NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2020-2021

Quantum metrology using superconducting quantum circuits

General Scope: One of the present leading technologies for the realization of a universal quantum computer is based on *superconducting quantum circuits* (SQCs). It exploits superconducting circuits based on Josephson junctions, which are characterized by quantized energy levels and for this reason can be adopted as quantum bits (qubits), the basic units of quantum information.
The idea of this project is to take advantage of this technology to finally observe an effect that has been elusive to physicists for 40 years: voltage Bloch oscillations. This could allow to close the electrical metrology triangle (see figure) and is an important milestone towards quantum-defined metrology. It would bridge the two existing electric quantum standards, the Josephson Voltage Standard (JVS) and the Quantum Hall Resistance (QHR) standard. In the 80's it was predicted that the dual of the ac Josephson effect, voltage Bloch oscillations (vBO), could occur in Josephson junctions embedded in a high-impedance environment [1]. It would link frequency and current via the electrical charge 2e and thus close (i.e. check the consistency of) the metrological triangle formed by the JVS, the QHR and the vBO (see figure).
Recent development of a novel high impedance metamaterial in our team suggests that the observation of vBO is now within reach [2].

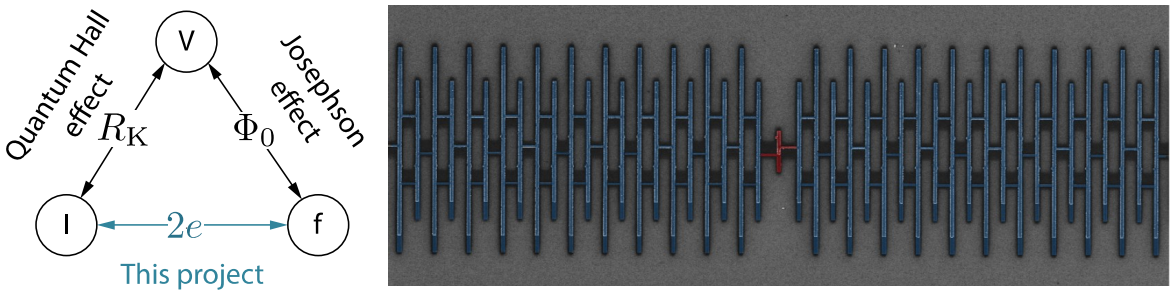

Figure 1: (Left) The electrical metrology triangle links the second, the Volt and the Ampere through only quantum constants. Implementing the missing bottom arm would check the consistency of the existing Volt and resistance standards via purely quantum effects. (Right) Example of the superconducting quantum circuit we will use to observe vBO. A Josephson junction (in red) couples to a superconducting metamaterial (in blue). This metamaterial offers a very high impedance which is required to provide a proper current bias to the Josephson junction.

[1] Likharev, Zorin, Theory of the Bloch-wave oscillations... J Low Temp Phys 59: 347 (1985)
[2] S. Leger, et al., Observation of quantum many-body effects due… Nature Communications 10, 5259 (2019)

Research topic and facilities available: Our team has a strong experience in nanofabrication, microwave electronics and cryogenic equipment. First, the student will be in charge of the theoretical modeling of the circuit aimed at observing vBO. She/He will then carry out the measurements of the device at very low temperature (20mK), using one of the four fully equipped dilution refrigerators of the team. The devices are fabricated in the clean room of the Neel Institute (Nanofab).

Possible collaboration and networking: This internship proposal is part of the ANR project 'TRIANGLE', regrouping four teams based in Grenoble and Paris.

Possible extension as a PhD: yes (funded position)

Required skills: Master 2 or Engineering degree. We are seeking motivated students who want to take part to a state of the art experiment and put some efforts in the theoretical understanding of quantum metrology using Josephson quantum circuits.

Starting date: Flexible

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