NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2024-2025

Many body entanglement with flying electron wave packets

General Scope: Coherent manipulation of single electrons in solid-state devices is attractive for quantum information purposes because they have a high potential for scalability. Depending on the system used, the charge or the spin may code binary qubit information. A particular appealing idea is to use a single flying electron itself as the conveyor of quantum information. Such electronic flying qubits allow performing quantum operations on qubits while they are being coherently transferred. Information processing typically takes place in the nodes of the quantum network on locally controlled qubits, but quantum networking would require flying qubits to exchange information from one location to another. It is therefore of prime interest to develop ways of transferring information from one node to the other. The availability of flying qubits would enable the possibility to develop new non-local architectures for quantum computing with possibly cheaper hardware overhead than e.g. surface codes.

Research topic: The aim of the proposed M2 internship is to participate in the development of an original flying qubit architecture using ultra-short single-electron charge pulses. Such an electron flying qubit can be realized through an electronic Mach-Zehnder interferometer as shown in the figure to the right. By coupling 2 electronic Mach-Zehnder interferometers through Coulomb interaction we will demonstrate quantum entanglement between the two propagating single electron wave packets (see Fig. 1).

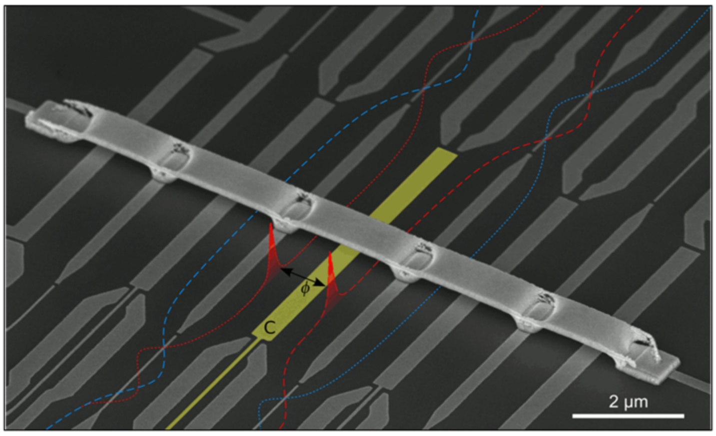

Fig. 1. SEM image of a multi-qubit flying electron architecture. The image shows four quantum interferometers that can be simultaneously operated owing to a common bridge that connects the islands of each device. The dashed lines schematically indicate the paths of two single-electron wave packets in two neighboring interferometers. The intermediate gate C (highlighted in yellow) allows for controlled Coulomb coupling of the single-electron wave packet and thus in-flight entanglement.

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”, REVIEW ARTICLE; https://doi.org/10.1140/epjqt/s40507-022-00139-w

Possible extension as a PhD: yes

Required skills:
The candidate should have a good background in quantum mechanics 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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