National Aeronautics and Space Administration

FY23 Strategic Initiatives Research and Technology Development (SRTD)

Long Wavelength Kinetic Inductance Detectors for PRIMA

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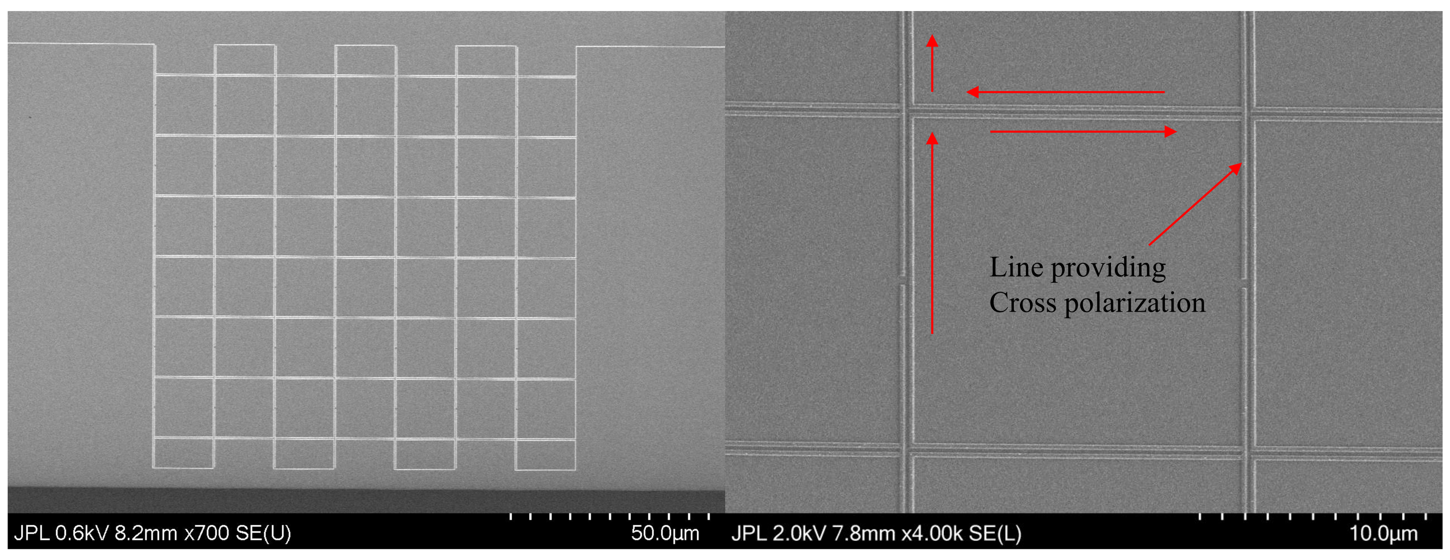
Strategic Focus Area: Long-Wavelength Detectors | **Strategic Initiative Leader:** Charles Lawrence

Objectives and Background:

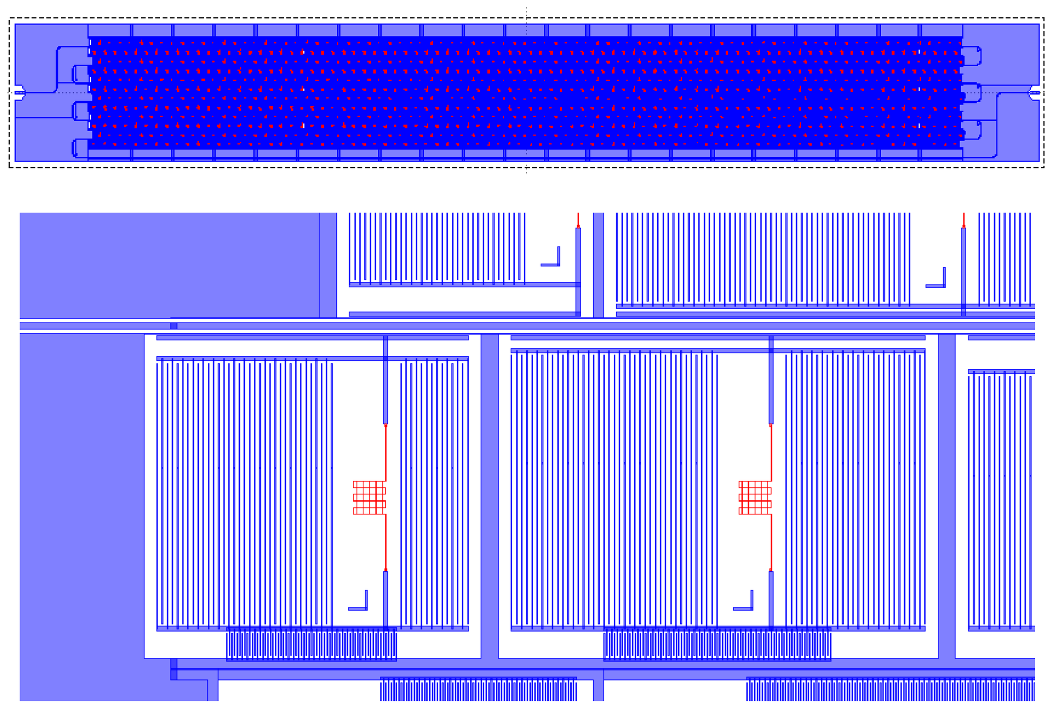
The most exciting far-IR astrophysics missions under study feature actively-cooled telescopes which offer the potential for orders of magnitude observing speed improvement at wavelengths where galaxies and forming planetary systems emit most of their light. The Probe far-Infrared Mission for Astrophysics (PRIMA) is one such mission under study, emphasizing low and moderate resolution spectroscopy throughout the far-IR. Full utilization of PRIMA's cold telescope requires far-IR detector arrays with per-pixel noise equivalent powers at or below 10^-19 W/rtHz. We are developing low-volume kinetic inductance detector (KID) arrays to reach these sensitivities.

