National Aeronautics and Space Administration

Kinetic Inductance Detector array development for the Balloon Experiment for Galactic INfrared Science (BEGINS)

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Program: FY22 R&TD Topics
Strategic Focus Area: Direct/Coherent Detectors and Arrays

Objectives:

- Demonstrate detector modules that will provide the groundwork for the production of a focal plane array (FPA) for a balloon mission matching the requirements of BEGINS:
  - 2,500 titanium nitride Kinetic Inductance Detectors (KIDs)
  - Wavelength range of 25 to 400 microns
  - Background limited sensitivity
  - 250 microns pixel pitch at the shortest wavelengths

Background:

- BEGINS will combine a 0.5-meter telescope with a compact hyperspectral imager from 25 to 400 microns to map spectral energy distributions over large areas.
  - A hyperspectral imager will utilize linear-variable filters for a spectral resolving power of R= λ / $\Delta\lambda$ = 10 from 25 to 64 microns.
  - From 65 to 400 microns, where the spectral energy distributions have been characterized better by previous observations, the spectral resolving power will be R = 3.5

Approach and Results:

- *MIR lens-coupled TiN MKID arrays:*
  - Baseline sub-stoichiometric TiN detectors, which have heritage at JPL
  - In this first year of the project, we have demonstrated that MKID arrays with parallel plate capacitors can be fabricated with useful properties on a 250-micron pitch, ie. about 16 times denser than state-of-the-art
- *MIR lenses:*
  - Laser machined lenslets can be used at >~ 65 microns, but are too rough at shorter wavelengths
  - Silicon micromachines Fresnel lenslets are being developed separately
  - Prototype 25-micron arrays used Fresnel zone plate lenses to allow detector characterization measurements
- *MIR linear variable filters*
  - Crosses etched in a conductive film with varying dimensions across an array
  - In our first year, we have produced a working 25-micron band pass filter for use in our testbed.

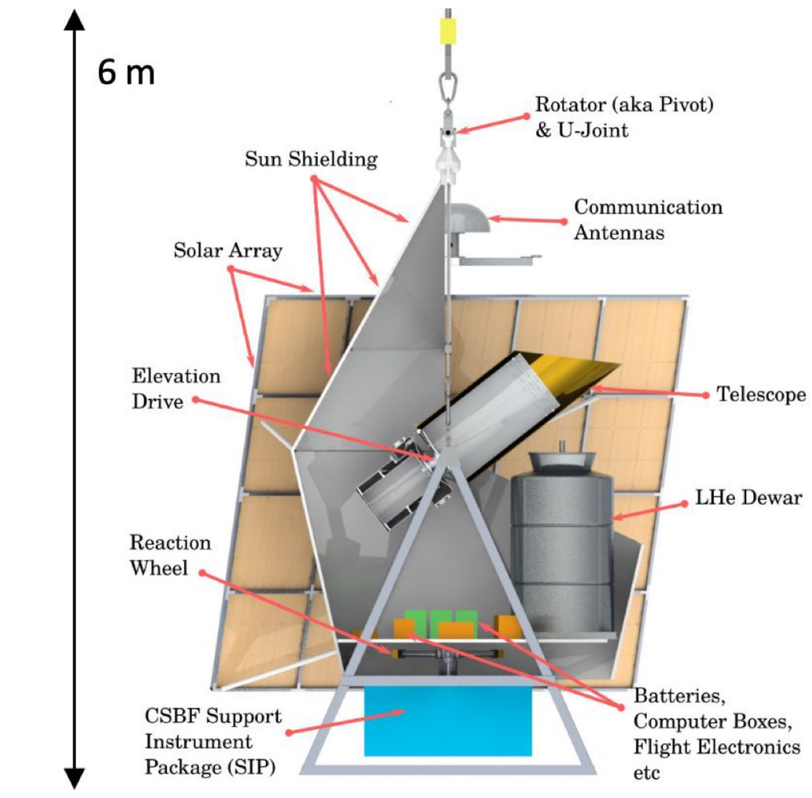

Figure 1. Conceptual BEGINS gondola with major components labeled.

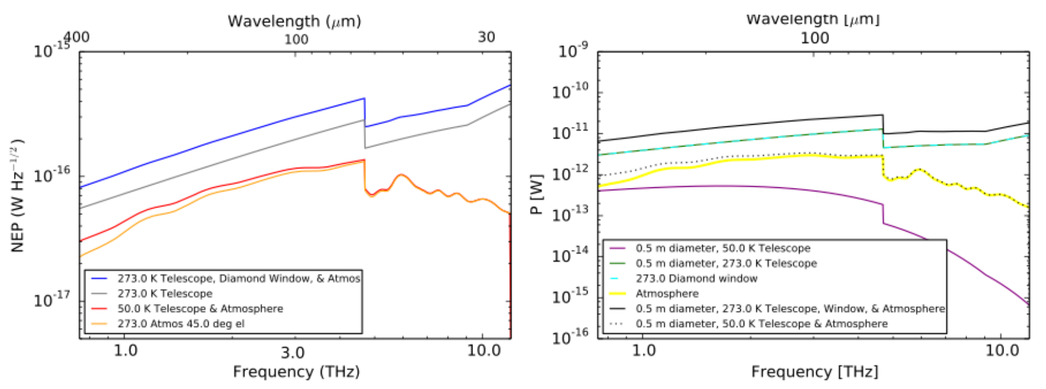

Figure 2. Left: Estimated contributions to the detector photon noise for the BEGINS optical environment. Right: Contributions to the optical power absorbed by the detector.

