Master 2/3rd year Engineer internship topic (2021)

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”Silicon Photonics for On-Chip Quantum Communications”

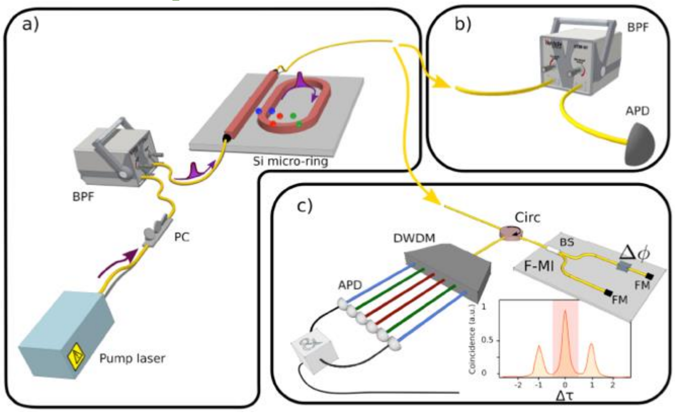
Research project description:

Of the physical approaches to quantum communication and cryptography, photonics plays a major role. Photons represent a natural choice for secure quantum communication tasks, as they interact weakly with their environment, can be generated, routed, and manipulated using integrated components, distributed through fibre and free-space links, and offer a broad variety of choices for quantum encoding, ranging from discrete to continuous-variable observables. In this context, quantum integrated photonics has now reached a level of maturity allowing the development of first practical and scalable solutions, holding the promise of technological breakthroughs in quantum information technologies (QITs). One of today’s strong driving routes lies in the implementation of quantum systems for real-world applications and use-cases, with high societal and economic impacts. Relying on already mature classical technologies, photonic-based QITs still have to comply with fragile quantum properties and strict constraints on their manipulation. In this context, the host research team is involved in a national research project (ANR) that will begin in April 2021 and that aims at addressing the design and realization of new generation photonic quantum systems allowing to create, manipulate, and exploit high-dimension photonic quantum states – qudits and clusters - encoded in the frequency domain. The chosen photonic integration platform is based on **silicon photonics**.

The internship topic consists in contributing to the preliminary efforts of the C2N host research team to several key goals including:
- Designing advanced passive and active silicon photonic components matching the specifications of on-chip communications
- Defining concrete on-chip architectures for enabling on-chip quantum communications
- Developing specific architecture design robust to on-chip optical noise.
- Defining architectures incorporating from the very design the feedback knowledge on the constraint acquired from both classical and quantum characterizations.
- Characterizing photonic chips (eg semiconductor samples) with in/out fiber light stages within a metrology optical lab environment in various configurations
- Understanding the constraints and the opportunities of clean room fabrication techniques, both at C2N and at a partner institution (CEA-LETI) to design efficient components and chips for quantum communications

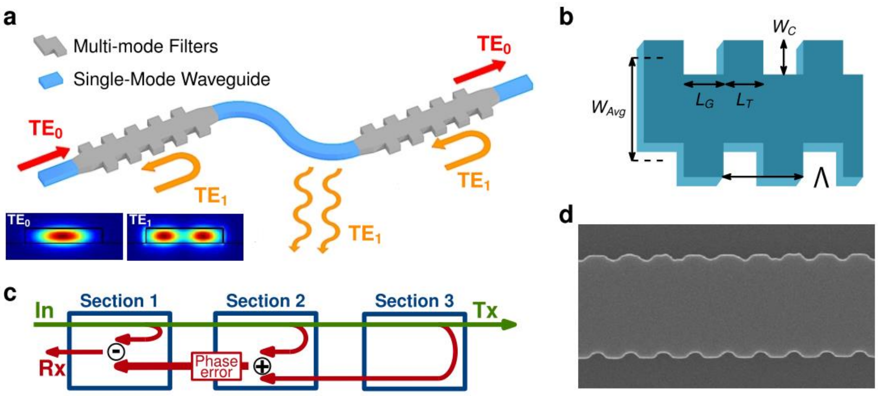
Thèse “Integrated silicon photonics for quantum optics”, par Dorian Oser
http://www.theses.fr/2019SACLS455

Recent achievements by the host research team:



Florent Mazeas, Michele Traetta, Marco Bentivegna, Florian Kaiser, Djeylan Aktas, et al.. High quality entanglement on a chip-based frequency comb. Optics Express, Optical Society of America - OSA Publishing, 2016, 24 (25), pp.28731-28738. 10.1364/OE.24.028731 . hal-01411319v1

In collaboration with IMPHYNI, we report an efficient energy-time entangled photon-pair source based on four-wave mixing in a CMOS-compatible silicon photonics ring resonator. Thanks to suitable optimization, the source shows a large spectral brightness of 400 pairs of entangled photons /s/MHz for 500 _W pump power, compatible with standard telecom dense wavelength division multiplexers. We demonstrated high-purity energy-time entanglement, i.e., free of photonic noise, with near perfect raw visibilities (> 98%) between various channel pairs in the telecom C-band. Such a compact source stands as a path towards more complex quantum photonic circuits dedicated to quantum communication systems.



(a) Schematic view of the proposed cascaded filter approach. Fundamental mode (TE0) is back-reflected into first order mode (TE1). Single-mode waveguide sections separating adjacent filters radiate the back-reflected TE1 mode away, precluding coherent interaction among different stages. (b) Schematic of shifted Bragg geometry providing Bragg back-reflections in higher order TE1 mode. (c) Block diagram illustrating the detrimental effect of phase errors in cascaded Bragg gratings with coherent interaction. (d) SEM image of a fabricated shifted grating.

"Coherency-Broken Bragg Filters: Overcoming On-Chip Rejection Limitations"
Dorian Oser, Florent Mazeas, Xavier Le Roux, Diego Pérez-Galacho, Olivier Alibart, Sébastien Tanzilli, Laurent Labonté, Delphine Marris-Morini, Laurent Vivien, Éric Cassan, Carlos Alonso-Ramos
First published: 15 July 2019 https://doi.org/10.1002/lpor.201800226
Laser an photonics review 13 (8), 1800226 (2019).

Selective optical filters with high rejection levels are of fundamental importance for a wide range of advanced photonic circuits and especially for quantum applications. A new approach based on coherency-broken Bragg filters was proposed to overcome this fundamental limitation on rejection filters. Non-coherent interaction among modal-engineered waveguide Bragg gratings separated by single-mode waveguides is exploited to yield effective cascading, even in the presence of phase errors. This technologically independent approach allows seamless combination of filter stages with moderate performance free of active control, providing a dramatic increase of on-chip rejection. Based on this concept, on-chip non-coherent cascading of Si Bragg filters is experimentally demonstrated, achieving a light rejection exceeding 80 dB, the largest value reported for an all-passive silicon filter.

Send an email to Eric Cassan to get these references and for any question.

We expect from you:

- Enthusiasm (!) and strong involvement in your project (!), a fast and growing autonomy, and the ability to address your PhD topic as a project with milestones and deliverables
- Taste for electromagnetism&optics and Quantum mechanics + Taste for simulation (python, electromagnetic commercial softwares) and optical delicate experiments
- Ability to communicate and work in a group (4 researchers/teacher-researchers, and around 10 post-doc fellows and doctoral candidates)