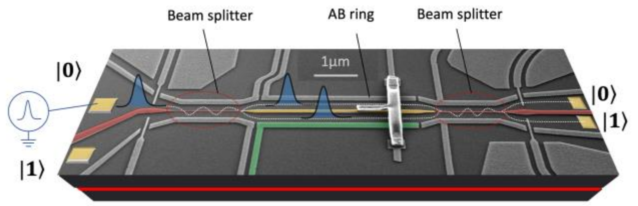
NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

Aharanov-Bohm oscillations with flying qubits

General Scope: The ability to build scalable quantum information devices based on single flying electron qubits require the coherent manipulation of single electrons over large distances. A promising architecture to study long-distance qubit manipulation is an electronic Mach-Zehnder interferometer. Similar to its optical analogue, the electron wave packet can take different paths through engineered electronic waveguides. A tunable tunnel barrier serves as a beam splitter and applying an external magnetic field allows to measure quantum oscillations of the current at the exit of the device. These so-called Aharonov–Bohm (AB) oscillations are a direct measurement of the coherence and allow probing flying qubit manipulation, a key requirement for quantum computing.

Research topic: The aim of the proposed M2 internship is to obtain a better understanding of ongoing flying qubit experiments in electronic Mach-Zehnder interferometers using numerical simulations. Realistic simulations of the device, as shown by the figure on the right, have been performed with the *Kwant* and *Nextnano* softwares and point out the role of reflections for the visibility of the AB oscillations. The goal of the internship is to perform numerical simulations in order to determine the best possible device design with increased coherence properties. In addition, new experiments using ultrashort single-electron wave packets show an increased visibility of AB oscillations. A route to understand these new findings is to use time-dependent simulations using the *Tkwant* code.



Scanning Electron Micrograph of an electronic Mach-Zehnder interferometer. Single electrons are injected into the upper quantum rail (state I0>) using ultrashort voltage pulses. The MZ interferometer is composed of two tunnel-coupled wires acting as beam splitters and connected to an Aharonov-Bohm (AB) ring.

References:

- Yamamoto *et al., Nature Nanotechnology* 7, 247 (2012); arXiv:1709.08873, Bautze *et al., Phys. Rev. B* 89, 125432 (2014); arXiv:1312.5194, Bauerle *et al., Rep. Prog. Phys.* 81 056503 (2018); arXiv:1801.07497, Groth *et al., New J. Phys.* 16, 063065 (2014), arXiv:1309.2926, Birner *et al., IEEE Transac.*, 54 2137 (2007), Kloss *et al., New J. Phys. 23, 023025 (2021); arXiv:2009.03132*.

Possible collaboration and networking: This project is part of the priority projects of the French National Strategy on Quantum Technologies. It is realized in close collaboration with 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. Programming skills in Python are recommended.

Starting date: open (preferentially beginning 2023)

Contact:

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