NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2024-2025

THz Quantum Nanoelectronics

General Scope: The continuous drive for miniaturization and increased speed in microelectronic devices challenges conventional semiconductor technologies. This trend inevitably pushes both industry and the scientific community into a realm where quantum effects are crucial at the nanoscale. As length scales decrease, the field is moving towards frequencies in the tens of GHz range, where new device functionalities and novel modes of information processing are anticipated. Similar to high-energy physics, where each increase in energy reveals new types of collisions and potentially new particles, quantum nanoelectronics is now at a threshold where increasing the frequency will unlock a wealth of new phenomena. A completely unexplored field is quantum nanoelectronics at ultra-high frequencies (exceeding hundreds of gigahertz), where the wavepacket size is much shorter than the quantum device as shown in Fig. 1b. Reaching this new regime requires the generation of ultrashort electron wavepackets and sufficiently large interferometers to induce interference between the front and back of these wavepackets as depicted in Fig. 1. At these high frequencies, we can access the internal characteristic time scales that govern the quantum dynamics of quantum devices, opening up new opportunities to study the dynamic aspects of quantum mechanics.

Research topic: The aim of the proposed M2 internship is to participate in the development of a novel THz opto-electronic setup to generate voltage pulses down to 1ps. In order to generate such ultra-short electron wave packets, we will leverage on the progress made on THz photon production and use photon to electron conversion devices to engineer THz electronic charge pulses. With this we will pioneer a new area of research in quantum nanoelectronics and demonstrate novel quantum interference effects that unveil the internal dynamics of quantum systems.

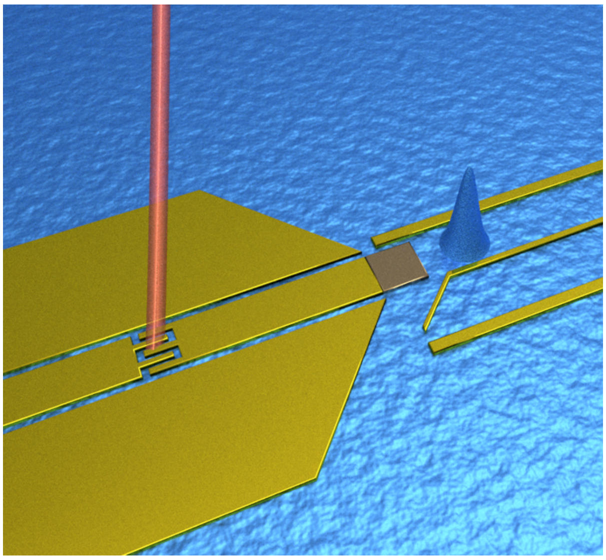

Fig. 1. A femtosecond laser pulse (in red) irradiates a photo-conductive switch deposited on a two-dimensional electron gas (in blue). An ultrashort electron wavepacket is launched into the quantum conductor through an electronic wave guide.

References:

Bäuerle et al., Rep. Prog. Phys. **81**, 056503 (2018) ; arxiv.org/abs/1801.07497, Edlbauer et al., EPJ Quantum Technology **9**: 21(2022); in COLLECTION ON "QUANTUM INDUSTRY" ; Giorgos Georgiou et al., ACS Photonics **7**, 6, 1444–1451 (2020).

Possible extension as a PhD: yes

Required skills:
The candidate should have a good background in quantum mechanics, quantum optics and/or solid-state physics. Programming skills in Python would be a plus. We are looking for a highly motivated student to participate in this ambitious research project.

Starting date: spring 2024

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