National Aeronautics and Space Administration

FY24 R&TD Innovative Spontaneous Concepts (ISC)

MgB_2 TKID for High Background Imaging

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Strategic Focus Area: Innovative Spontaneous Concepts

Objectives:

- Developing superconducting bolometer technology using magnesium diboride (MgB_2) thin films, targeting a wide operating temperature range (4-25 K)
- MgB_2 offers a critical temperature of 30 K or higher, suitable for moderate temperature operation
- Previous technologies
  - Low temperature superconductors (Al, NbN)
  - High temperature superconductors (YBCO)
- MgB_2 combines the advantages of low temperature superconductors with fewer fabrication challenges than YBCO, offering a path to high TRL science instrumentation

Background:

- Remote sensing across wavelengths from a few microns to millimeters serves both NASA science and non-NASA imaging applications
- High sensitivities with NEP < 10^{-15} W/√Hz
- Ambient thermal environments pose significant challenges, requiring detectors and optics to operate at sub-K temperatures for higher sensitivity
- Room temperature detectors
  - Acceptable NEPs for some applications
  - Failure to reach the noise limits for sensitive observations
- Existing detector technologies, such as BIB detectors, operate at single-digit Kelvin temperatures but only detect up to 25 microns and face challenges with scalability and reading out large arrays

Approach and Results:

- Utilizing MgB_2 superconductive material to enhance detector performance and sensitivity
- Successfully fabricated MgB_2 lumped element resonators with the inductor component on a membrane
- Measured responsivity and noise on MgB_2 TKIDs
- Demonstrated phonon-limited noise performance and operation across a wide temperature range

Significance/Benefits to JPL and NASA:

- The technology enhances various earth and planetary science concepts
- Enhanced sensitivity
  - Crucial for studying atmospheres of earth and planetary bodies
  - Lower NETD, enabling the detection of minute atmospheric changes
- Moderate cooling requirements (20-25 K), allowing for practical implementation space missions
- Passive mm-wave sensing enables non-NASA applications, such as object detection through cloud cover under large optical loadings
- TKIDs scale to large arrays with a single readout, enabling or enhancing imaging and mapping applications

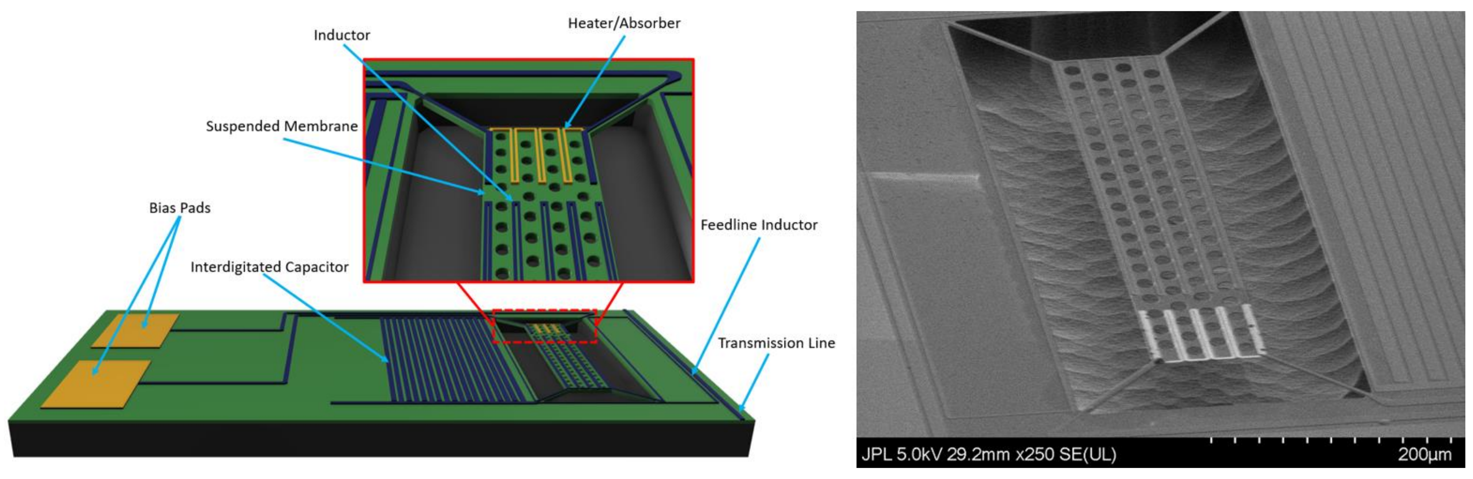

Figure 1. (Left) Schematic diagram of first iteration of MgB_2 TKID devices. (Right) SEM of a membrane released from substrate with MgB_2 inductor and gold resistor patterned onto membrane.

