Departement/Team: Photonique/ODIN
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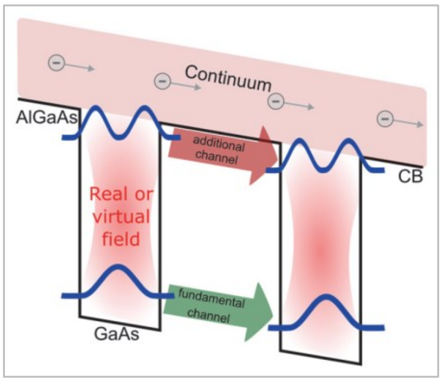
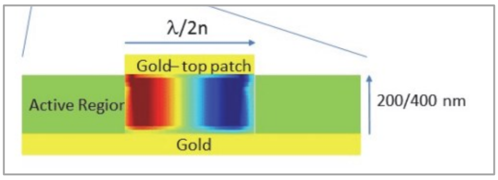
Optoelectronic devices enabled by vacuum field photons

Optoelectronic devices are an integral part of our daily life and are expected to play an increasingly important role in the future. As the basic operating principles of optoelectronic devices are known, their improvement – while important – is often incremental. Finding new avenues to implement novel functionalities is a key challenge: cavity quantum electrodynamics (QED) promises new approaches to innovate such devices by exploiting the quantum mechanical principles of strong (SC) and ultra-strong (USC) light-matter coupling regimes [1] in microcavities.



When the light-matter interaction becomes comparable to the unperturbed electronic transition energy, one reaches the so called ultra-strong (USC) coupling regime. **The sole presence of the cavity can induce modifications of ground and excited states,** and therefore of the device electronic behavior. Such effects have been observed in several systems like organic conductors [2] or 2D electron gas [3], laying the grounds for the field of polaritonic chemistry [4].

The project's goal is **is to elucidate the direct influence of the electro-magnetic vacuum on the electronic energy levels and the electronic transport properties in semiconductor optoelectronic quantum devices.** The research will focus on optoelectronic devices relying on so-called *intersubband* transitions between quantum-confined electronic states in semiconductor quantum wells (QWs). Such transitions are the building blocks of mid-infrared/THz quantum devices (quantum cascade lasers, infrared QW detector).



These devices perfectly suit the exploration of new phenomena where cavity electrodynamics and electronic transport both play a fundamental role. For instance the structure reported in the figure on the side is an ideal practical realization of a photoconductor device that can exhibit vacuum-field assisted transport. When real photons are absorbed, a photocurrent is generated as electrons are promoted in the continuum: it behaves as a detector. When operating as a detector in **strong coupling,** selective excitation of the polaritonic states permits access to their resonant *extraction* into an electric current, as recently demonstrated by the host team [5] [6]**. In USC in the dark, this additional channel (orange arrow) is activated by virtual photons.**

The internship we propose is experimental, and aims at measuring the effect of a cavity on the electronic transport in this system. The active region will be embedded in metal-metal ribbon cavities that confine the electromagnetic field inside the semiconductor active region (see figure below), and current-voltage measurements will be performed as a function of the temperature in a closed-cycle cryostat (from 4K to 200K) AND as a function of the cavity energy. This latter parameter is crucial as it affects the details of the light-matter interaction. An important part of the internship will be devoted to setting up the measurement system (the equipment is already in place), **mostly in terms of automation with a PC *via* programming in python.** This will permit to focus on the science, and optimize the system in order to maximize the light-matter interaction and the expected effect on the transport.

Methods and techniques: Quantum design of semiconductor heterostructure, python instrument control, optoelectronic characterization (mid-IR Fourier transform spectroscopy, current-voltage measurement)

Possibility to go on a PhD: yes
Funding: research grant or doctoral school grant