

INTERNSHIP PROPOSAL

Laboratory name: Laboratoire de Physique, Ecole Normale Supérieure de Lyon
CNRS identification code: UMR5672
Internship director's surname: **Benjamin Huard**
e-mail: benjamin.huard@ens-lyon.fr Phone number: +33426731424
Web page: www.physinfo.fr
Internship location: **ENS de Lyon**
Thesis possibility after internship: YES
Funding: YES Type of funding: **Cifre with Alice&Bob**

Cat qubits based on dc-biased Josephson junctions

Quantum computers need error correction, and it currently costs about a thousand physical qubits to build a single useful one. A cat qubit does part of that job in hardware. The information is stored in two coherent states $|\alpha\rangle$ and $|\alpha\rangle$ of a microwave resonator, and a dissipation that removes photons only in pairs keeps the state within that manifold. Bit flips are then suppressed exponentially with the cat size $|\alpha|^2$, with lifetimes already exceeding 10 s, while the remaining phase-flip errors grow only linearly [1–3].

How it is done

The pair dissipation comes from a Josephson junction converting two photons of the memory into one photon of a lossy mode, at a rate κ_2 . It is usually activated by a microwave pump, which also switches on parasitic Kerr terms that unfortunately introduce errors. We propose to use a dc voltage bias V instead. Cooper pairs then tunnel at the Josephson frequency $\omega_J = 2eV/\hbar$, and setting ω_J at the pump frequency selects the two-photon process while every unwanted term rotates at ω_J and averages to zero [4,5].

Where it stands

We have just demonstrated this mechanism in Lyon in collaboration with Alice & Bob [6]. A voltage-biased SQUID connects a memory resonator to a lossy buffer, and the bias voltage alone selects whether 1, 2 or even 4 memory photons are converted into a single buffer photon. Wigner tomography of the memory gives an engineered two-photon loss rate κ_2 ten times larger than its natural photon loss. What is still missing to get a qubit is the drive that pins the two coherent states, together with a cleaner bias line.

The project

You will measure the next generation of this circuit and turn the dissipation into a working qubit. The first goal is to stabilize a two-component cat, to image it by Wigner tomography and to measure how its bit-flip and phase-flip times scale with the cat size. The second goal is more ambitious, a four-component cat, in which a photon loss becomes a detectable event rather than a phase-flip error [7]. It calls for a much stronger four-photon dissipation, which grows as the eighth power of the zero-point phase fluctuations of the memory, hence for a high-impedance resonator that you will help design.

The team

You will join the Quantum Circuits Group at ENS de Lyon and work on microwave design, nanofabrication, cryogenic setups, pulsed measurements and quantum state tomography, together with the company Alice & Bob. This work is part of the RobustSuperQ project from PEPR Quantique and you will work with our postdoc Ambroise Peugeot and finishing PhD student Marco Paradina.

1. M. Mirrahimi et al., New J. Phys. 16, 045014 (2014) — 2. Z. Leghtas et al., Science 347, 853 (2015)
3. U. Réglade et al., Nature 629, 778 (2024) — 4. M. Hofheinz et al., Phys. Rev. Lett. 106, 217005 (2011)
5. T. Aissaoui et al., Phys. Rev. Applied 25, 044046 (2026) — 6. M. Paradina et al., arXiv:2608.31154 (2026)
7. N. Ofek et al., Nature 536, 441 (2016)

Condensed Matter Physics:	YES	Soft Matter and Biological Physics:	NO
Quantum Physics:	YES	Theoretical Physics:	NO