Superconducting quantum circuits in Grenoble

Contact persons: Olivier.Buisson@neel.cnrs.fr, Francois.Lefloch@cea.fr

Superconducting circuits made from Josephson junctions are one of the most advanced quantum devices for quantum information (Fig. 1).

Efforts to increase the number of qubit operations within a coherence time include quantum error correction protocols or non-destructive quantum measurements. More and more complex design architectures are developed together with new measurement schemes at the quantum limit, in which all the elementary blocks are perfectly controlled.

Superconductivity is also exploited to enable new quantum devices like topologically protected qubits and Josephson field effect transistors. The coupling of a superconductor to several normal conductors and the use of semiconducting device or 2D materials including graphene are two examples of the natural flexibility of superconducting hybrid devices (Fig. 2 and Fig. 3).

Based on a long tradition on low temperature engineering and micro-fabrication, Grenoble is a stronghold for mesoscopic superconductivity and hybrid devices. Some recent activities concern superconducting qubit, kinetic inductance detector arrays, SQUIDs, electronic coolers, Josephson junction chains, quantum-dot single electron turnstiles. Finally, a variety of disordered superconductors like indium oxide or titanium nitride are studied for the implementation of high-inductance dissipationless elements for quantum circuits. Recent, pioneering experimental and theoretical results allow us to address key scientific challenges.

Superconducting quantum circuits in Grenoble addresses the following challenges:

- **Quantum optics:** Single photon emitters and detectors in the Terahertz domain are developed using NbN technology. We investigate a novel ultrafast quantum non-demolition read-out of a qubit as well as single photon transistor using inductively coupled transmons.
- **Superconductor-semiconductor devices**: Semiconducting nanowires or two-dimensional materials can be driven into a topological superconducting phase once connected to superconducting electrodes. We are looking for reliable signatures for the predicted peculiar excitations, including Majorana fermions.
- **Analog quantum simulation:** Combining superconducting artificial atoms with microwave resonators, circuit-QED is a powerful platform to study light-matter interactions. We develop quantum bath engineering to simulate complex many-body problems (Fig. 4).
- **Quantum-limited detection for metrology:** We investigate superconducting quantum phase-slip devices and quantum-limited amplifiers as promising circuits for quantum metrology.

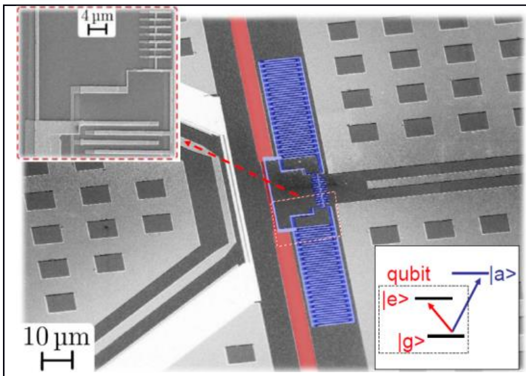

Fig. 1: **Two inductively coupled transmon qubits** leading to a V-shaped energy diagram[1]. Such a system leads to new quantum functionalities such as coherent conversion in time domain and ultrafast high-fidelity qubit read-out.

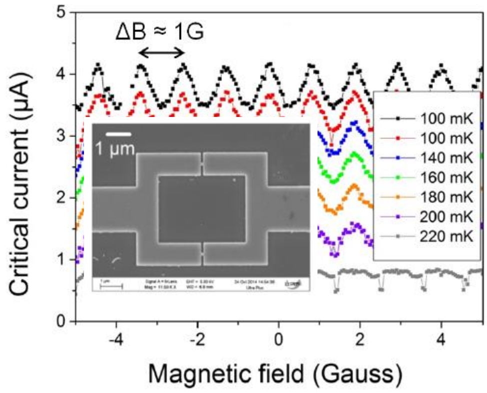

Fig. 2: **Silicon SQUID** showing flux modulation[2]. The superconducting silicon is obtained by using pulse laser annealing for heavily doping bare silicon with boron atoms.

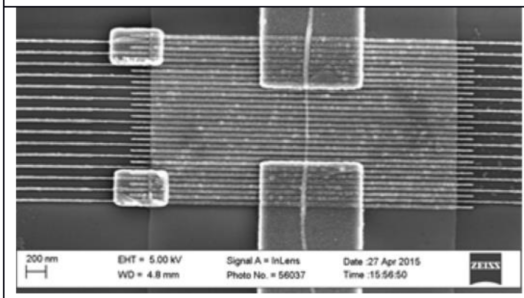

Fig. 3: **Connected SiGe nanowire** sitting on top a series of underneath metallic gates. The two large contact can be superconducting to reveal (quasi) ballistic Andreev levels.[3] A complementary approach is based on electromigrated nano-gaps grafted with a nano-particle.[4]

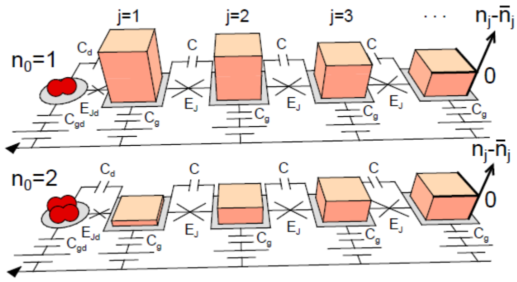

Fig. 4: **Engineering analog quantum simulators** of complex condensed-matter problems, here the widely-sought Kondo screening cloud[5], in a controlled and tunable experimental setting based on superconducting qubits.

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