Dark Current Measurements of a Submillimeter Photon Detector

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Overview

- The “SQPC” – a high-sensitivity sub-mm detector
- Contributions to dark currents
- Aluminum Junction Characterization
- Implications on overall sensitivity
- Future Work

Motivation

- Sub-mm: ~ 100 **m**m -- 1 mm

- Sub-mm detectors today:

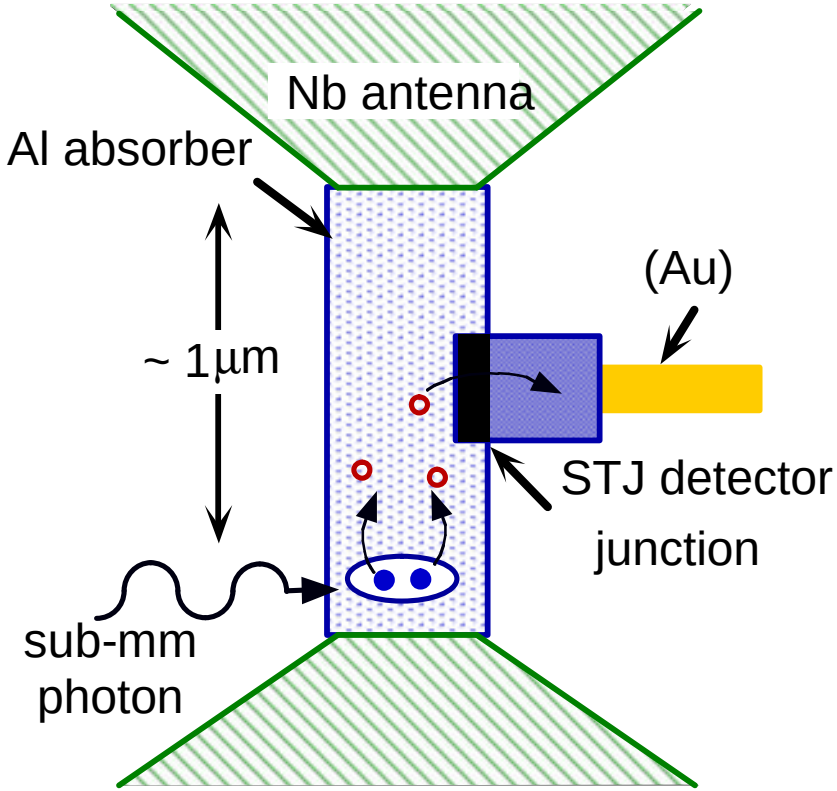
$$NEP \sim 10^{-17}\, W \Big/ \sqrt{Hz}$$

- Future NASA missions will require :

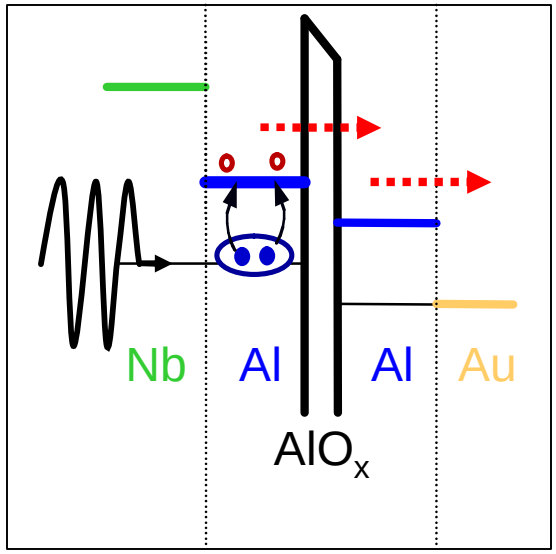
$$NEP \sim 10^{-20}\, W \Big/ \sqrt{Hz}$$

- Detectors should also be:
  - Fast
  - High quantum efficiency
  - Scalable for arrays

The SQPC: Single Quasiparticle Photon Counter

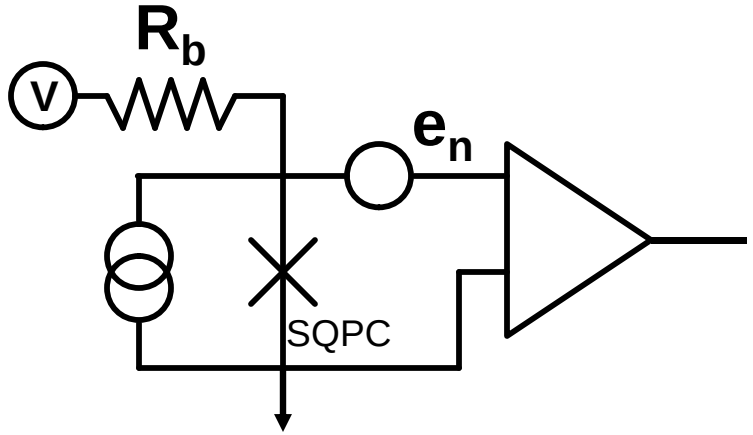


- Antenna-coupled Superconducting Tunnel Junction (STJ)
- Photoconductor direct detector
- Each Photon with $2\Delta_{Al} \le \hbar w \le 2\Delta_{Nb}$ excites 2 quasiparticles



