NÉEL INSTITUTE Grenoble

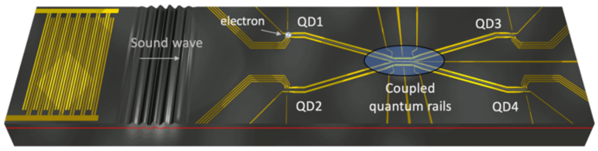
Topic for Master 2 internship – Academic year 2020-2021

Electronic flying qubits

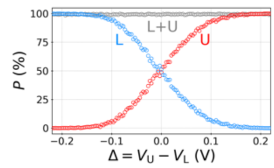
General Scope: Control and coherent manipulation of single electrons is one of the important ingredients towards single electron circuitry as well as the realization of flying qubit architectures using single electrons.

With this M2 internship project we would like to explore a novel platform for quantum electron optics with the goal of bringing it to the level of its photonic counterpart. The advantage of performing quantum optics experiments with flying electrons is the existing Coulomb coupling between the electrons. Photons are basically non-interacting quantum particles and they therefore have a longer coherence time than electrons. However, due to the absence of interactions it is more difficult to construct a two-qubit gate, which operates at the single-photon level.

We will leverage on the recent progress on single-electron transport using surface acoustic waves (SAW) and we propose to develop coherent control of single flying electrons in waveguide nanostructures. This will on the one hand open the possibility to perform quantum optics experiments at *the single-electron level* and on the other hand lay the grounds to exploit this novel system in quantum technologies.



Schematic (top) of a quantum device allowing to realizeof a tunable beam splitter for sound-driven single electrons. Gate electrodes (in yellow) at the surface of a semiconductor define the quantum circuit. The electron initially trapped in the upper source quantum (QD1) dot is partitioned at will in the coupled quantum rails. Right: Transfer probability P of an electron ending up in the upper/lower receiver quantum dot (QD3/QD4) (*see S. Takada et al., Nature Communication 2019*)



Research topic: The aim of the proposed M2 internship is to participate in an ongoing research project to realize flying qubit architectures by propelling single electrons with sound. The fact that electrons transported by sound waves travel 5 orders of magnitude slower than the speed of light allows to implement real-time manipulation of the quantum state of the electrons “in-flight”. This novel real-time control will be developed during the Masters project within the QUANTECA team of the Néel Institute.

References:

- Hermelin et al., Nature **477**, 435 (2011); Bertrand et al, Nature Nanotechnology **11**, 672 (2016), Takada et al., Nature Communications **10**, 4557 (2019)

Possible collaboration and networking: This project is realized in close collaboration with the Quantum Metrology laboratory (NMJI-AIST), Tsukuba, Japan and the theory group of CEA Grenoble (X. Waintal)

Possible extension as a PhD: yes

Required skills: The candidate should have a good background in quantum mechanics and solid-state physics. We are looking for a motivated candidate who is interested in continuing this research project towards a PhD degree.

Starting date: open (preferentially beginning 2021)

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