INTERNSHIP PROPOSAL

Laboratory name: **Matériaux et Phénomènes Quantiques (MPQ)**
CNRS identification code: UMR 7162
Internship director'surname: **Florent BABOUX**
e-mail: florent.baboux@u-paris.fr Phone number: 0157276201
Web page: https://mpq.u-paris.fr/annuaire/baboux-florent/
Internship location: Bâtiment Condorcet, 10 rue A. Domon et L. Duquet, 75013 Paris

Thesis possibility after internship: YES
Funding: YES If YES, which type of funding: Doctoral school, QuanTip

Quantum simulation with photons in nonlinear waveguide arrays

Light plays a crucial role in exploring quantum phenomena, both to reveal fundamental properties of nature and to enable transformative technologies. Within the burgeoning field of photonic quantum information, two key challenges are driving current research efforts: (i) **increasing the dimensionality of quantum states** of light to unlock novel capabilities for quantum information, and (ii) developing **miniaturized photonic circuits** that integrate both the generation and manipulation of quantum states, paving the way for real-world applications. This internship/PhD project proposes to address both challenges, by utilizing **arrays of nonlinear waveguides** (Fig. 1) fabricated from a well mastered semiconductor platform (AlGaAs) [1]. A classical pump beam (shown in red) is sent into the array, where it generates photon pairs (shown in blue) thanks to the strong optical non-linearity of the material. These photon pairs then jump from one waveguide to the other during their propagation, implementing **random quantum walks**. This results in a high-dimensional entangled state cannot be produced by classical means.

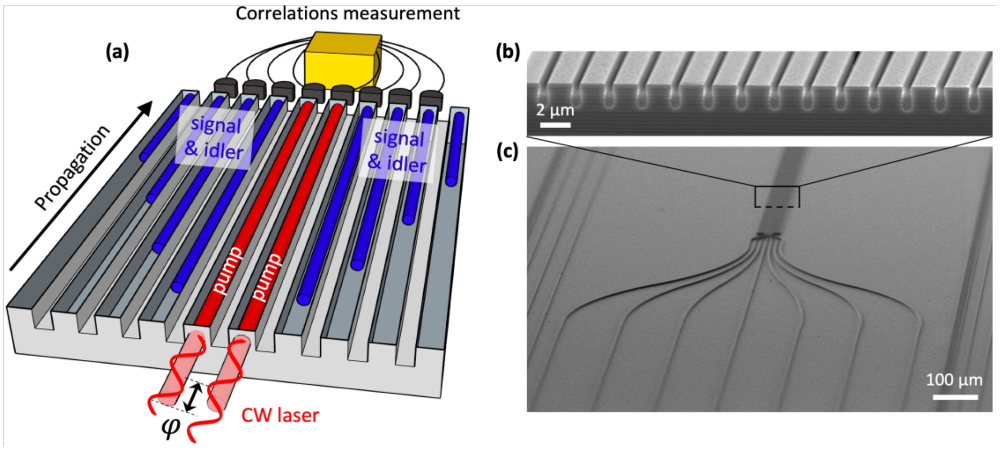

Figure 1: (a) Sketch and (b-c) SEM image of a nonlinear AlGaAs waveguide array.

We have recently shown how this concept can be exploited to realize a compact and reconfigurable source of spatially entangled states of light, operating at room temperature and telecom wavelength [2]. In the continuity, the goal of the internship/PhD project will be to harness this platform for **quantum simulation** and **quantum state engineering** tasks. For this we will tune the coupling between waveguides to implement various lattice geometries, allowing to implement the quantum Fourier transforms of entangled states, Anderson localization in a quasi-periodic potential, or the topological protection of quantum states of light in the Su-Schrieffer-Heeger model. This opens up the stimulating perspective to simulate with photons physical problems that are otherwise difficult to access in condensed matter systems.

[1] F. Baboux, G. Moody, S. Ducci, Optica **10**, 917 (2023) ; S. Francesconi et al., Optica **7**, 316 (2020) ; O. Meskine et al., Phys. Rev. Lett. **132**, 193603 (2024)
[2] A. Raymond et al., Phys. Rev. Lett. (2024), to appear, arXiv:2405.08176 (2024).

Methods and techniques: Clean room fabrication, quantum optics experiments, numerical simulations