National Aeronautics and Space Administration

TKIDs for CMB Polarimetry and Sub-mm Astrophysics

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Program: Strategic RTD

Project Objective:

The project objective was to develop thermal kinetic inductance detectors (TKIDs) for Cosmic Microwave Background (CMB) polarimetry. Our three year program sought to advance this technology to TRL3 by demonstrating background limited sensitivity and prototyping antenna-coupled detectors.

FY18/19 Results:

- Demonstrate Background limited noise performance for first proposed deployment site: BICEP Array at the South Pole
- Verified that the fundamental noise is phonon in the legs.
- Tested arrays of 36 detrectors, showing ~75% yield.
- Used diode array to verify physical location of detectors and to inform efforts at yield improvements.
- Studied cosmic ray generated glitches to show improvement over non-released resonators.
- Fabricated antenna-coupled TKIDs. Currently under test, funded by follow on SAT funds.
- Measured quasiparticle lifetime to be τ~0.2ms from both LED tests and Cosmic Ray analysis

Benefits to NASA and JPL:

- Advances bolometer state-of the art:
  - Eliminates *O*(10,000) wire bonds between detectors and multiplexer that modern TES bolometers and SQUID readout require
  - Reduces complexity and integration risk
- Advances resonator detector state of the art:
  - TKIDs have more design parameters than KIDs:
    - Leg conductivity G
    - Island temperature (in addition to Tc and substrate temperature)
    - Independently optimize absorption efficiency and responsivity
    - Inductor volume V.
  - TKIDs do not need small volume inductors (they do not rely on direct photo-generation of quasiparticles). Can use larger volume to decrease read frequencies for simpler electronics, or reduce capacitor size.
  - TKIDs have better immunity to cosmic rays than non-membrane suspended KIDs.
- Possible detector technology for the recently studied NASA-probe mission PICO, a satellite born CMB polarimeter with 13,000 detectors.
- Possible detector for NASA's proposed flagship Origin Space Telescope.
- This TKID program can inform work on a parallel effort to build YBCO TKIDs for planetary observations.

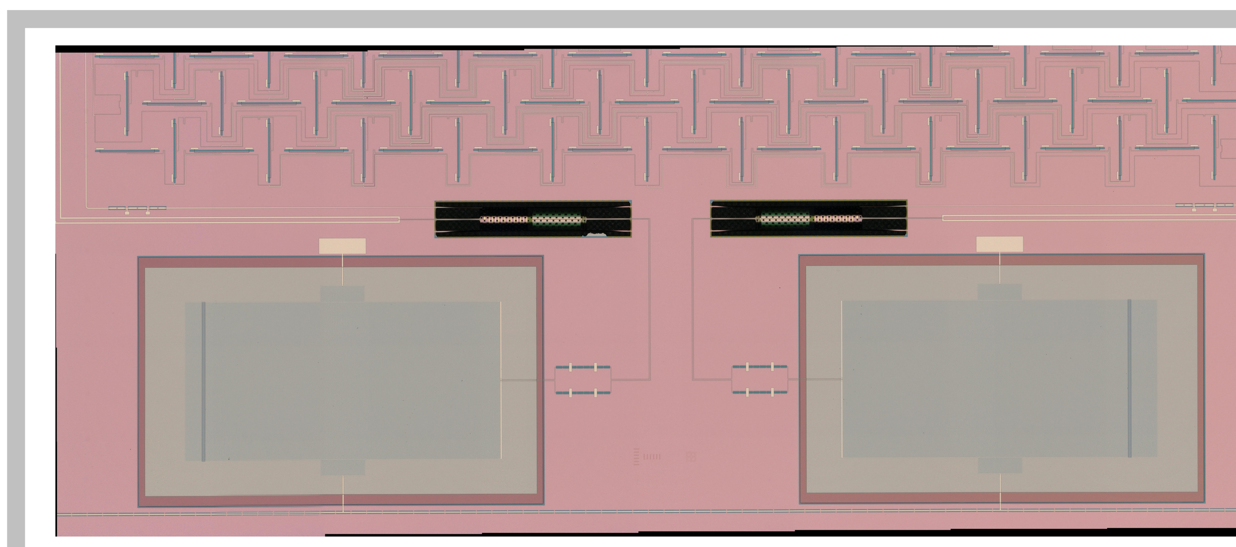
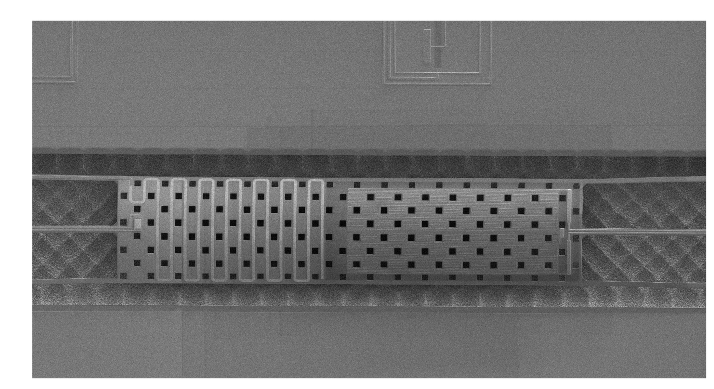