Responsivity=2e/photon=e/**D**=5000A/W

Electrical Circuit Model and Noise



$$dI = \sqrt{2eI_{dark} + \frac{4kT}{R_b} + \frac{e_n^{\,2}}{Z_{\square}^{\,2}}} \approx \sqrt{2eI_{dark}}$$

Shot Noise **Johnson Noise** **Amplifier Noise**

$$Sensitivity \square dI \square \sqrt{2eI_{dark}}$$

Contributions to the Dark Current

Supercurrent

•Cooper pair tunneling affects the subgap current both at zero and finite voltages

•Due to rectification of the AC Jospephson Effect:

$$I_{dark}(B) = \frac{I_c^2(B)\,\mathrm{Re}\,Z(w_J)}{2V_{bias}}$$

Temperature

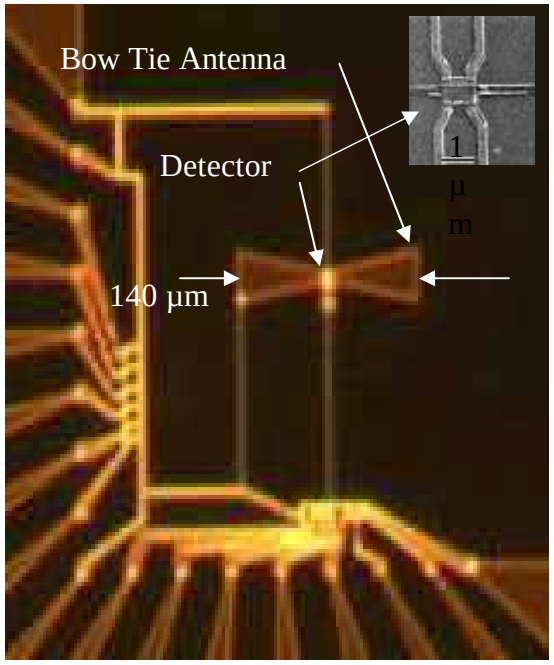
•Thermal energy breaks Cooper pairs and excites quasiparticles

•BCS Predicts:

$$I_{dark}(T) \propto e^{-\Delta/k_B T}$$

Experimental Set-up and Testing

•Small area junctions fabricated using double angle evaporation

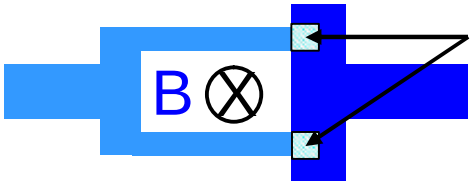


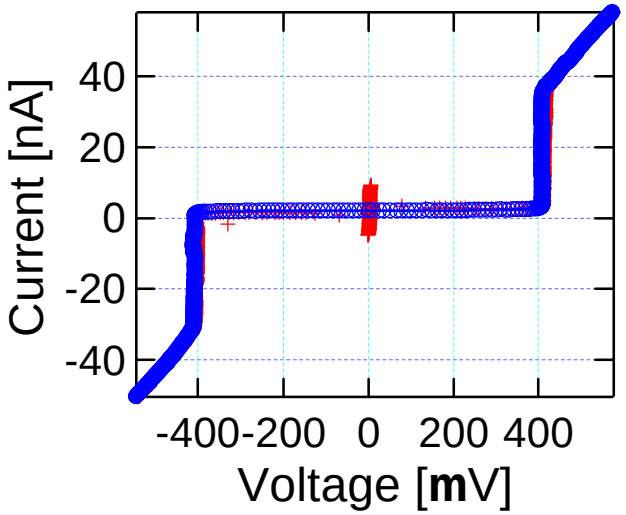
•Device mounted in pumped He3 cryostat (T~250mK)