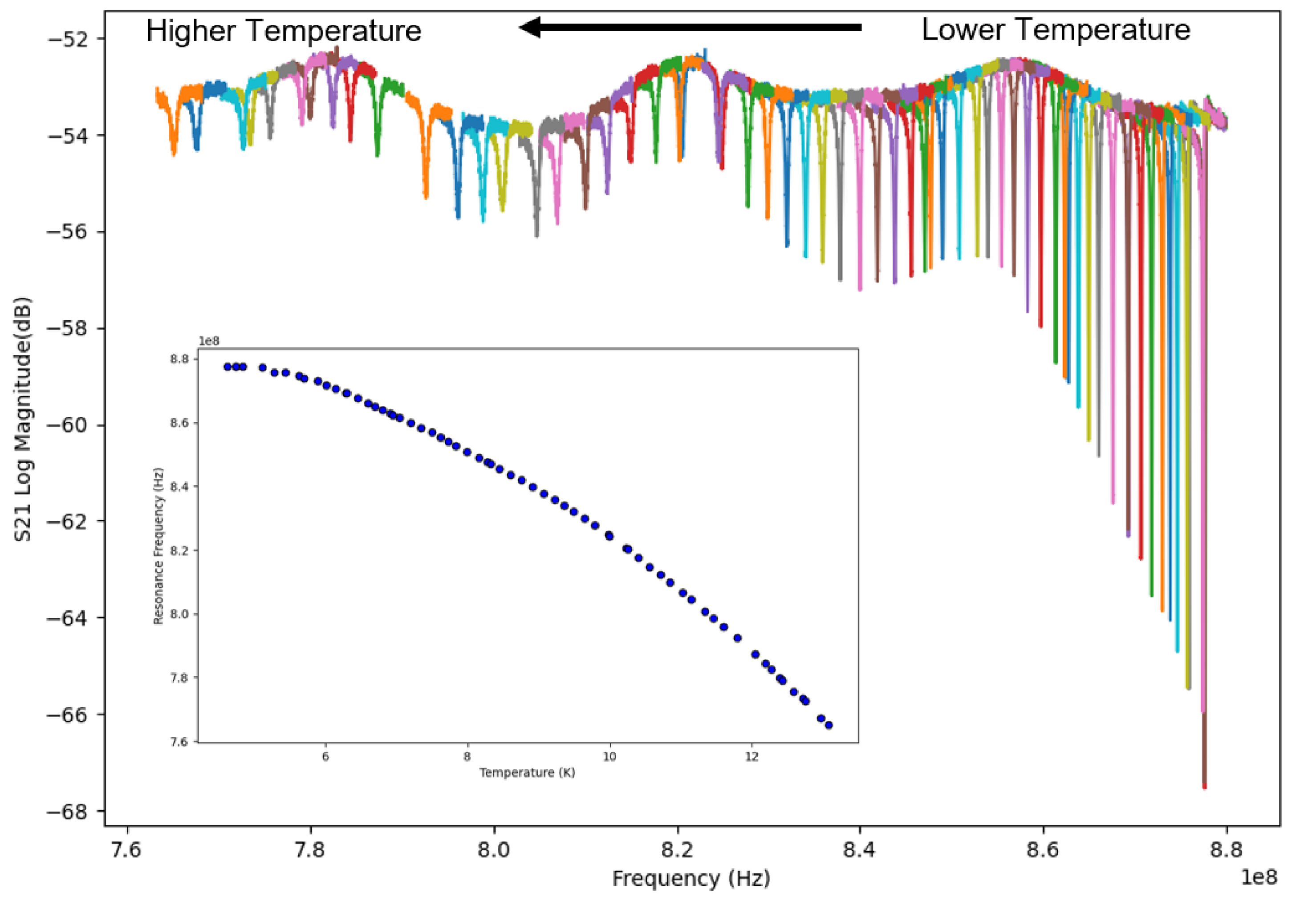

Figure 2. S21 transmission data for the MgB_2 TKID device at different temperatures. At lower temperatures, the resonance frequency is deeper than at higher temperatures. As the temperature increases, the depth decreases, and the resonator shifts downward. The inset shows the resonance frequency as a function of temperature.

