Quantum Error Correction with Superconducting Circuits

Record number : OPR-1457

Overview

RESEARCH DIRECTION

Benjamin Brock, Professeur - Department of Physics

INFORMATION

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ADMINISTRATIVE UNIT(S)

Faculté des sciences
Département de physique

LEVEL(S)

1er cycle
2e cycle
3e cycle

LOCATION(S)

Département de physique et Institut quantique de l'Université de Sherbrooke

Project Description

Join the Brock Lab - we are recruiting interns, MSc students, and PhD students to develop and demonstrate novel experimental strategies for quantum error correction with superconducting circuits.

Context

Quantum computing promises transformative capabilities, from simulating complex materials and chemical reactions to solving optimization problems far beyond the reach of classical computers. The critical bottleneck on the path to realizing these capabilities is quantum error correction (QEC): without it, fragile quantum states decohere before useful computation can be completed. QEC requires a quantum computer to be large enough to host many redundant copies of the logical quantum states being used for computation, which is conventionally achieved by using many physical qubits to encode each logical qubit. While effective, this approach is extremely resource-intensive, requiring hundreds or even thousands of physical qubits per logical qubit. Reducing this resource cost is one of the central challenges in quantum computing today.

Our lab tackles this challenge by using multi-level quantum systems, such as oscillators (infinite levels) and qudits (d levels), as the fundamental building blocks of a quantum computer. The first advantage of these multi-level systems is that they provide greater redundancy than qubits, enabling QEC codes that require fewer individual physical systems per logical qubit. The second advantage is that working with qudits as the fundamental unit of quantum information enables more efficient gate synthesis, algorithm compilation, and quantum simulation. Combining these two advantages, our flagship result is the first experimental realization of error-corrected logical qudits, achieved using an oscillator for redundancy in a so-called "bosonic code" [Brock et al., Nature 641 (2025)].

We explore these ideas experimentally using superconducting circuits, one of the most promising platforms for quantum computation. Research in the group is centered around two themes, bosonic codes and qudit codes, each with several active projects.

Projects

Bosonic codes: Bosonic codes store quantum information redundantly within the large Hilbert space of a harmonic oscillator, protecting that information even when photons are lost. Active projects within this theme include: fault-tolerant QEC of bosonic codes with biased-noise qubits, improving state preparation fidelity of bosonic codewords, and fabricating scalable 2D resonators for bosonic QEC.

Qudit codes: Transmon superconducting circuits are naturally multi-level systems. We are investigating how to exploit these extra levels directly for QEC, both by embedding logical qubits within a single transmon qudit and by building multi-qudit codes. Active projects within this theme include: fabricating transmon qudits with more than 8 available states, characterizing transmon qudit errors, structuring transmon qudit errors with strong drives, and developing the building blocks of multi-qudit codes.

Training

Students in the Brock Lab gain hands-on training in device fabrication in a state-of-the-art cleanroom, cryogenic measurements in dilution refrigerators, and microwave control of quantum systems. You will also develop strong intuition for QEC codes and open quantum systems, all of which are skills in high demand across Canada's (and the world's) rapidly growing quantum industry.

Apply

We are actively recruiting talented and highly motivated students at all levels. To apply, send your CV, transcripts, and a short motivation email to
Benjamin.Brock@USherbrooke.ca

Discipline(s) by sector

Sciences naturelles et génie

Physique

Funding offered

Yes

The last update was on 20 October 2026. The University reserves the right to modify its projects without notice.