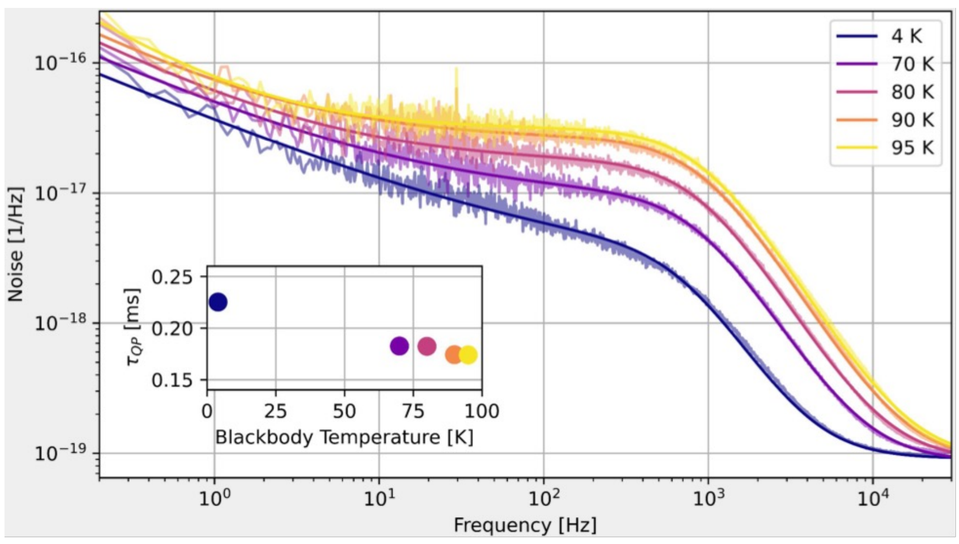

Figure 5. Noise measurements of the prototype BEGINS KID array at various black body temperatures. The inset shows the detector response time, set by quasiparticle recombination, derived from fits to the noise spectra.

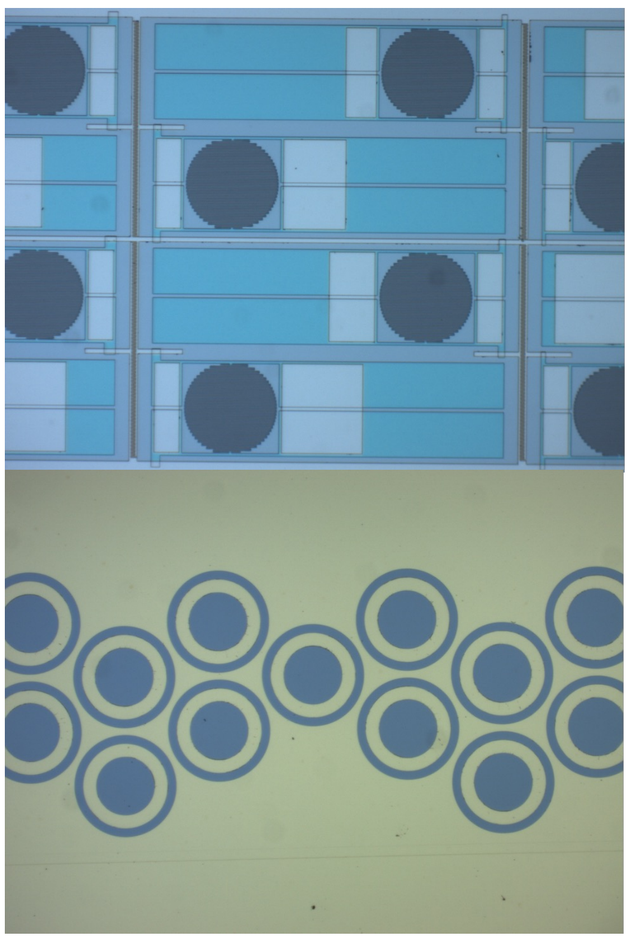

Figure 3. BEGINS prototype MKID array. Circular structures are the meandered TiN inductors that absorb radiation focused by the lens array. The absorbers are arranged hexagonally on a 250-micron pitch. Unique capacitors define the resonance frequency of each detector.

Figure 4. Lithographically patterned aluminum Fresnel zone plate (FZP) lenses. Each set of rings comprises a FZP lens and is aligned to a KID absorber on the chip's backside.

Significance/Benefits to JPL and NASA:

- Mid-infrared (MIR) KIDs are a new development, but they will be crucial for future NASA observatories, such as the GEP and the Origins Space Telescope.

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Publications:

[A] Nicholas Cothard, Byeong Ho Eom, Jason Glenn, Henry Leduc, Joanna Perido, Andrew Beyer and Peter Day, "Parallel plate capacitor TiN KID array development for the Balloon Experiment for Intergalactic Science (BEGINS)," poster presented at *SPIE Astronomical Telescopes and Instrumentation,* Montreal, BC, Canada 2022.

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