Figure 1: Microscope images of antenna coupled TKIDs. Results on this poster are from detectors without the antenna, but otherwise identical. Antenna coupled measurements currently underway.



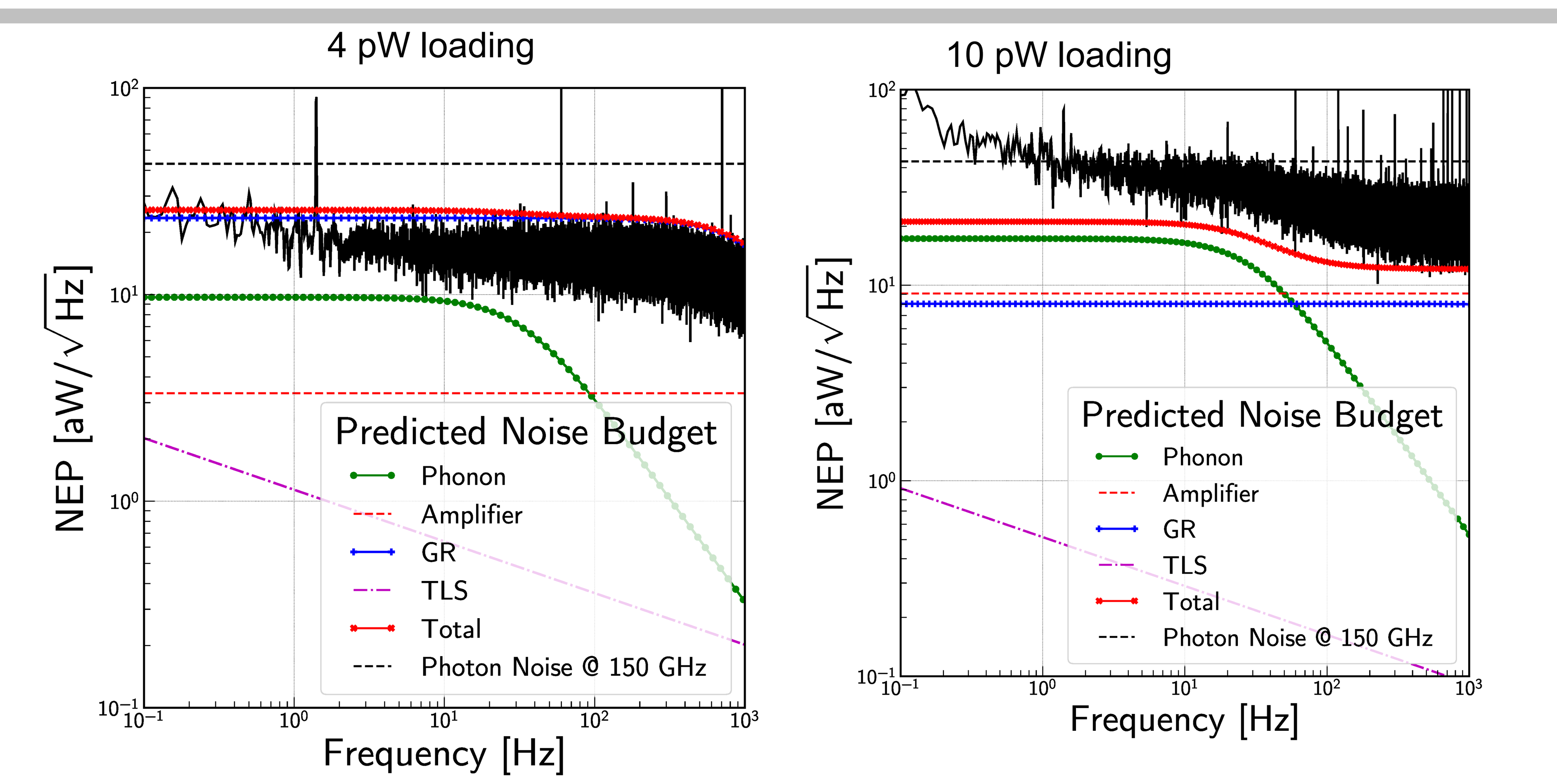


Figure 2: Noise spectra vs models at different loading levels. The horizontal dashed line shows background at the south pole at 150GHz at ~6pW loading. The higher loading measurement shows evidence of the bolometer thermal bandwidth (~30Hz).

