Detection of zeptojoule microwave pulses using electrothermal feedback in proximity-induced Josephson junctions

J. Govenius[1], R. E. Lake[1], K. Y. Tan[1], and M. Möttönen[1]*
[1] Department of Applied Physics, Aalto University, Helsinki
**: presenting author, email: joonas.govenius@aalto.fi*

Introduction

(This abstract is adapted from Ref. 1.)

Superconducting qubits coupled to microwave transmission lines have developed into a versatile platform for solid-state quantum optics experiments,[2] as well as a promising candidate for quantum computing. However, compared to optical photodetectors, detectors for itinerant single-photon microwave pulses are still in their infancy. This prevents microwave implementations of optical protocols that require feedback conditioned on single-photon detection events. For example, linear optical quantum computing with single-photon pulses calls for such feedback.[3] Photodetection and feedback can also act as a quantum eraser of the phase information available in a coherent signal, as we recently discussed in Ref. 4.

Methods and Results

We experimentally investigate and utilize electrothermal feedback in a microwave nanobolometer based on a normal-metal nanowire with proximity-induced superconductivity. The feedback couples the temperature and the electrical degrees of freedom in the nanowire, which both absorbs the incoming microwave radiation, and transduces the temperature change into a radio-frequency electrical signal. We tune the feedback in situ and access both positive and negative feedback regimes with rich nonlinear dynamics. In particular, strong positive feedback leads to the emergence of two metastable electron temperature states in the millikelvin range. We use these states for efficient threshold detection of coherent 8.4 GHz microwave pulses containing approximately 200 photons on average, corresponding to 1.1 zJ (7.0 meV) of energy.

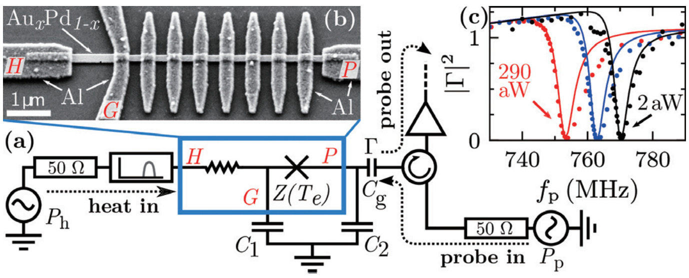

Fig. 1. (a) Simplified diagram of the detector, including (b) a micrograph. (c) Reflected fraction of probe power versus probe frequency for different steady-state heating powers.

Conclusion

The energy of the detected pulses is an order of magnitude lower than what has been demonstrated using other thermal detectors.[5] This is an encouraging step toward the thermal detection of individual itinerant microwave photons.

References

1. J. Govenius, *et al.*, *Phys. Rev. Lett.* **117** (2016) 030802.
2. M. H. Devoret and R. J. Schoelkopf, *Science* **339** (2013) 1169.
3. P. Kok, *et al.*, *Rev. Mod. Phys*. **79** (2007) 135.
4. J. Govenius, *et al.*, *Phys. Rev. A*. **92** (2015) 042305.
5. B. S. Karasik, *et al.*, *IEEE Trans. Terahertz Sci.* **1** (2011) 97; *Appl. Phys. Lett.* **101** (2012) 052601.

CV of Presenter

Joonas Govenius received his B.A. from Princeton University in 2010, his M.Sc. from ETH Zurich in 2012, and defended his doctoral thesis in 2016 at Aalto University, Finland. His doctoral thesis focused on photodetection in the context of microwave quantum optics experiments. Previously he worked on superconducting qubits, which are the typical photon sources in such experiments.