Call for PhD Applicants for the project:

Quantum frequency conversion of single photons for entanglement-based quantum communications

In a nutshell

This call for applicants aims to attract talented students for a PhD project in the Quantum Structured Light Laboratory (QSLab), at the Physics Institute of the University of São Paulo (IFUSP). The project will be developed within the StruQT project, a FAPESP project focused on developing sources and detectors of quantum light for use in entanglement-based quantum network. The resources developed in the laboratory will be deployed in the Quantum Network of São Paulo (QneSP), built using optical fibers within and between campuses of the University of São Paulo.

The student in charge of the project will focus on the development of a key quantum technology for the widespread implementation of quantum networks: upconversion detectors. The student will conduct theoretical and experimental investigations on quantum frequency conversion, which is the process of changing a photon's color while maintaining its quantum information intact. This process is important as it enables the detection of photons in the telecommunications band using standard Silicon-based detectors. Along this project, the student will develop, test and deploy an upconversion detector module based on the cavity-enhancement of the driving laser field.

This PhD project will be supervised by Prof. Rafael Barros, a Tenure Track professor at the Physics Institute of the University of São Paulo. The ideal starting time for the PhD fellowship would be the second semester of 2025, but the first semester of 2026 is also acceptable.

Proposed research activities

The activities that the student is expected to perform are described in chronological order in the following. A breakdown of the project's timeline is shown in Fig. 1.

A1. Theoretical investigation on the limiting factors for cavity-based upconversion detectors.

The student will investigate the fundamental and technical aspects of quantum frequency conversion, unveiling the optimal architectures, laser sources, and nonlinear media to be used for optimal performance. The analysis will be focused on the limiting factors of upconversion detectors, when compared to direct detection methods, with the goal of identifying in which conditions upconversion detectors are advantageous.

A2. Construction of Telecom-Visible upconversion detector based on a cavity-enhanced fiber laser.

Along with the theoretical analysis, the student will investigate experimentally the implementation of polarization-preserving upconversion detectors, aiming at the application in polarization-entanglement-based quantum communications. The student will develop prototypical implementations in the laboratory environment, focusing on optimizing the quantum efficiency and noise of the detectors, and analyzing its adequacy for field tests in the QneSP network.

A3. Field implementation of entanglement-based quantum key distribution with upconversion detectors.

Once the upconversion detectors leave the development stage, the student will turn to their implementation in the QneSP network. The student will be responsible for establishing quantum-secure communication within the Backbone-USP network, experimentally implementing the BBM92 QKD protocol with polarization-entangled photon pairs detected with the upconversion detection modules developed.

PhD2	Year 1				Year 2				Year 3				Year 4			
Activity/Quarter	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
A1																
A2																
A3																

Figure 1: Timeline for the work plan of the proposed project.

About the supervisor

My name is Rafael Barros, and I am a tenure-track professor at the University of São Paulo. I did my PhD at Universidade Federal Fluminense, in Niterói, with Prof. Antonio Zelaquett, and a 4-year postdoctoral period at Tampere University, Finland with Prof. Robert Fickler. My research focuses on structured light in nonlinear and quantum optics, with emphasis on the manipulation of quantum states for use in quantum information. Please check my previous works and send me any questions you might have, and check also this video (in Portuguese) for a recent seminar on structured light.

Recently, I had the StruQT proposal approved by FAPESP, with a total budget of 1MUSD between late 2024 and late 2029. The funding includes the equipment to set up a state-of-the-art laboratory at the University of São Paulo, and to implement the resources developed there in a deployed network of dark fibers belonging to the university. The laboratory is currently being assembled, and its equipment includes spatial light modulators, superconducting nanowire single-photon detectors, SPADs, Time taggers, FPGAs, mode-locked and CW lasers, plenty of nonlinear materials, including lithium niobate waveguides, and so on.