National Aeronautics and Space Administration

Superconducting Detector Arrays for Imaging and Spectroscopy at Mid-Infrared Wavelengths

Principal Investigator: Peter Day (389); Co-Investigators: Henry Leduc (389), Byeong Eom (389), Charles Bradford (326), Pierre Echternach (389), Joanna Perido (NASA), Nicholas Cothard (NASA), Jason Glenn (NASA), Steve Haily-Dunsheath (Caltech)

Program: FY22 R&TD Strategic Initiative

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

Objectives:

- Optically demonstrate closely-packed, micro-lens coupled KID arrays with the required detector NEPs for both imaging and spectroscopy for a space mission with a cooled telescope in the wavelength range of 15-400 microns.
- We have taken the requirements for PRIMA as guidance.
- In year 1, we have targeted an array for 25 microns, which is toward the short-wavelength (and hence more difficult for superconducting detectors) end of PRIMA's range.
- The pixel spacing for this array is 500 microns
- NEP target for for the PRIMA imaging instrument (PRIMA-I), approximately 10-18 W Hz-1/2 at 25 microns.
- NEP target for the PRIMA spectrometer instrument (PRIMA-S) is 2x10-19 W Hz-1/2 at that wavelength.

Background:

- The Astro 2020 Decadal Survey strongly endorsed a line of Astrophysics Probe missions.
- JPL intends to compete a concept, now called PRIMA, based the Galaxy Evolution Probe (GEP) (fig. 1) in the proposal call expected in 2023.
- PRIMA baselines mid- and far-infrared kinetic inductance detectors (KIDs), whose TRL must be raised from 2 to 5 by 2024, with substantial progress toward that goal for a fall 2023 Probe proposal submission.
- This project's goal is intended in part to meet the PRIMA TRL requirements in time for the proposal submission and the end of Phase A and include demonstration of NEPs of 4×10^{-20} W $Hz^{-1/2}$ and high yield over arrays of 10^4.

