

QUANTIC



Quantum computation is becoming a reality. Around the world, several research laboratories and large computer-based companies are developing the first prototypes of quantum computers using diverse physical systems. Among these, superconducting circuits have become one of the most promising due to their favorable scalability which permits building systems with tens of qubits while maintaining the advantageous individual properties.

Our group is divided in two well-separated, yet very interrelated teams: quantum algorithms (software) and quantum processors (hardware).

There are two main lines of research in quantum algorithmia. A first possibility is to use pure quantum logic based on gates that build circuits. The fact that the readout of a quantum machine is non-deterministic brings an element of difficulty to the construction of quantum algorithms and its application to real problems. A second possibility consists in dropping the quantum circuit philosophy in favor of a quantum annealing strategy. This second solution makes it feasible to tackle optimization problems, which are relevant for important, real-life industries such as pharmaceuticals, oil and gas, and chemistry, among many more.

On the hardware side, we build quantum processors out of superconducting quantum circuits. Superconducting qubits are built using Josephson junctions, which are nonlinear, nondissipative elements that give anharmonicity to spectrum of the circuit, a key element to being able to control its quantum state. The Josephson tunnel junction is a very thin superconductor-insulator-superconductor barrier that permits

tunneling of the superconducting wave function across it. In engineering language, it behaves as a nonlinear inductor.

Superconducting qubits are obtained out of two of the states of the Josephson circuit nonlinear spectrum. There exist different types of superconducting qubits depending on whether the Josephson energy stored in the junction dominates over the capacitive energy. The most widely used qubits are the persistent current flux qubit and the Cooper pair box transmon qubit. We employ either type of qubit depending on the applications we are exploring.

We have a long list of collaborators, both national and international. We have active collaboration with the Physics and Engineering of Nanodevices Group at the Catalan Institute of Nanoscience and Nanotechnology (ICN2) led by Prof. Sergio Valenzuela. We also collaborate with the laboratories of Prof. Will Oliver's group at MIT, Dr. Nicolas Roch group in Grenoble, Prof. Christopher Wilson at IQC Waterloo (Canada), and Prof. Martin Weides from the University of Glasgow. On the theory side, we actively collaborate with Prof. Barbara Kraus (Innsbruck), Prof. Juan Rojo (VU Amsterdam), Prof. Enrique Solano in UPV-EHU Bilbao, Dr. Juan José García-Ripoll from IFF-CSIC, and Prof. Germán Sierra (IFT-CSIC).

Objectives

- Develop strategies to exploit small and medium size quantum computers
- Adapt realistic problems to quantum annealing
- Develop a quantum operating system to run a small quantum device
- Build a small-sized quantum processor made of multiple superconducting quantum bits
- Implement quantum algorithms on our processor to run applications on optimization, quantum simulation and machine learning

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