

Integrated non-linear devices for light-matter entanglement and frequency conversion in quantum networks

Position: Master 2 internship

Duration: 4 to 6 months

Supervisor: Félicien Appas & Yoan Léger, CNRS researchers at FOTON institute, INSA Rennes

Department : Optoélectronique, Hétéroépitaxie et Matériaux, located at INSA Rennes

Funding program: PEPR électronique OFCOC (web site [here](#))

Key words: quantum communications, quantum technologies, integrated photonics, photon-pair sources, solid-state quantum memories

Possibility of continuing with a PhD thesis: yes

Subject:

Quantum networks relying on distribution of entanglement between stationary matter qubits are expected to powerful applications in computing, sensing, and secure communication [1]. However, a major challenge is how to share quantum entanglement across long distances. Quantum repeaters have been proposed as a solution. They consist of two elementary building blocks: sources of non-classical light and quantum memories [2]. In addition, to unlock potential real-life applications they need to be developed on an integrated physical platform allowing for reliable and large-scale fabrication [3]. At FOTON institute, we propose to achieve this goal by combining, on the one hand, low-loss semiconductor photonic circuits to perform nonlinear photon-pair generation and quantum frequency conversion and, on the other hand, chip-integrated rare-earth-ion ensembles in the solid-state acting as a quantum memory.

In the framework of the internship, the student will carry out key steps towards this goal, which can include:

- design of nonlinear photonic devices for generation of frequency-comb-like entangled photons pairs and frequency conversion compatible with the transitions of target rare-earth ion species (Fig 1 (a))
- design of a hybrid nanophotonic cavity enabling in-situ optical addressing of rare-earth ions on a photonic chip (Fig 1 (b))
- nanofabrication of a prototype device in the nanoRennes cleanroom facilities
- development and testing of cryogenic-compatible fiber-to-chip coupling solutions (grating couplers, tapered fibers)

The candidate will have the opportunity to develop hands-on skills in integrated photonic design (electromagnetic simulation, nonlinear optics) as well as basics of cleanroom fabrication (electron-beam lithography, optical lithography, dry etching techniques) and photonic chip characterization.

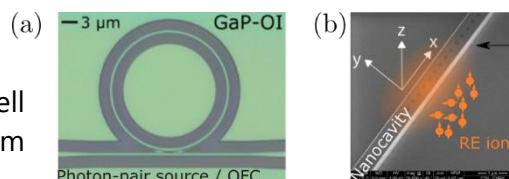


Figure 1 (a) Microresonator for frequency conversion/pair generation (b) Nanophotonic cavity for interfacing with rare-earth ions

The project will benefit both from the well-established expertise of FOTON Institute at the national and European level in nonlinear integrated photonics (French research priority program PEPR Electronique for the development of low-loss nonlinear devices for frequency conversion) and from an emerging research line on quantum technologies (quantum sensing and quantum communications with an emphasis on integrated devices). Those efforts are supported by key national collaborations on both topics (C2N, CEA Leti, INL, LMPQ Paris).

Student Profile

The internship is dedicated to M2 students with a background in photonics and quantum mechanics showing a strong interest in experimental research in quantum optics and quantum communications. Previous experience in an optics laboratory is preferable. Due to the multicultural working environment, proficiency in English is required.

Research environment

The internship will be located within the OHM department of FOTON institute, based at INSA Rennes, under the supervision of CNRS Researchers Félicien Appas and Yoan Léger. The student will join a dynamic team of two PhD students, as well as researchers, technicians and engineers working on the topic of nonlinear integrated photonics and quantum technologies.

Complementary information – application

Send your CV to:

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References

- [1] S. Wehner et al. Science **362**, eaam9288 (2018)
- [2] J. Hänni, A. E. Rodríguez-Moldes, F. Appas et al. Phys. Rev. X (2025) *In press*
- [3] L. Labonté et al. PRX Quantum **5**, 010101 (2024)