Performance of a Low-parasitic Frequency Domain Multiplexing Readout

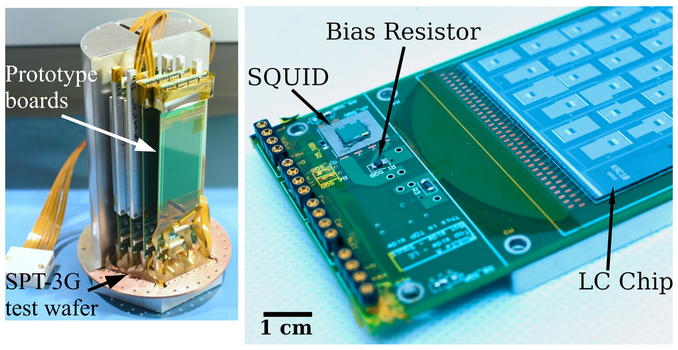
Amy E. Lowitz[1], Amy N. Bender[2], P. Barry[2], T. Cecil[2], C. Chang[1,2], R. Divan[2], M. Dobbs[3], A. Gilbert[3], S. Kuhlmann[2], M. Lisovenko[2], J. Montgomery[3], V. Novosad[2], S. Padin[1,2], J. Pearson[2], G. Wang[2], V. Yefremenko[2], J. Zhang[2]

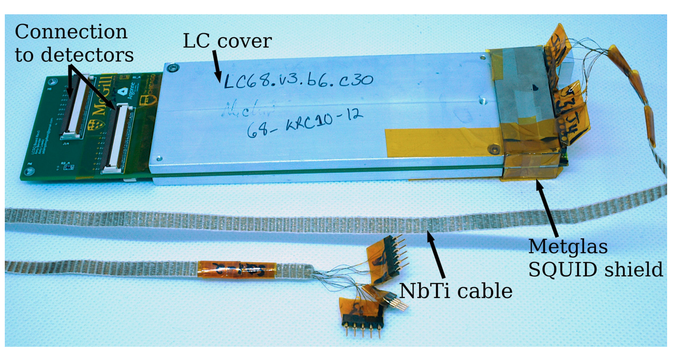
[1]University of Chicago, [2]Argonne National Laboratory, [3]McGill University

Introduction

- Frequency Domain Multiplexing (fMux) is a TES readout technique used on current CMB experiments
- Parasitic impedance in fMux is a dominant source of crosstalk and limits operation of lower-R_n bolometers
- We have designed and implemented a readout with the SQUID next to the LC
  - Reduced wiring length→ reduced parasitics
- Here we show performance of the prototype system alongside SPT-3G readout hardware for comparison

Design and Implementation





- Move the SQUID from the 4 K stage to the 250mK stage
- This reduces the wiring length between the SQUID and LC chip and hence reduces parasitic impedance
  - Reduces crosstalk
  - Enables operation of low-resistance bolometers
- Improves scalability

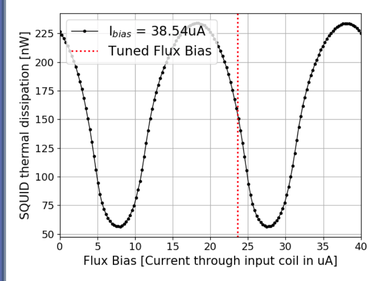
- Retained as much of the existing DfMux design as possible.
  - This reaps the benefits of **reduced crosstalk, reduced parasitic resistance, and improved scalability, while retaining as much technological maturity as possible.**

- **Magnetic shielding** for the SQUID: six layers of Metglas.

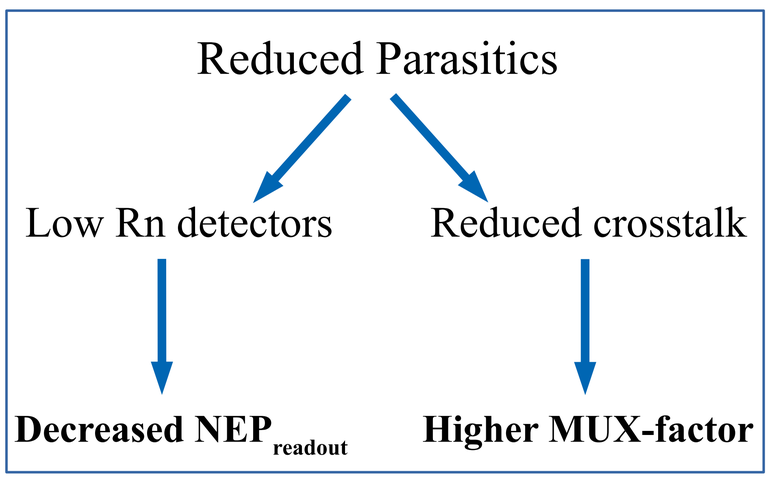
- Prototype boards are sized so they can be a **drop-in replacement** for SPT-3G-style LC boards in any of the SPT-3G testbeds or, in principle, the telescope itself.