Approach and Results:

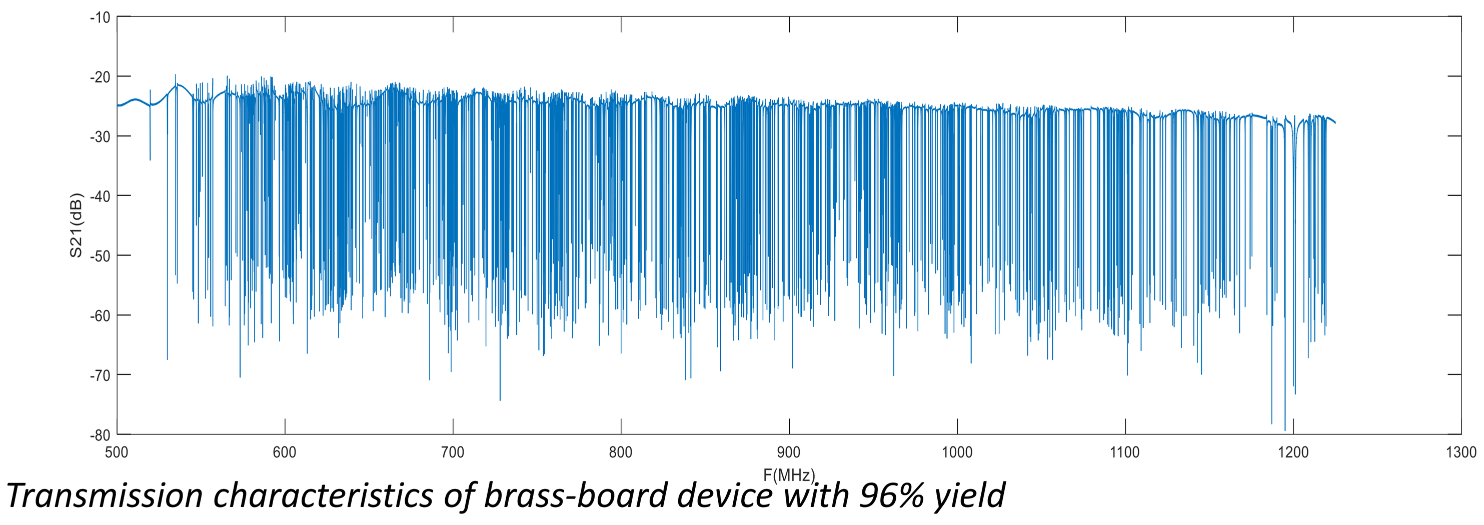
Kinetic Inductor Detectors are devices with pixels consisting of superconducting resonators in which the inductor doubles as the radiation absorbers. In a KID, radiation absorbed by the inductor/absorber breaks Cooper-pairs thereby changes its inductance. This is in turn sensed by the shift of the resonator resonance frequency. To obtain detectors with NEPs as low as $1x10^{-19}W/Hz^{1/2}$ The approach chosen was to use small volume (11-20 cubic micron) to increase the responsivity (change in inductance with respect to optical signal and large interdigitated capacitors) to reduce noise.