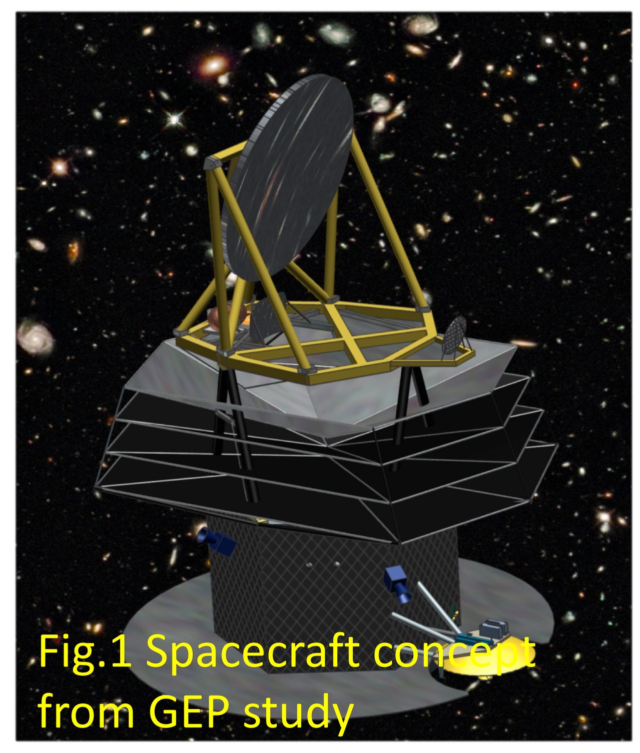

Fig.1 Spacecraft concept from GEP study

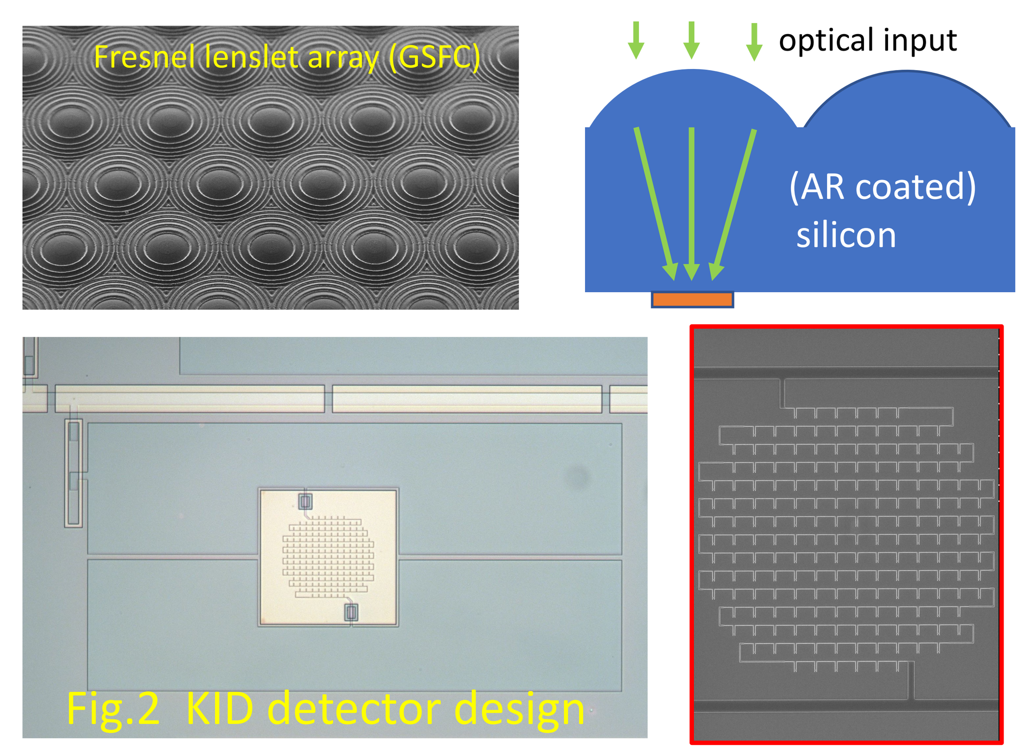

Fig.2 KID detector design

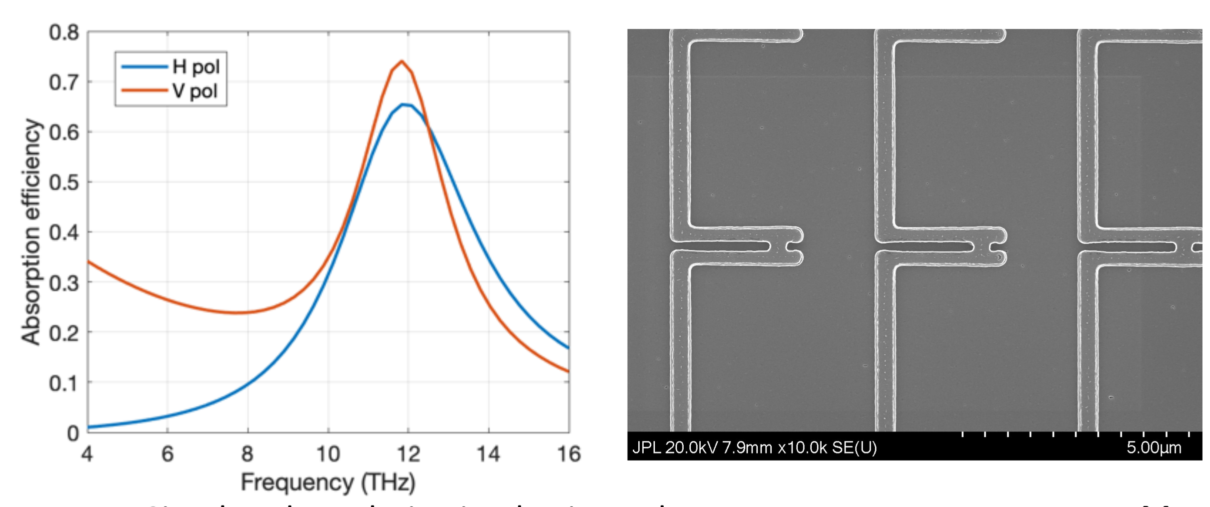

Fig.3 resonant absorption characteristics of periodic structure

Approach and Results:

Detector array implementation:

- Lenslet-coupled aluminum KID arrays (fig. 2)

