Noise mitigation in Single Microwave Photon Detection by Repeated Quantum Measurements

Alexandre MAY [1,2]
L. Sutevski[2], J. Solard[1], G. Cardoso[1], L. Carde[1], L. Pallegoix[2], R. Lescanne[1], D. Vion[2], P. Bertet[1], E. Flurin[1]
1-Alice&Bob, 53 boulevard du Général Martial Valin, 75015 Paris
2-Université Paris-Saclay, CEA, CNRS, SPEC, 91191 Gif-sur-Yvette Cedex, France
alexandre.may@cea.fr

Detecting single photons in the optical frequency band is a well-established practice; however, this capability is just emergent at microwave frequencies. Single microwave photon detectors (SMPDs) are instrumental for efficiently detecting weak signals from incoherent emitters, with applications in axion searches [1], hybrid quantum systems [3], and superconducting quantum computing [4]. At microwave frequencies, SMPDs rely on superconducting qubits to encode the presence or absence of an itinerant photon [7,6,5]. Such quantum interaction provide a quantum non-demolition (QND) measurement of the photon state, in constrast with absorptive optical Single Photon detectors (SPDs). In this work, we leverage the QND nature of this interaction to repeatedly measure the photon state in a cascaded manner [2]. By encoding the information on multiple qubits, we mitigate the intrinsic local noise of individual qubits, achieving a two-order-of-magnitude reduction in intrinsic detector noise at the cost of a slight reduction in efficiency. The photon detector concatenates two four wave mixing process coherently on a single chip. This scheme ensures fully quantum coherent dynamic of photon detection, enabling dynamical tuning of the detector's bandwidth — a critical feature for practical use in setups affected by thermal photons.

We show how to balance the strengths of the parametric processes to maximize sensitivity and evaluate the core metrics of such a device. We demonstrate an intrinsic sensitivity of (8+-1)x10^{-24} W.Hz^{-1/2} at 8.798 GHz, with the detector noise entirely dominated by the thermal noise of the input resonator. The bandwidth tunability is 100 kHz. Current limitations are discussed and addressed in very recent work with a detector at 11.7 GHz.

References

[1] Braggio C. & al., arXiv:2403.02321 (2024)
[2] Distante E. & al. (PRL, 2021)
[3] Wang Z. & al. (Nature, 2023)
[4] H. J. Briegel & al. (Nature Physics, 2009)
[5] Besse J.-C. & al. (PRX, 2018)
[6] Kono S. & al. (Nature Physics, 2018)
[7] Lescanne R. & al. (PRX, 2020)

Figures

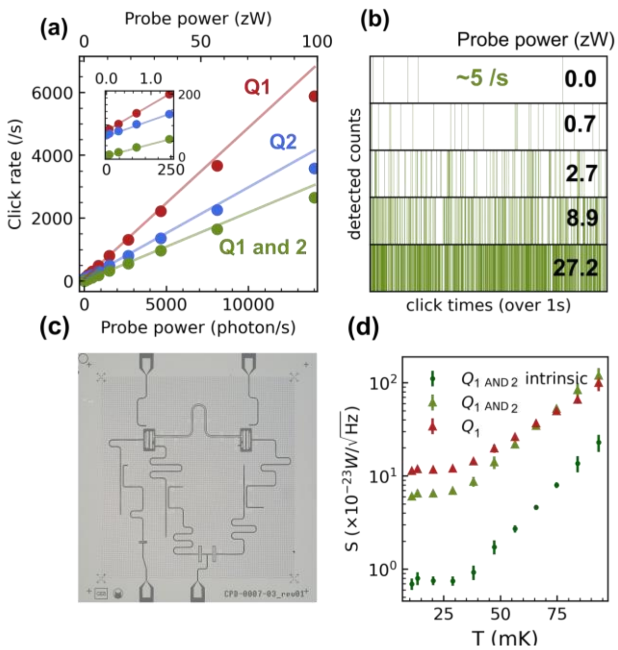

Figure 1: (a) Detector efficiency calibration. (b) Count trace vs input power to be detected. (c) Experimental device. (d) Sensitivity of the individual (first half of the cascaded detector) and cascaded detectors as a function of temperature.