Performance of a Low-parasitic Frequency Domain Multiplexing Readout

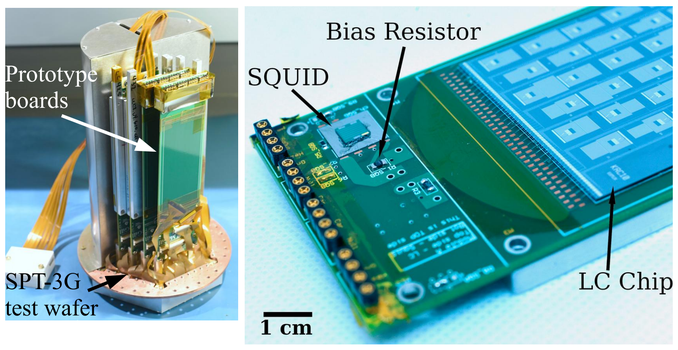
Amy E. Lowitz[1], Amy N. Bender[2], P. Barry[2], T. Cecil[2], C. Chang[1,2], R. Divan[2], M. Dobbs[3], A. Gilbert[3], S. Kuhlmann[2], M. Lisovenko[2], J. Montgomery[3], V. Novosad[2], S. Padin[1,2], J. Pearson[2], G. Wang[2], V. Yefremenko[2], J. Zhang[2]

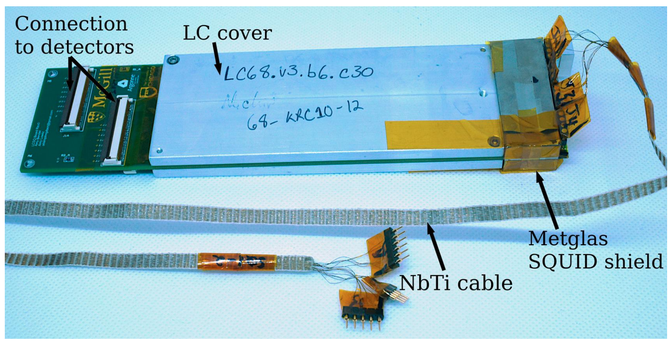
[1]University of Chicago, [2]Argonne National Laboratory, [3]McGill University

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 tests of the prototype system alongside SPT-3G readout hardware for comparison

Design and Implementation

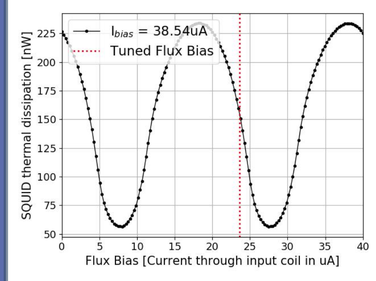




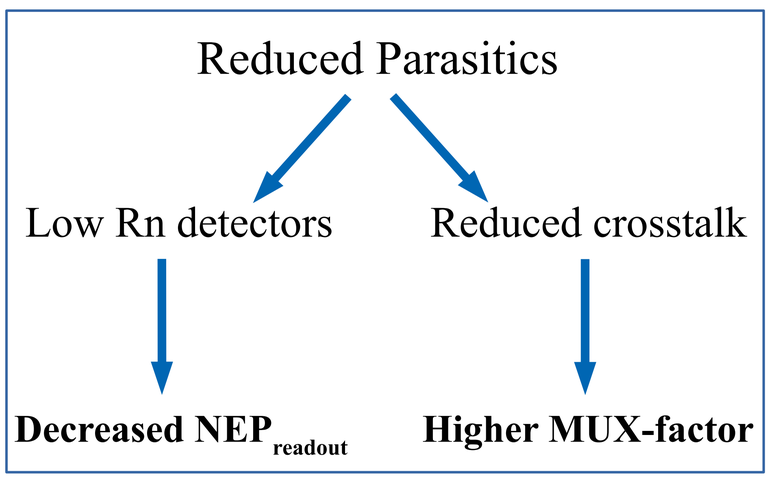
- Moving the SQUID from the 4 K stage to the 250 mK stage
- This reduces the wiring length between the SQUID and LC chip
  - Reduced parasitic impedance
    - Reduces crosstalk
    - Enables operation of low-resistance bolometers
  - Improves scalability
- Retained as much of the existing DfMux design 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

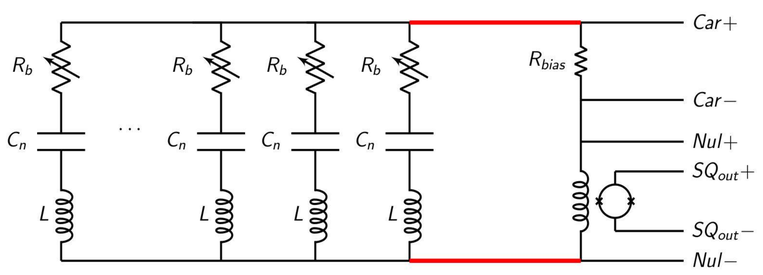
- Noise and Crosstalk Characterization
- Low-R bolometer integration
- Testing with calibrated resistors, and eventually low-R bolometers
- Scaling
- Testing with a larger number of combs
- SQUID improvements
  - Lower thermal dissipation required for operation at scale with a sorption refrigerator



