PhD offer – University Paris-Saclay

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Non-classical free-electron light sources

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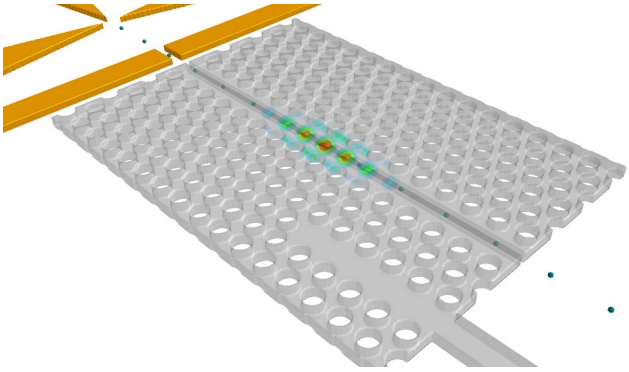
The perspective of applications in quantum computing, quantum cryptography, and metrology has triggered the development of numerous non classical light sources able to generate "on demand" single photons, squeezed states of light (i.e. with a non trivial statistics) or entangled states of light composed of two photons or more. Today there is fierce competition to demonstrate highly efficient, miniaturized and integrated on-chip non-classical light sources. Recently, it has been proposed to use a free electron beam evolving near a photonic structure to generate single photon sources [1] and more generally to efficiently shape quantum photonic states [2].



Principle diagram of what could be an on-chip non classical light source. Electrons from the electron gun (yellow, composed of cathode, grid and anode) move across a slotted photonic crystal (PhC – in grey on the picture, 10-µm long here). While traveling through the PhC, they excite the optical mode in the center of the PhC. The light can be extracted thanks to the guide coupled to the cavity (bottom).

In this context, during this PhD thesis, we propose to study the interaction of a free electron beam with a very high quality factor ($Q=10^6$) micro-cavity or waveguide in order to study their quantum properties (creation and manipulation of Fock states for instance) or fabricate sources of non classical light. The structures for enabling on-chip light generation typically include a periodic structure, making it possible to achieve the required phase matching between light and electron speeds to enhance light emission. Among them, photonic crystals (PhC), whose dielectric constant is periodic in two (2D) directions of space, are particularly attractive since they are known to be particularly effective for highly confining light in small volume with high quality factor, of the order of a few millions [3,4]. Moreover, interaction with nano-plasmonic structures will also be investigated in collaboration with L2n (Troyes). Characterization with 100 keV electron beams will take place with the LPS (Orsay) and CEMES (Toulouse), our two other partners within the QUENOT project, funded by in the french National Research Agency (ANR).

The PhD student will participate in developing the models, in designing, simulating and characterizing the photonic structures. The PhD student will also be in charge of the fabrication processes and their optimization in the C2N clean room. Finally, characterization with 100 keV electron beam will take place in collaboration with LPS (Orsay).

To apply, a good knowledge of electromagnetism and, at least, a basic knowledge on the quantum description of light-matter interaction is necessary as well as some experience with electromagnetic simulation (FDTD for instance). A basic knowledge of the characterization of optoelectronics components and of clean room processing is a plus. These aptitudes, as well as the interest and motivation for the subject, must be attested by the CV and developed in a convincing cover letter.

[1] X. Bendana, et al., "Single-Photon Generation by Electron Beams" Nano Lett. 2011, 11, 12, 5099–5103
[2] A. Ben Hayun, et al.,"Shaping quantum photonic states using free electrons" Science Advances, 7(11) eabe427 (2021)
[3] Z. Han, et al., Optics Comm. 283, 4387–4391 (2010).
[4] T. Asano, et al., Opt. Express 25, 1769 (2017).