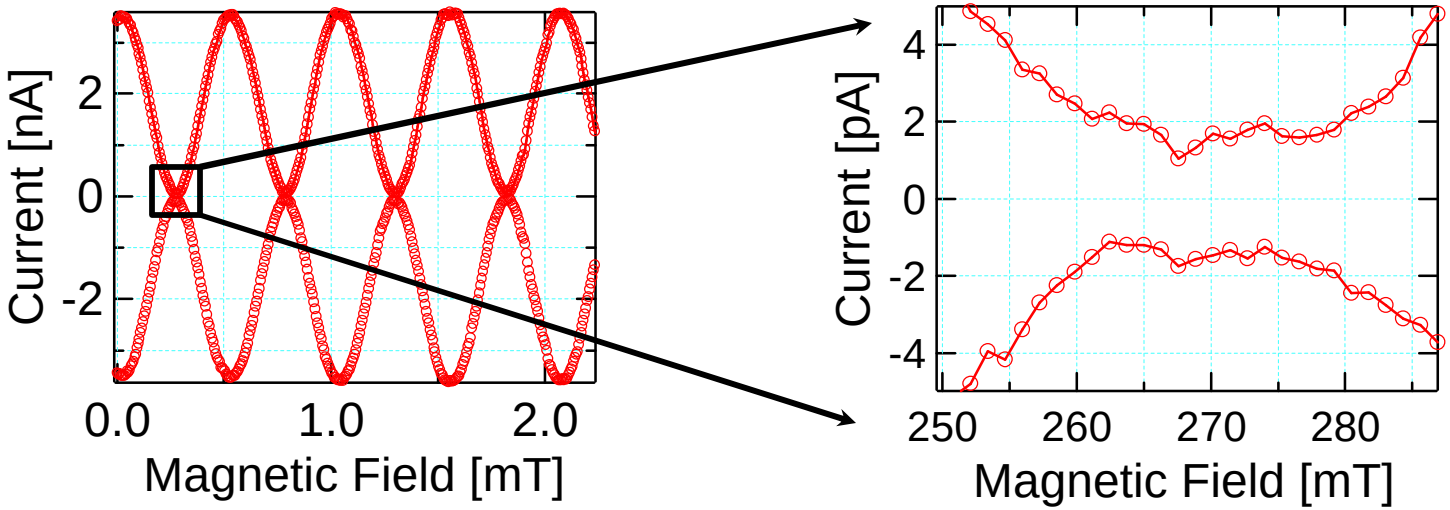
Supercurrent Suppression

SQUID w/ R_{tot} = 44 kΩ

Al/AlOx/Al Junctions: ~ 60 x 100 nm

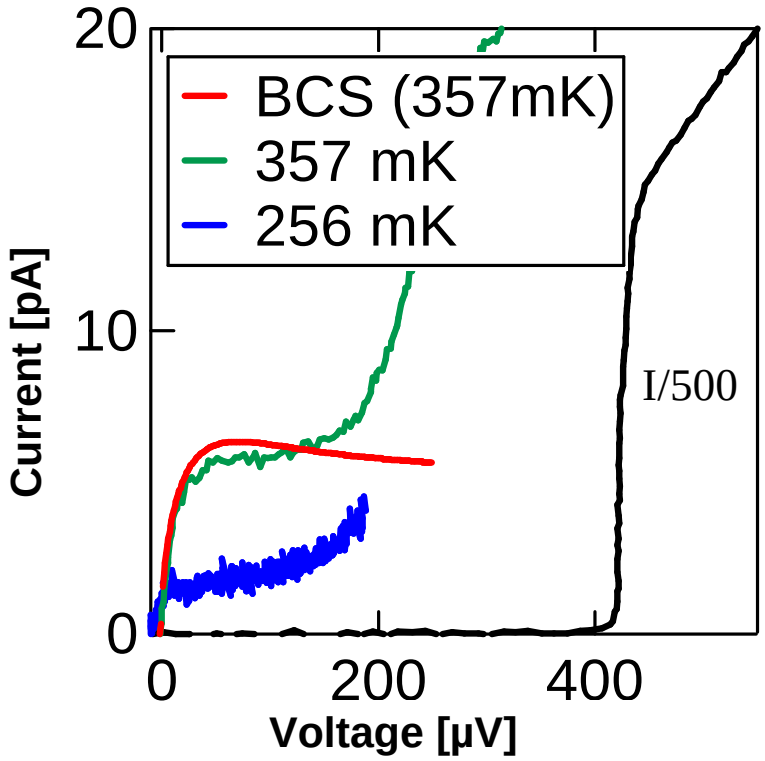


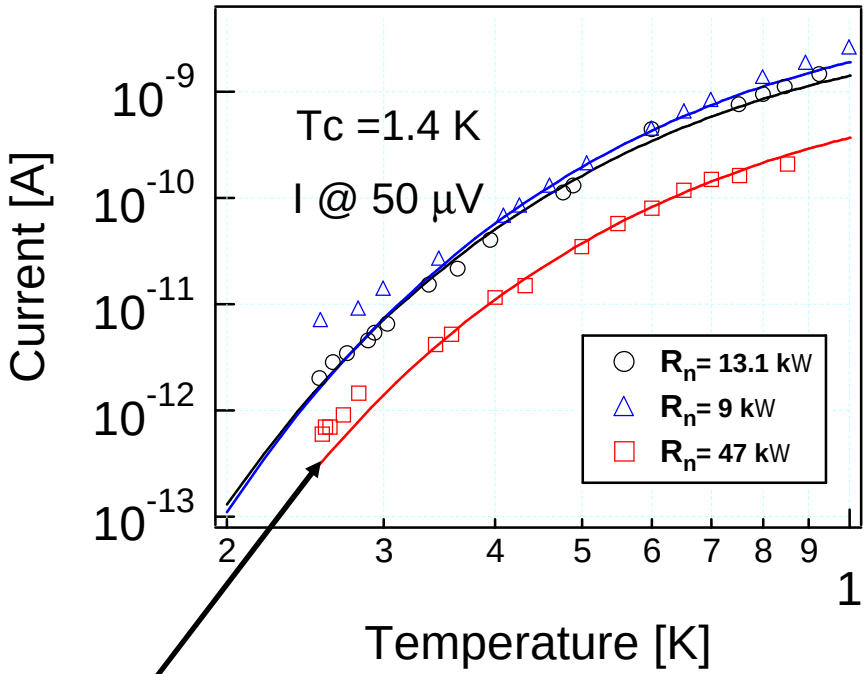




Thermal Dark Current Measurements

BCS Predicts: $I_{dark}(T) \propto e^{-\Delta/k_B T}$

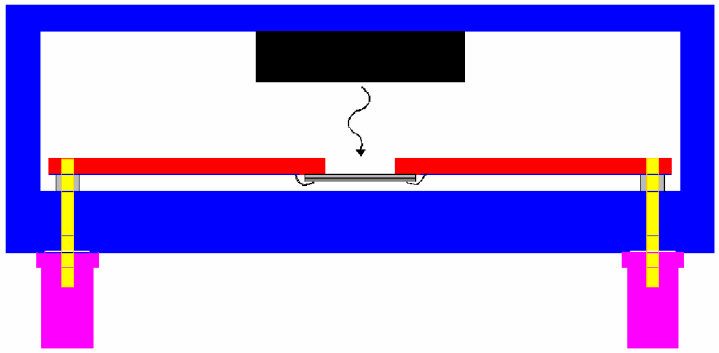


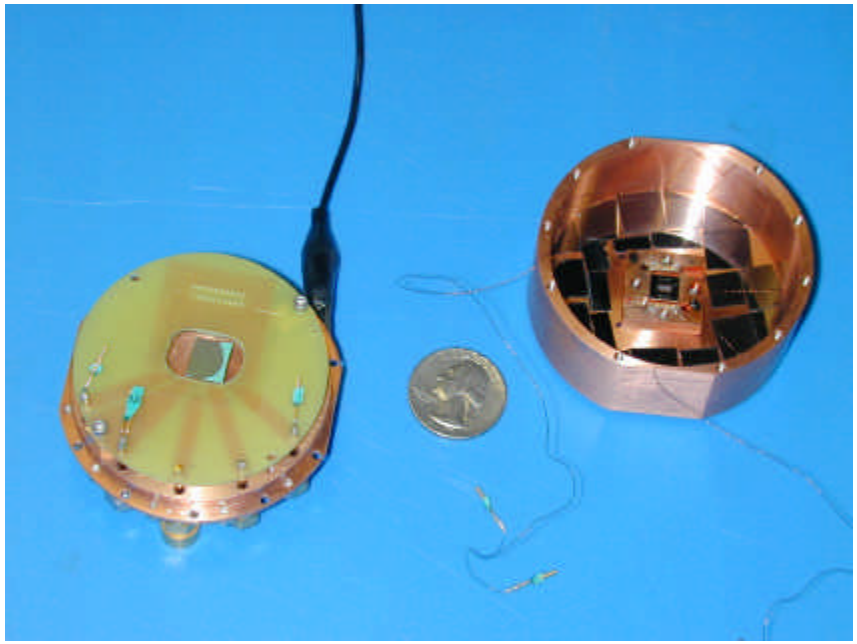


$$I_{\min} \sim \tfrac{1}{2}\, pA \rightarrow NEP < 10^{-19}\, W/\sqrt{Hz}$$

Future Work: Detecting Photon

Use a low thermal conductance blackbody to shine photons on detector





Conclusions

- SQPC: a sub-mm detector capable of NEP < $10^{-19}\, W/\sqrt{Hz}$
- Characterized two sources dark current
- Measured dark current < 0.5 pA
- Tests with Blackbody source underway