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Position Description

1. General Information

Name of the position	**Quantum optics on Lithium Niobate On Insulator platform**
Foreseen enrolment date	1 July 2024
Position is funded by	• COFUND, Marie Skłodowska-Curie Actions (MSCA), Horizon Europe, European Union • Centre National de la Recherche Scientifique (CNRS) • Royal Melbourne Institute of Technology (RMIT)
Research Host	Centre of Nanoscience and Nanotechnology (C2N) - Centre National de la Recherche Scientifique (CNRS)
PhD awarding institutions	Université Paris Saclay & RMIT University
Locations	Primary: Palaiseau, France Secondary: Melbourne, Australia
Supervisors	Kamel Bencheikh (CNRS, C2N) and Arnan Mitchell (RMIT)
Group of discipline	Nonlinear optics, Quantum Optics, Integrated photonics

2. Research topics (only one of these projects will be funded)

Project 1: *Quantum optics at the single photon level in thin film lithium niobate waveguides*
The generation and the manipulation of quantum states of light is a fundamental issue for quantum information. Among these states, twin-photon states whose quantum entanglement and quantum superposition allowed exciting and breakthrough demonstrations in the field of quantum information. Over the last years, a new platform for the generation of twin-photon states has emerged. It is based on thin film lithium niobate on insulator (LNOI), a material widely used by the quantum and nonlinear community for its large nonlinear coefficients. On this platform, lithium niobate thickness is below 1 µm and the advances in nanotechnology fabrications allow reduced-size waveguides in which optical modes with cross sections less than 1 μm^2 can propagate. On this new platform, we can design sophisticated integrated circuits, compatible with telecom band, to generate nonclassical states of light and manipulate their quantum properties with high efficiencies due the high nonlinearities obtained thanks to the tight optical confinement. The nanofabrication of the waveguides on this LNOI platform is done at RMIT University.

This project has received funding from the European Union's Horizon Europe research and innovation programme under the Marie Skłodowska-Curie grant agreement № 101081465

The thesis project objective is to explore the generation and manipulation of quantum states on this new platform at the single photon level. The quantum states will be generated through spontaneous parametric generation, where a pump photon at 780 nm is converted into twin photons at 1560 nm, called “signal” and “idler”. The aim is to demonstrate the quantum entanglement of the generated twin photons and use this remarkable property for entanglement swapping, where two independent photons generated in separate waveguides become entangled after a Bell-like quantum measurement. The required architecture of the LNOI waveguides will be designed and fabricated during the project and an experimental setup dedicated to the quantum demonstrations will be set. For the demonstration, two independent periodically poled LNOI waveguides will be fabricated on a same chip to generated twin photons. The LNOI chip will as well include a tunable integrated beam-splitter to mix the two “signal” modes for the Bell-State projection and measurement. Extra building blocks will be added to root, select, and shape the different optical modes.

The project will be performed in collaboration between the primary institutions C2N and RMIT and associated collaboration with Adelaide, gathering their expertise in nonlinear and quantum optics, nanophotonic and LNOI nanotechnology.

Supervisors: Kamel Bencheikh (CNRS, C2N), Arnan Mitchell (RMIT), Alfredo De Rossi (Thales Research and Technology), Andreas Boes (University of Adelaide)

Research Fields: integrated photonics, nonlinear optics, quantum optics, lithium niobate on insulator LNOI

Project 2: *Multi-mode quantum entanglement on thin film lithium niobate platform*

Quantum entanglement is a remarkable resource for several quantum information protocols such as quantum key generation and distribution or quantum teleportation. So far, this resource has been implemented using twin-photons with mostly a limitation to two-mode entanglement.

Over the last years, a new platform for the generation of twin-photon states has emerged. It is based on thin film lithium niobate on insulator (LNOI), a material widely used by the quantum and nonlinear community for its large nonlinear coefficients. On this platform, lithium niobate thickness is below 1 µm and the advances in nanotechnology fabrication allows reduced-size waveguides in which optical modes with cross sections less than 1 μm^2 can propagate.

The thesis project aims to explore the multi-mode entanglement generation on LNOI platform, in an array of coupled periodically poled waveguides. When pumped at 780 nm, twin-photons at degeneracy (1560 nm) are generated in a single fundamental mode propagating in the waveguide. When the waveguides are close enough to each other, the fundamental mode can couple evanescently to the adjacent waveguides. Both nonlinear interaction and linear coupling create the multi-mode entanglement between the fundamental modes at the output of the waveguides array.