Next Steps

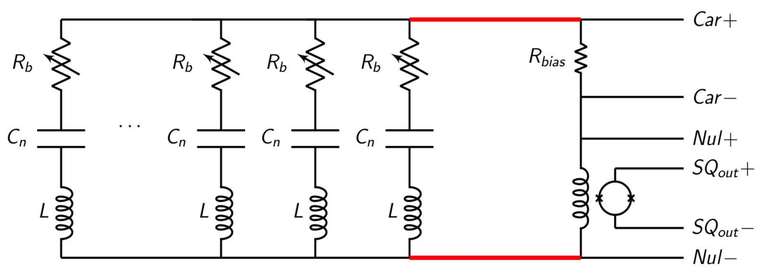
- Noise and Crosstalk Characterization
- Low-R bolometer integration
- Testing with calibrated resistors, and eventually low-R bolometers
- Scaling
- Testing with a larger number of combs
- SQUID improvements
  - Lower thermal dissipation required for operation at scale with a sorption refrigerator



Key Benefits



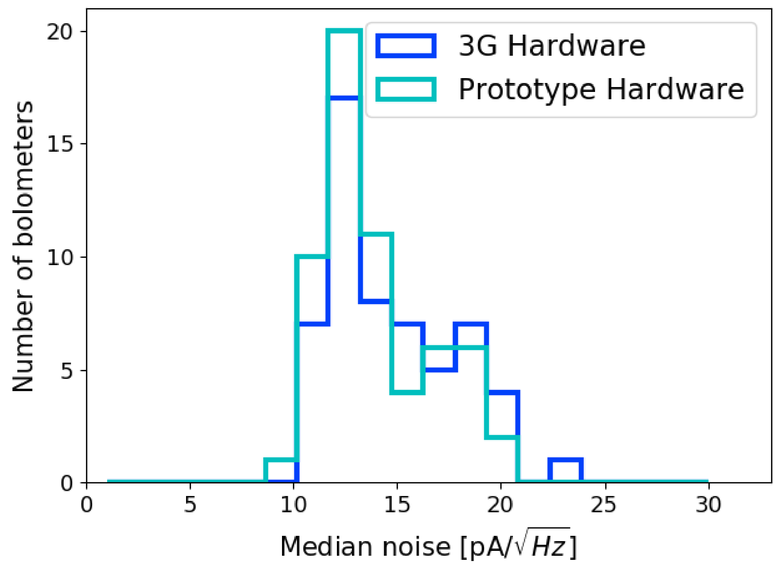
- Decreased stray resistance enables **operation of lower-R_n bolometers, to better optimize noise**.
  - **Reduces $NEP_{readout}$** because the bolometers can be operated with lower V_{bias}. Optimal R for a typical fMux is ~0.5-1.0 Ohms.
- Reduced crosstalk enables denser packing of bolometers in frequency space
  - **This allows for higher multiplexing factors and improved scalability.**
- Leverages much of the existing DfMux architecture, which has proven on-sky performance
- Drop-in replacement for 3G-style LC boards



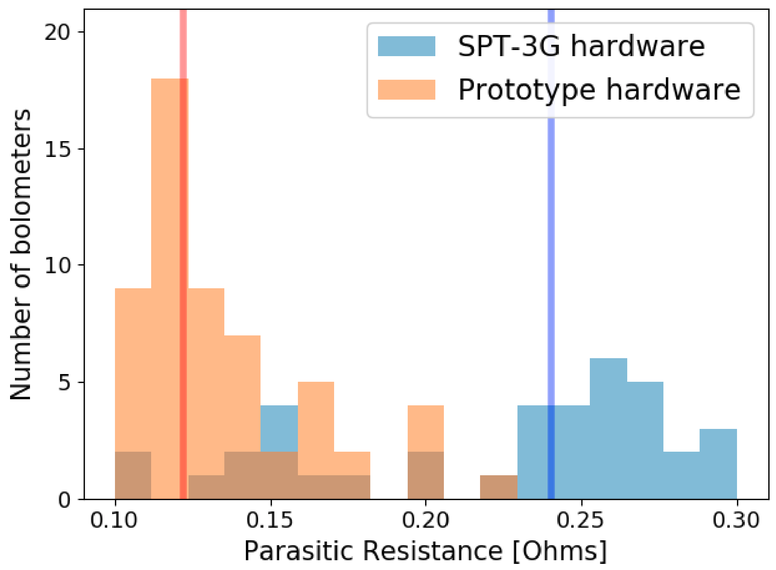
Schematic of the DfMux readout. The wires highlighted in red run between the LC resonators and the SQUID. Stray impedance in these wires create a voltage divider effect which is the dominant source of crosstalk in the existing DfMux system.

Performance

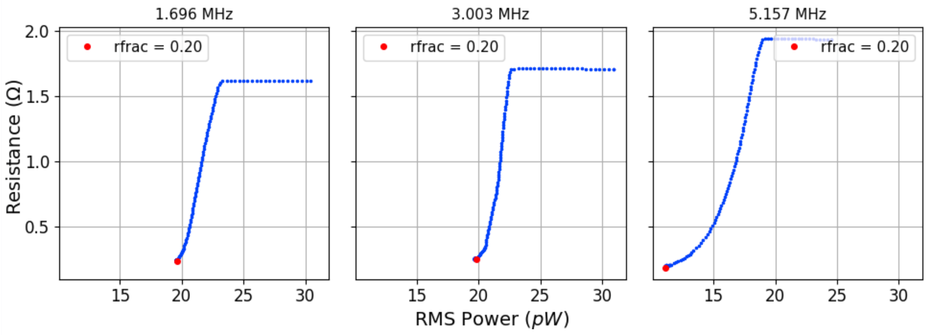
The T > Tc **noise performance** of the prototype system is comparable to the performance of the standard SPT-3G hardware.



The median **parasitic resistance** of the prototype is half that of 3G DfMux hardware. Vertical lines indicate the medians.



Resistance vs Power curves for three representative bolometers. These curves have been corrected to remove the parasitic resistance.



V-phi curve for a representative NIST SA13 SQUID at three temperatures. We see slight improvement in peak-to-peak and transimpedance at lower temps.