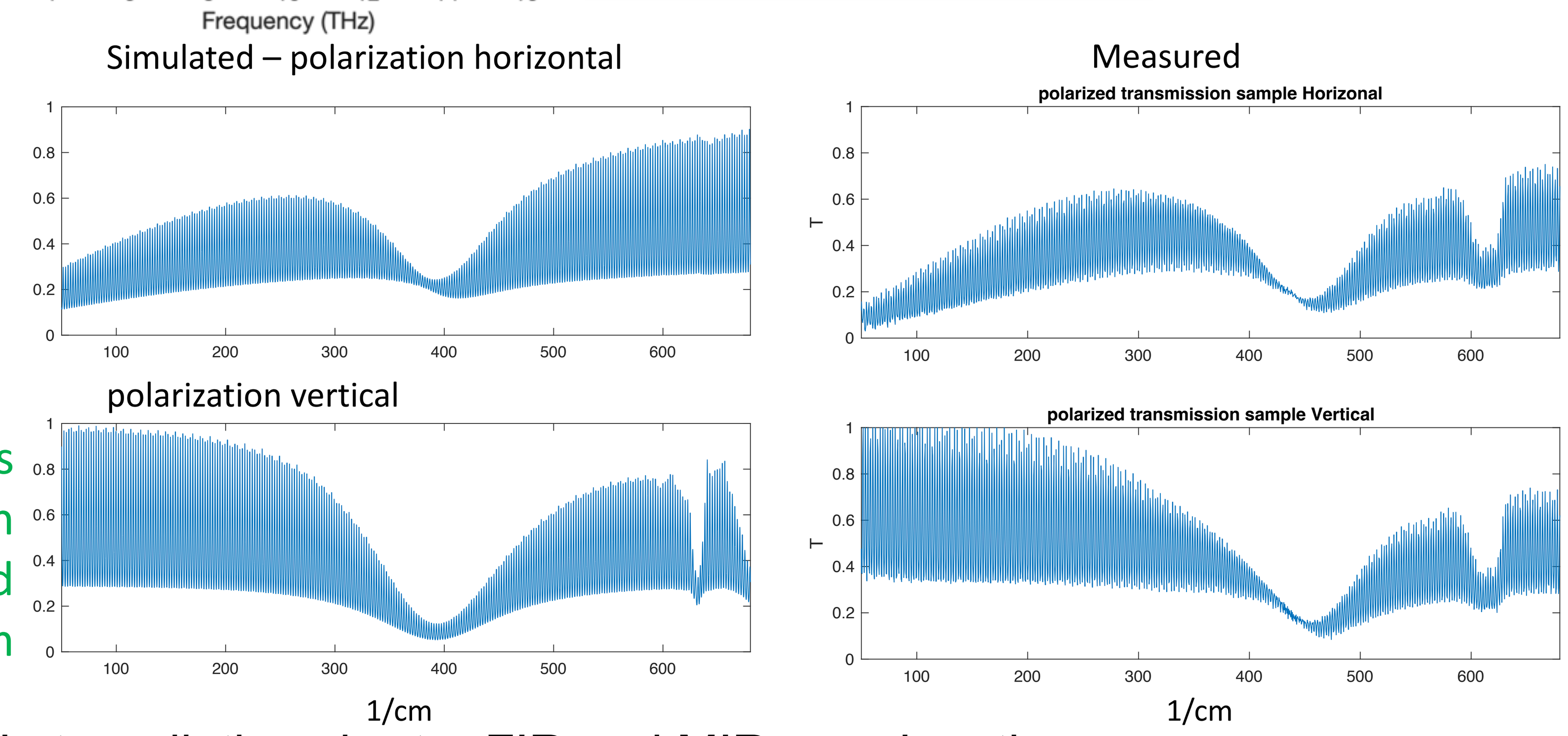

Fig.4 FTS measurements compared to simulation showing absorption around 25 um

Resonant absorbers:

- As a high electrical conductivity metal, aluminum detectors are difficult to couple to radiation shorter FIR and MIR wavelengths.
- To meet this challenge, we have developed a resonant absorber concept that allows for the extension of the frequency range of aluminum KID arrays down to as short as 10 μm.
- The concept is to pattern the aluminum absorbing element of the KID into a frequency selective surface with resonant characteristics that effectively impedance match free space to the lower surface impedance of the aluminum film. The 0.2 μm linewidth of the resonant absorber allows for rapid production on the stepper has resulted in > 90% yield for the arrays.
- In the first year of this project, arrays tuned for 25 μm wavelength were be fabricated and tested electrically (figs. 2 and 3). The absorption characteristics of the resonant absorber were tested separately by fabricatingthe absorber pattern over a large area and measuring transmission with an FTS (fig. 4).

Parallel-plate capacitors with amorphous Silicon (aSi) dielectric:

- Deposited dielectrics have been avoided in the past in KID construction because of associated two-level systems (TLS) noise and dissipation.
- In recent work, particularly by Andrew Beyer (JPL) and Sunil Golwala's group on campus, aSi films have been produced with loss tangent d = 10^{-5} (Q = 100,000), which is easily large enough for the KID resonator.
- We have measured the dielectric fluctuation noise of these films and have found it comparable to good single layer KID resonators and actually better than resonators using single layer inter-digital (IDC) capacitors with narrow line/space dimensions.
- The capacitance of the parallel plate structure is much larger than an IDC, allowing for a reduction in resonance frequency, which increases the multiplexing factor of the readout

Significance/Benefits to JPL and NASA:

- Beyond direct application to PRIMA, we are developing new techniques and applying recent innovations to produce superconducting detector arrays spanning the mid- and far-infrared wavelength ranges. Major future orbital astronomical facilities, including the Surveyor-class Origins Space Telescope (OST), will require large arrays of mid- and far-infrared detectors. Origins will require 5×10^4 detectors spanning wavelengths continuously from 10 μm to 400 μm, with noise equivalent powers (NEPs) of 4×10^{-20} W $Hz^{-1/2}$

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

Clearance Number: CL#
Poster Number: RPC#R22025

Publications:

none

PI/Task Mgr. Contact Information:

Email: Peter.K.Day@jpl.nasa.gov