During the PhD, we will explore a simple case of two-coupled waveguides and then an array of 3 and 5 waveguides and potentially more complex multi-mode structures. We will investigate continuous variables (CV) multimode entanglement. In this regime, the quantum fluctuations of the quadratures of the fundamental modes are entangled, offering a new powerful resource for quantum information protocols. Moreover, the engineering of the optical excitation in each waveguide allows to reach various entanglement graphs, it means the entanglement relation between the different optical fundamental modes.

The project will be performed in collaboration between the primary institutions C2N and RMIT and associated collaboration with Adelaide, gathering their expertise in nonlinear and quantum optics, nanophotonic and LNOI nanotechnology.

Supervisors: Kamel Bencheikh (CNRS, C2N), Arnan Mitchell (RMIT), Alfredo De Rossi (Thales Research and Technology), Andreas Boes (University of Adelaide)

Research Fields: integrated photonics, nonlinear optics, quantum optics, LNOI

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Project 3: *Non-Gaussian quantum states generation on thin film lithium niobate platform*
Quantum information tasks based on Gaussian statistics can be efficiently simulated by classical computational resources. To highlight the quantum advantages of these tasks, the involvement of non-Gaussian states is crucial. In optics, the optical modes that are involved in quantum information processing have Gaussian statistics, meaning that the quantum fluctuations of their fields exhibit a Gaussian distribution. The PhD project will explore the non-Gaussian states generation on Lithium Niobate On Insulator (LNOI) platform, combining nonlinear interaction and single photon detection. Indeed, a simple architecture to generate a non-Gaussian state is to remove a single photon from a squeezed vacuum state. On LNOI platform this achievement requires a periodically poled LN waveguide to generated squeezed vacuum, followed by a 99:1 integrated beam-splitter. When a single photon is detected on the 1%-output channel, the quantum state on the other output is non-Gaussian. During the PhD studies, we will first study this simple case, before proposing a design on LNOI platform to generated entangled non Gaussian optical states. The design will be based on several PPLN waveguides followed by an array of linear waveguides. Additional devices will also be added on the LNOI chip to shape the single photon state for a high detection efficient and quantum projection. The project will be performed in collaboration between the primary institutions C2N and RMIT and associated collaboration with Adelaide, gathering their expertise in nonlinear and quantum optics, nanophotonic and LNOI nanotechnology.
Supervisors: Kamel Bencheikh (CNRS, C2N), Arnan Mitchell (RMIT), Alfredo De Rossi (Thales Research and Technology), Andreas Boes (University of Adelaide)
Research Fields: integrated photonics, nonlinear optics, quantum optics, LNOI

3. Employment Benefits and Conditions

CNRS offers a 36-months full-time work contract (with the option to extend up to a maximum of 42 months). There is a probation period of 2 months and the total working hours per week is 38h30.

The remuneration, in line with the European Commission rules for Marie Skłodowska-Curie grant holders, will consist of a gross annual salary of 27,000 EUR. Of this amount, the estimated net salary to be perceived by the Researcher is 1,850 EUR per month. However, the definite amount to be received by the Researcher is subject to national tax legislation.

Benefits include

- Becoming a Marie Skłodowska-Curie fellow and be invited to join the Marie Curie Alumni Association
- Access to all the necessary facilities and laboratories at C2N and RMIT University, including state of the art photonic chip characterisation and system demonstration labs
- Tuition fees exemption at both PhD awarding institutions
- Yearly travel allowance to cover flights and accommodation for participating in AUFRANDE events
- 10,000 EUR allowance to cover flights and living expenses for up to 12 months in Australia
- 45 days paid holiday leave

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- French Social security coverage
- Sick leave
- Parental leave
- Language classes
- Other courses in transferable skills are proposed by Université Paris Saclay

4. PhD enrolment

Successful candidates for this position will be enrolled by the following institutions and must comply with their specific entry requirements, in addition to AUFRANDE's conditions.

Applicants must hold a Master's degree (or equivalent) that includes a research component comprised of at least 25% of a full-time academic year (or part-time equivalent) with an overall high distinction or a master degree without a research component with at least a high distinction average.

Applicants will also need to meet English proficiency requirements: https://www.rmit.edu.au/study-with-us/international-students/apply-to-rmit-international-students/entry-requirements/english-requirements.

More information on Université Paris Saclay's entry requirements

The successful Applicant to AUFRANDE selection process will be required to submit his/her application on ADUM and be accepted by the doctoral school.

Important: the authorisation of the Defence Security Officer may be required before admission. In case of denial, the enrolment will not be carried out.

Visit the website: https://www.universite-paris-saclay.fr/en/research/doctorate-and-habilitation-supervise-research-hdr-french

More information on RMIT University's requirements

Visit the website: https://www.rmit.edu.au/research/research-degrees/how-to-apply

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