Master thesis Project

Highly tunable single-photon sources emitting in the telecom bands

Context:

Efficient sources of non-classical light are key devices for photonic quantum technologies. Ideally, such sources should emit in telecom bands, be compatible with on-chip integration notably with the well-established silicon technologies. Monolithically integrated telecom-band single photon sources (SPSs) have been realized using III-V semiconductor quantum dots (QDs) and optically active defects in SiC or Si. Semiconductor quantum dot-nanowires (QD-NWs) constitute an appealing platform, with exceptional attributes: over 99% single photon purity, 0.72 collection efficiency, and a 1.2 ns coherence time. They are also capable of generating high-brightness entangled photon pairs and emit in the O and C telecom bands. Finally, QD-NWs offer tunable geometries for controlled photonic properties. However, a major challenge arises due to the inherent variations in emission wavelength among the QDs, hindering large-scale integration for quantum devices using photons as qubits.

We aim to address this very challenge by creating highly-tunable SPSs in the telecom band on silicon substrates. We propose to embed a III-V semiconductor QD-NW within a phase change material (PCM) shell. The concept relies on using PCM crystallization-induced volume changes to strain the QD-NW and adjust its emission energy in situ with a focused laser beam. This project focusses on the development of single photon sources using InGaAs/GaAs quantum dot nanowires grown by molecular beam epitaxy (MBE).

This research will explore two fabrication routes: the bottom-up approach (vapor-liquid-solid (VLS) growth) and the top-down approach (etching to define nanowires embedding a single or few QDs). On the one hand, the bottom-up fabrication route – more exploratory – features promising assets. On the other hand, the top-down approach has already demonstrated excellent results in terms of performance. To control the QD optical properties, we will apply a strain on the QD by controlling the phase change of a capping HfO_2 shell.

Objectives and means available:

The primary objectives of this M2/PhD proposal are as follows:

- To develop single photon sources using GaAs/InAs QD nanowires, employing both bottom-up (VLS) and top-down (SK and etching) approaches.
- To investigate the optical properties and performance of the fabricated single photon sources, focusing on the brightness and linewidth of the emitted single photons.
- To evaluate the influence of strain on the optical emission characteristics of the QD nanowires by capping them with a layer of HfO_2 and studying the resulting optical response.

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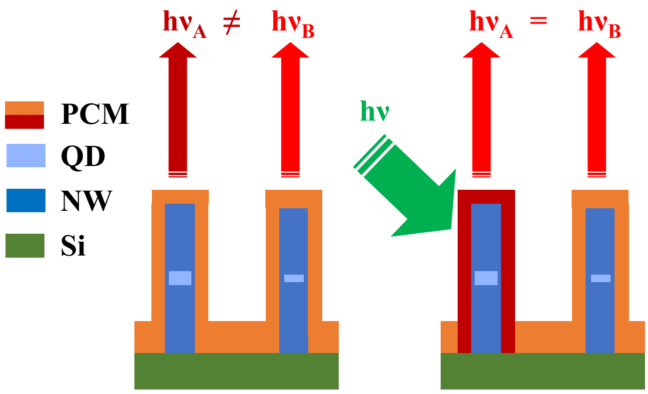

Figure 1: *Concept of the project: QD-NWs are grown on Si and capped with an amorphous PCM used as a shell. They emit single photon sources at two different wavelengths. The PCM crystallization state of one nanowire is controlled by heating with a laser light. Strain appears between the core and the shell of the nanowire due to the change in volume of the PCM. Consequently, the emission wavelength of the QD shifts. The amount of strain is tuned carefully to reach the desired wavelength.*

The available resources include a III-V molecular beam epitaxy (MBE) system for growing nanostructures, atomic layer deposition (ALD) equipment for depositing HfO2 shells, scanning electron microscopy (SEM), and access to cleanroom facilities. Optical characterizations will be conducted using micro-photoluminescence spectroscopy setups cooled to cryogenic temperatures. Additionally, the student will receive support from colleagues involved in the development of top-down structures in the cleanroom, which will help expedite the achievement of the project's goals.

The internship/PhD will take place within the ANR SONATE (granted in 2023). The different partners (material scientists, theoreticians and experimentalists) exchange regularly during meetings and research visits.

Possible collaboration and networking:
ANR SONATE partners: INL-Lyon, ILM-Lyon, IRIG-PHELIQS
Research Networks: GdR Matepi

Required profile:
We are looking for a student interested in experimental research. Knowledge in materials science and physics are mandatory. We are looking for a person curious with organizational skills and with ability to perform delicate experiments.

Possible extension as a PhD: yes, through the Quantalps PhD program (Spring 2024)

APPLY NOW!

To apply for this position, send your application (including CV) by e-mail to: moira.hocevar@cea.fr and julien.claudon@cea.fr