NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

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.

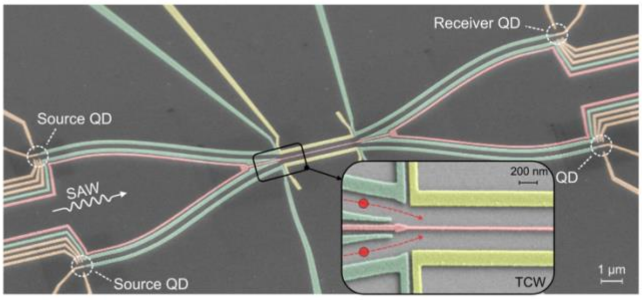

Fig. 1: SEM image of a two-electron collider. A pair of single electrons (red dots) is transferred via a SAW train between distant quantum dots (QD) along two quantum rails (green and yellow surface gates). Along a length of 40 µm, the two rails form a tunnel-coupled wire (TCW) where they are only separated by a narrow potential barrier (see inset).

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”. The student will participate in an ongoing experiment on two-electron collision (see Fig. 1) and will realize quantum transport simulations with the actual quantum device structure.

References:

- Takada et al., Nature Communications 10, 4557 (2019) ; Wang et al, (2022) to appear in PRX ; Edlbauer et al., EPI Quantum Technology 9: 21 (2022); in COLLECTION ON “QUANTUM INDUSTRY”, REVIEW ARTICLE; https://doi.org/10.1140/epjqt/s40507-022-00139-w

Possible collaboration and networking: This project is part of the French National Strategy on Quantum Technologies. It 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: we are looking for a candidate who is motivated to pursue the M2 internship towards a PhD; (PhD fellowship can be obtained)

Required skills: The candidate should have a good background in quantum mechanics and solid-state physics. Skills in Python programming would be a plus.

Starting date: open (preferentially beginning 2023)

Contact:

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