

Nonlinear Josephson Readout for Single Microwave Photon Detectors

Research internship leading to a CIFRE PhD with Qudigy

Detecting a single microwave photon requires converting its arrival into a reliable electrical signal. In the detectors developed by the Quantronics group at CEA Saclay, the photon leaves a record in an internal transmon qubit [4–6]. This internship will explore how Josephson nonlinearities can amplify that record and enable fast, faithful readout without a travelling-wave parametric amplifier.

The central idea is an asymmetric measurement: preserve the transmon's ground state to suppress false clicks, while using its excited state to trigger a strongly distinguishable nonlinear resonator response. A dedicated Josephson element, separate from the transmon junction, will provide control over the readout nonlinearity. Combining circuit modelling, phase-space analysis, quantum simulations and cryogenic measurements, the project will investigate how bifurcation and the onset of chaos affect signal discrimination and measurement backaction. The goal is to improve photon detection while preserving transmon coherence and allowing rapid detector reset.

The internship is intended to lead to a CIFRE PhD with Qudigy, a spin-off of the Quantronics group that plans to begin commercialising single microwave photon detectors in 2027.

Bifurcation readout circuit for SMPD

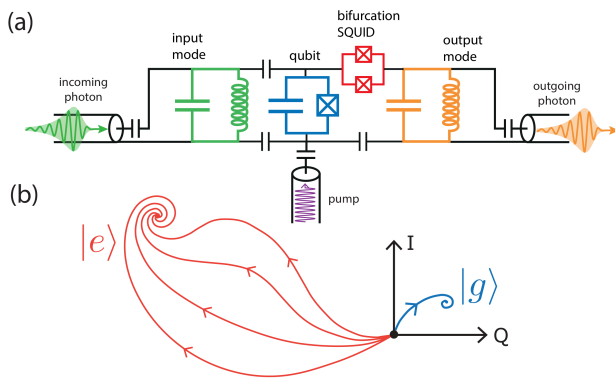


Figure 1. Proposed circuit and asymmetric readout dynamics.

(a) SMPD circuit concept: a microwave pump enables photon capture in the internal transmon, while a dedicated SQUID, distinct from the transmon junction, introduces readout nonlinearity. (b) Schematic phase-space responses of the driven output mode conditioned on the transmon state: a weak response for $|g\rangle$ (blue) and a larger nonlinear response for $|e\rangle$ (red). The aim is to preserve $|g\rangle$ while making a detected photon readily distinguishable. The spirals illustrate relaxation towards stable attractors; they are not simulated trajectories or evidence of chaos. Bifurcation readout [7] and the onset of chaos-induced measurement backaction [8] motivate the proposed investigation.

Internship project

Applications range from axion dark-matter searches [1] and single-spin magnetic resonance [2] to qubit readout, demonstrated with a different Josephson-photomultiplier architecture [3]. Beaulieu et al. demonstrated fast, high-fidelity bifurcation readout using a Josephson junction in parallel with the qubit–resonator coupling capacitor [7]. The project will adapt this approach to the SMPD while retaining HEMT amplification.

Preserving $|g\rangle$ during readout is a priority, since measurement-induced excitation can generate false clicks. For $|e\rangle$, state preservation may be relaxed once the detection record is reliably encoded in the resonator response, provided reset remains fast. The question is whether this asymmetry can improve discrimination without compromising detector sensitivity.

Phase-space portraits will guide the search for state-dependent attractors and their basins of attraction. Building on studies of chaos and measurement-induced transitions in driven transmons [8], the project will explore the boundary between useful bifurcation and chaotic dynamics that degrade readout.

The work will combine circuit modelling, classical phase-space analysis, quantum dynamics simulations and cryogenic measurements. The intern will optimise coupling and pulse parameters, then characterise readout fidelity and duration, state-resolved measurement backaction, transmon lifetime, detection efficiency and false-click rate across the detection–readout–reset cycle. Reset reliability and dead time will be included. Python will support simulations, experiment control and data analysis.

Candidate profile and PhD

The internship will take place in the Quantronics group at CEA Saclay. It is aimed at candidates with a background in quantum physics, microwave engineering or electronics who wish to gain hands-on experience with superconducting circuits and quantum measurement.

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References [1] Braggio et al., Phys. Rev. X 15, 021031 (2025); [2] Wang et al., Nature 619, 276–281 (2023); [3] Opremeak et al., Science 361, 1239–1242 (2018); [4] Lescanne et al., Phys. Rev. X 10, 021038 (2020); [5] Balembois et al., Phys. Rev. Applied 21, 014043 (2024); [6] May et al., arXiv:2502.14804 (2025); [7] Beaulieu et al., arXiv:2601.04975v1 (2026). [8] Cohen, Petrescu, Shillito and Blais, Reminiscence of Classical Chaos in Driven Transmons, PRX Quantum 4, 020312 (2023), doi:10.1103/PRXQuantum.4.020312.