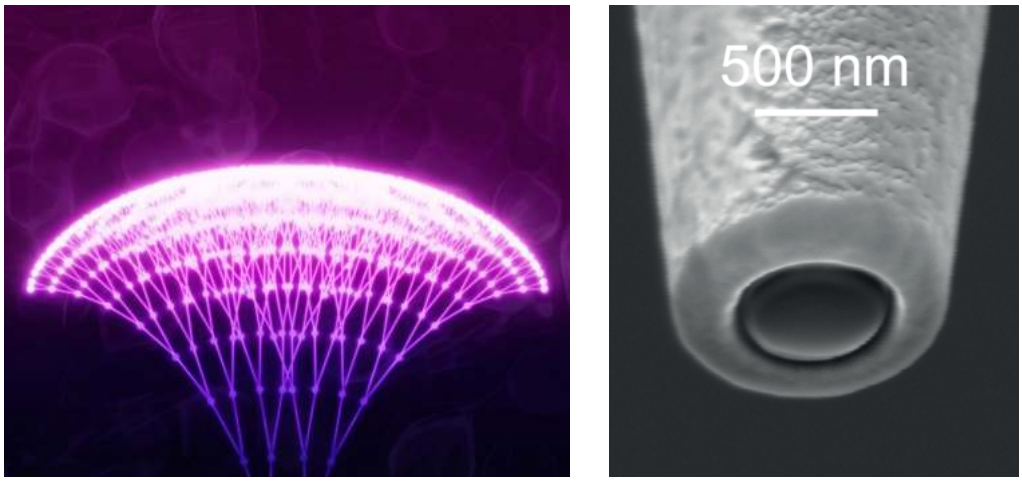

Figure 1. (Left) Illustration of a photon avalanche reaction triggered by only a few events. (Right) SEM image of an example of a plasmonic nano-antenna used to manipulate and control this highly non-linear quantum phenomenon.

Techniques/methods in use: Near-field optical microscope, Avalanche photo-diodes, Spectrometer, Numerical simulations, Analytical analysis
Applicant skills: Curiosity, Motivation and Experimental liking & skills
Industrial partnership: No
Contact: Mivelle Mathieu, mathieu.mivelle@sorbonne-universite.fr - Webpage. Feel free to reach out to other group members for additional information.
PhD fellowship: Funded by ERC