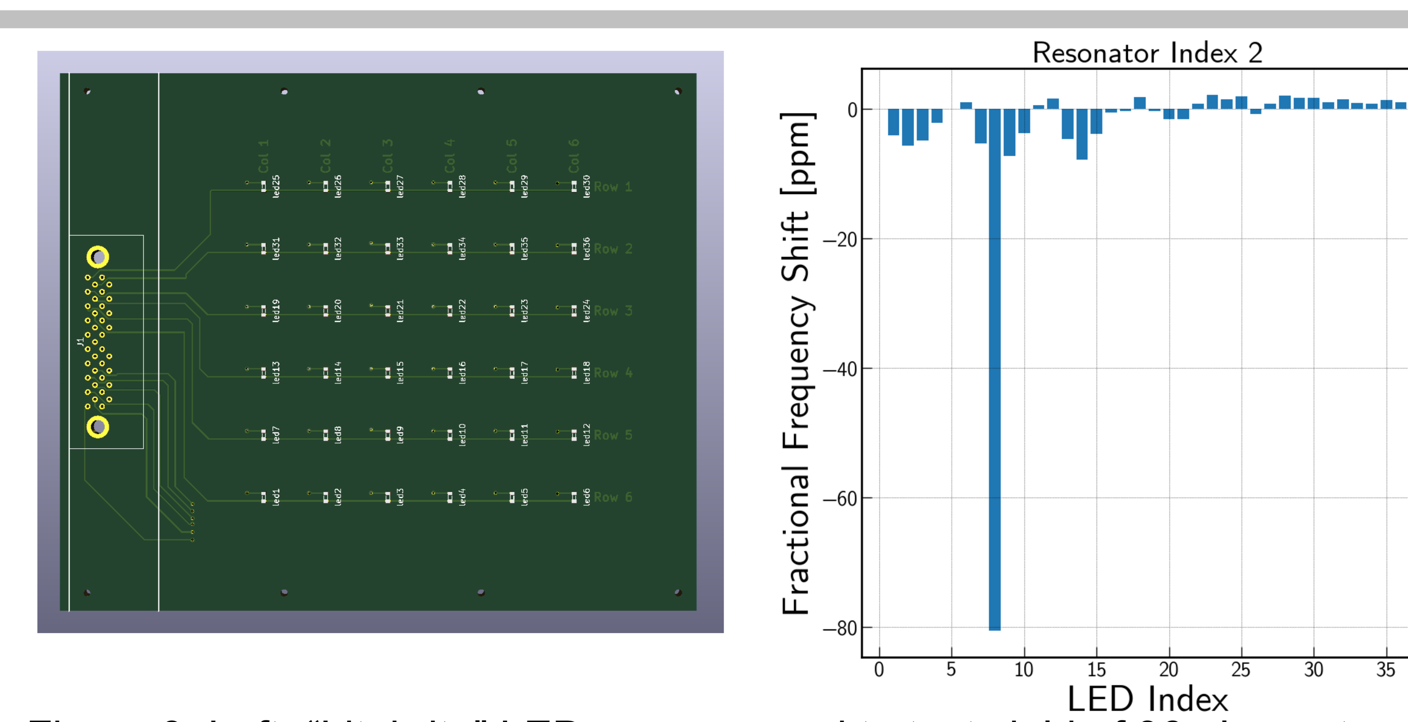


Figure 3: Left- "Litebrite" LED mapper used to test yield of 36 element arrays. The diodes illuminate detectors through columnating holes. Right- Response of all detectors to one LED, clearly indicating the position of the detector under the LED. Such studies have suggested 75% yield rates. Time constant measurements suggest a quasiparticle lifetime of 0.18ms

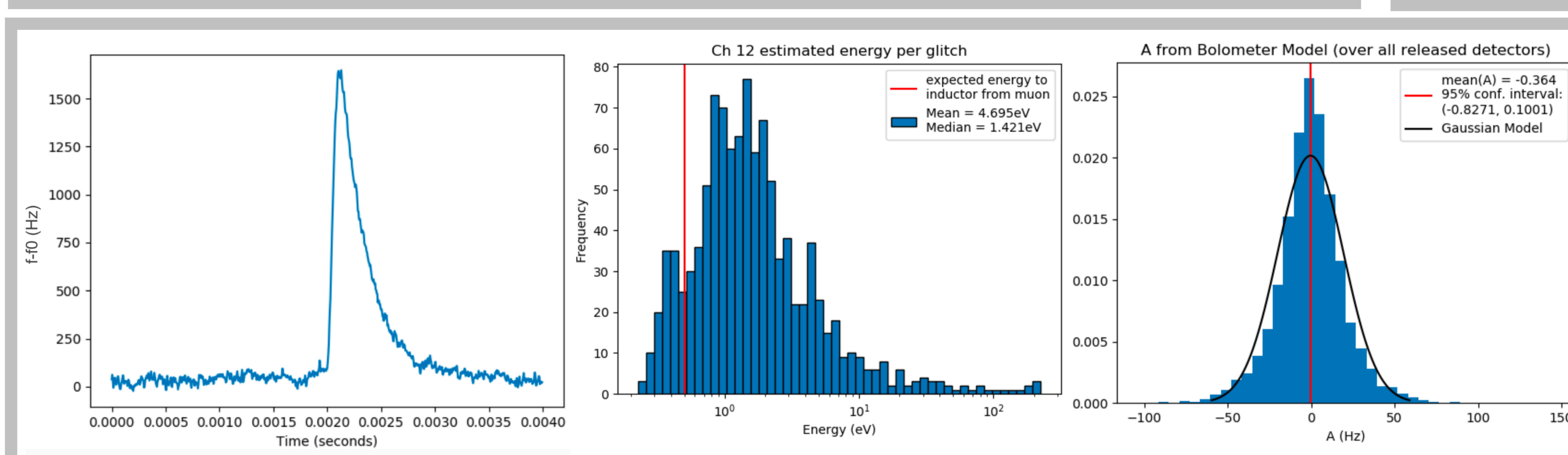


Figure 3: Left shows a typical time stream glitch in an unreleased device, with measured rates of 0.7/s consistent with expectations from Cosmic Rays (1/s at sea level). Quasiparticle Time constant is ~200 μs, similar to the "LiteBrite" measurements. Center: Reconstructed energy spectrum of cosmic rays from unreleased devices, with a median of 1.4 eV. Right: Glitch amplitude for released TKIDs, with a median bounded to energies less than 300 μeV (2-sigma).

Publications:

A. Wandui et al. "Thermal Kinetic Inductance Detectors for millimeter wave astrophysics." ready for submission to Journal of Applied Physics

K. Hughes et al. "Cosmic Ray impacts on Thermal Kinetic Inductance Detectors." in prep.

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