Centre de Radiofréquences, Optique et Micro-nanoélectronique des Alpes

Study of glass photonic structures at cryogenic temperatures for quantum computation

Over the past decade, quantum technologies have experienced unprecedented growth, driven in particular by the prospect of developing quantum computers. One of the challenges is to develop control circuits for these computers that operate at cryogenic temperatures and occupy a small footprint, in order to minimise the volume that needs to be cooled[1].

However, managing the power budget still remains a challenge. The aim is to ensure high-speed communication between the control chain and the quantum chip whilst limiting heat transfer between the chip — which is kept at a few mK — and the first stage of the control chain, where temperatures of a few Kelvin are allowed. For these communications located so close to the quantum chip, integrated photonics offers a dual advantage[2]: it enables very high data rates whilst providing better thermal insulation than electronic solutions.
Integrated photonics on glass has thus been identified as an enabling technology capable of meeting this ambitious challenge. Glass is indeed a very good thermal insulator and enables the creation of low-loss photonic circuits. Furthermore, the ion-exchange process on glass allows the fabrication of waveguides with excellent coupling (low loss and wide bandwidth) to optical fibres[3].

For over thirty years, the PHOTO team in CROMA has developed an internationally recognised expertise in this field. As such, it has joined IRT Nanoelec's QLoop project, which aims to develop external communication interfaces between the quantum chip and the conventional control system. In this project, CROMA is responsible for assessing the potential of its technology for cryogenic temperature applications. Indeed, the field of integrated photonics at very low temperatures remains largely unexplored at an international level. Therefore, research needs to be conducted on the impact of cryogenic temperatures on the technology's performance and CROMA aims to be a pioneer in this field by conducting a state-of-the-art study on the subject.

The work of this post-doctoral contract consists of the following tasks:

- Validating the fibred connections recently added to one of the laboratory's cryostats and those of our partners in the project (CEA-Leti)
- Testing and optimising the strength of the fibre pigtails on the waveguides at cryogenic temperatures (around 4K) in a cryostat.
- Measuring the impact of the temperature on the optical losses of the pigtailed component (from ambient temperature down to 4K).
- Studying the impact of temperature cycling on the fibred components.
- Studying the behaviour of more complex optical functions with respect to the temperature (e.g. Spiral waveguides, Mach-Zehnder interferometers, phasars, ...)

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Depending on the progress of the project, photonic components based on Bragg reflectors and hybrid structures may also be studied at cryogenic temperatures. To this end, the successful candidate will benefit from the long-term collaboration between CROMA and Institut Néel on integrated quantum optical memories based on YSO crystals (Quantum PEPR project – QMEMO).

To successfully carry out this project, the recruited person will be given access to the means of fabrication (clean room, ion-exchange on glass, pigtailing) and characterisation of the glass integrated photonics platform. They will also be in charge of the communication with the other laboratories involved in the QLoop project. They will also be responsible for the coordination of the different tasks of the project among the PHOTO team.

We also aim at disseminating the research results through publications in scientific journals and a presentation in an international conference.

Candidate profile

Applicants need to have in-depth knowledge of integrated photonics and a keen interest in experimental work. Prior experience in cleanroom manufacturing or cryogenics will be appreciated.

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3. Broquin, J.-E. & Honkanen, S. Integrated Photonics on Glass: A Review of the Ion-Exchange Technology Achievements. *Applied Sciences* **11**, 4472 (2021).