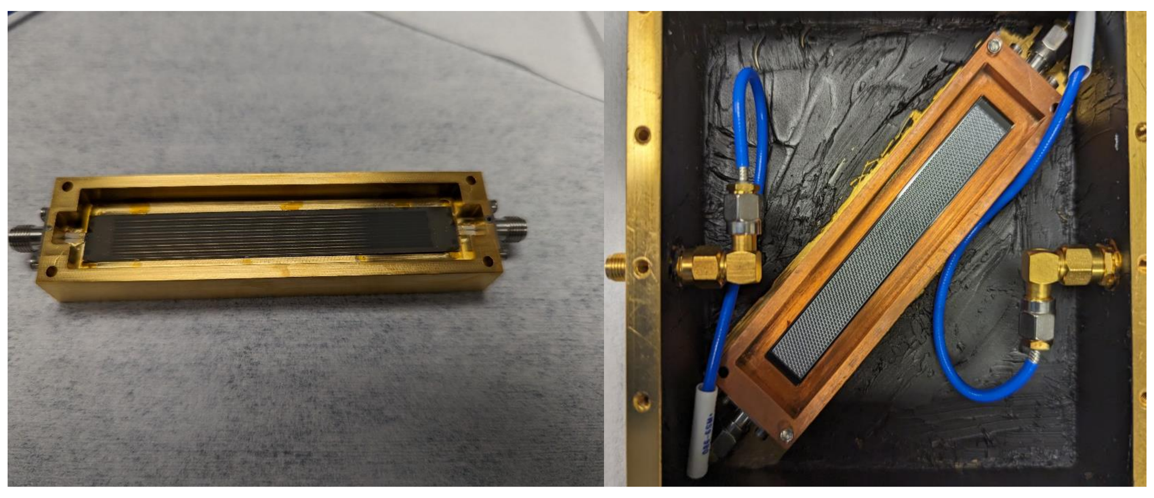
Scanning Electron Microscope picture of a small volume KID inductor with 20 μm^3 volume. Detail of a unit cell showing the current flow (red arrows) and the lines providing a capacitive coupling for the cross polarization. Design by Sven van Berkel. E-beam lithography by Richard E. Muller



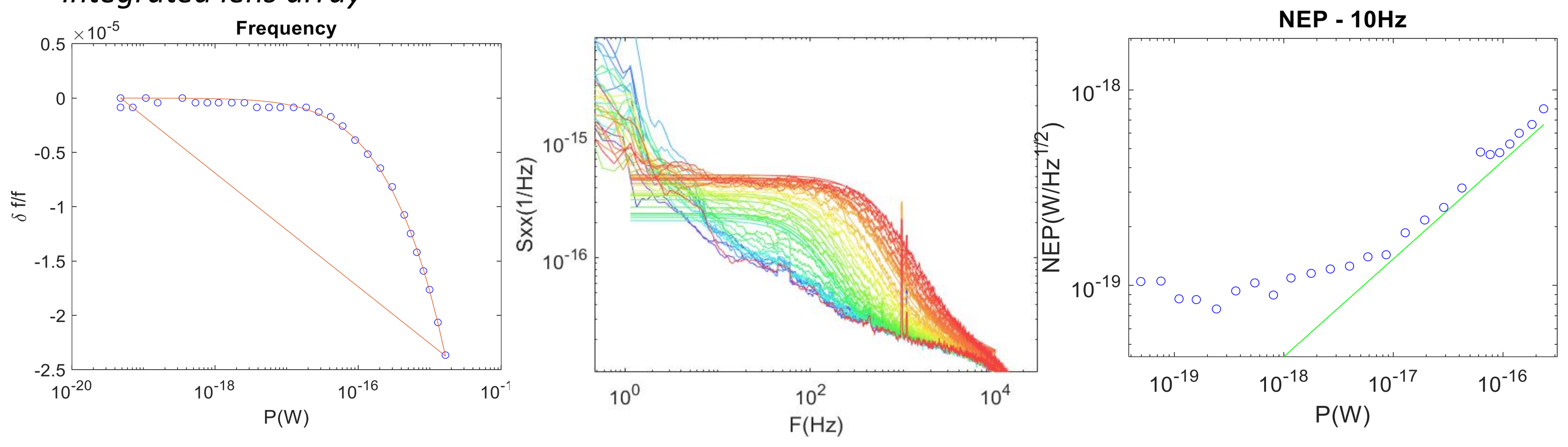
Brass-board design in a 12x84 format using IDC with 10 µm gap and 7x7 inductors (20 μm^3). Intended pixel readout frequencies ranged from 400MHz to 2GHz. Design by Reinier Janssen



Transmission characteristics of brass-board device with 96% yield



Left: brass-board devices (detector side up) without lens arrays. Right: Brassboard device with integrated lens array



Left: fractional frequency change of resonator as a function of optical loading; Center: Measured noise for various optical illumination levels (blue= low level, red = high level). The roll off corresponds to a maximum lifetime of the order of 1.2 ms; Right: NEP x optical power demstrating the brassboard satisfy PRIMA requirements

Benefits to NASA/JPL:

Demonstration of small volume KIDs will make the PRIMA proposal being prepared in response to an AO for a probe class mission very competitive

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