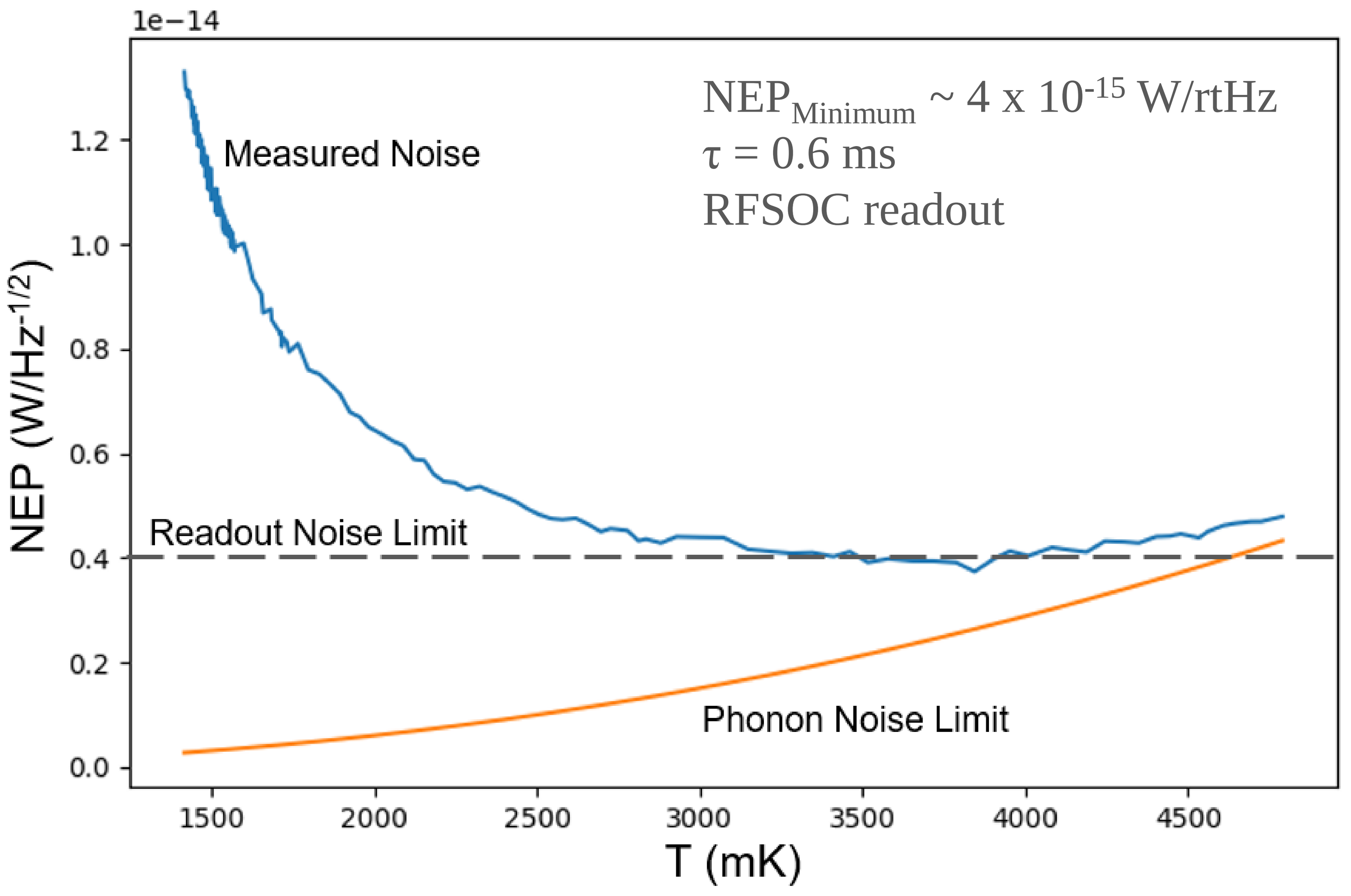

Figure 3. Measured noise in the first MgB_2 TKID devices. The lower limit is set by the readout system. Below 3.5 K, a small responsivity is expected. Above 3.5 K, the actual noise should follow the trend of phonon noise. The noise asymptote to this limit is above the readout limitations.

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