Key Benefits



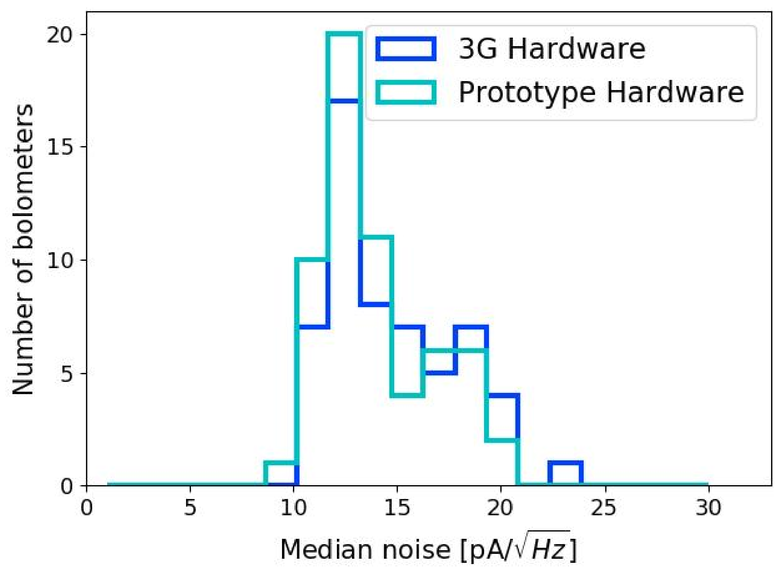
- Decreased stray resistance enables **operation of low-R_n bolometers**.
  - This **reduces $NEP_{readout}$** because the bolometers can be operated with lower V_{bias}.
- Reduced crosstalk enables denser packing of bolometers in frequency space
  - **This allows for higher multiplexing factors and improved scalability.**
- Leverages much of the existing DfMux architecture, which has proven on-sky performance
- Drop-in replacement for 3G-style LC boards



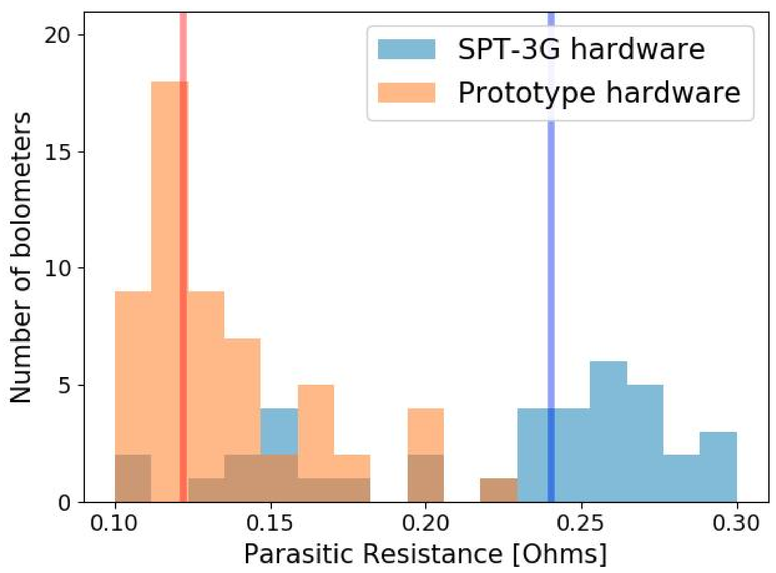
Schematic of the DfMux readout. The wires highlighted in red run between the LC resonators and the SQUID. Stray impedance in these wires create a voltage divider effect which is the dominant source of crosstalk in the existing DfMux system.

Performance

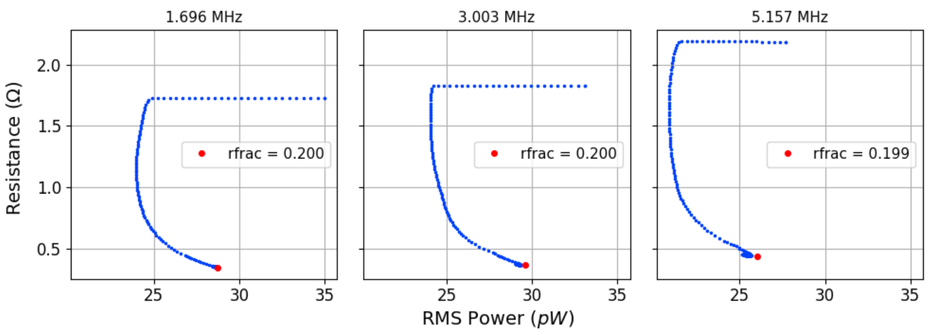
The warm overbiased **noise performance** of the prototype system is comparable to the performance of the standard SPT-3G hardware.



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



RP curves for three representative bolometers. The 'bendback' feature results from the parasitic resistance, which is significant compared to the bolometer resistance when very deep in the superconducting transition.



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.