

Technology Developments for FIR Bolometric Detector Focal Plane Assemblies



Ari Brown

Detector Systems Branch, NASA Goddard Space Flight Center

April 26, 2024

MAE Seminar, UC Irvine

NASA Goddard Space Flight Center



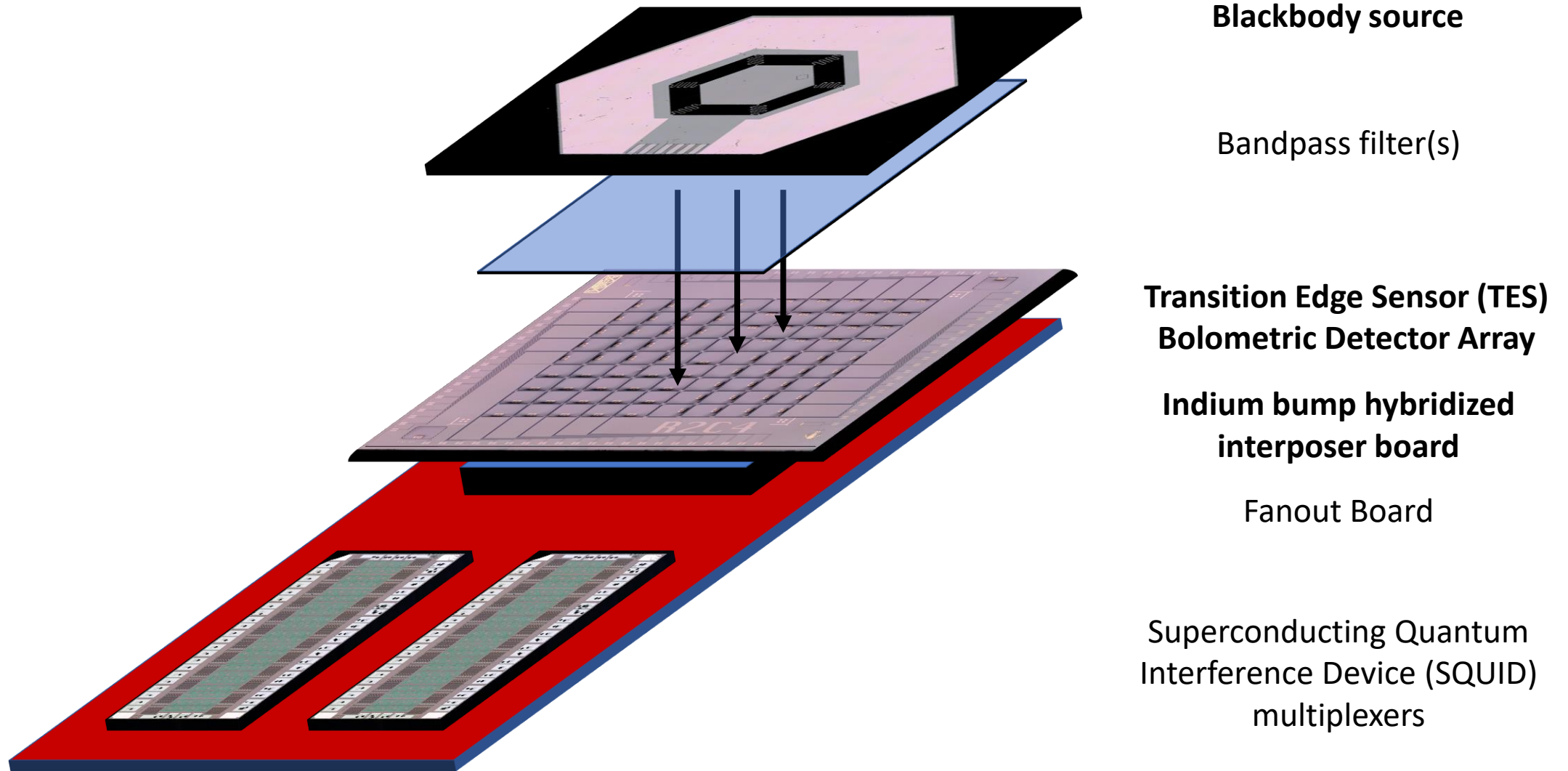
Goddard is NASA's premiere space flight complex and home to the nation's largest organization of scientists, engineers, and technologists who build spacecraft, instruments, and new technology to study Earth, the Sun, our solar system, and the universe.

NASA GSFC's Detector Systems Branch

- The Detector Systems Branch builds and characterizes a wide range of products from ***single custom detectors*** to entire instruments for NASA, other government agencies, universities, and industry.
- These detectors span the entire electromagnetic spectrum from the millimeter to cosmic rays.
- The Branch fabricates and tests Micro-Electro-Mechanical-Systems (MEMS) and nanotechnology components.
- Our detectors can be found on NASA's spacecraft, aircraft, balloons, and rockets, as well as on Earth-based telescopes.



Laboratory characterization of next generation pixelated far-infrared (FIR) focal plane assemblies



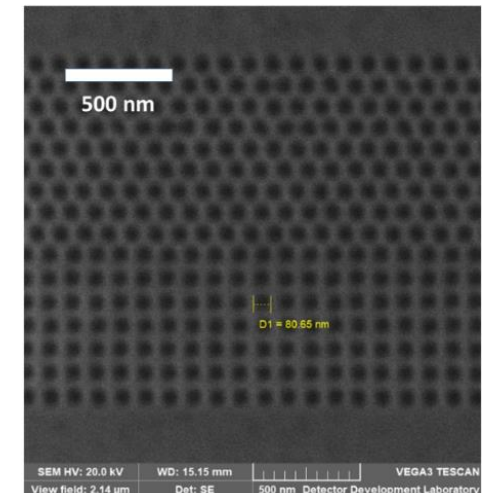
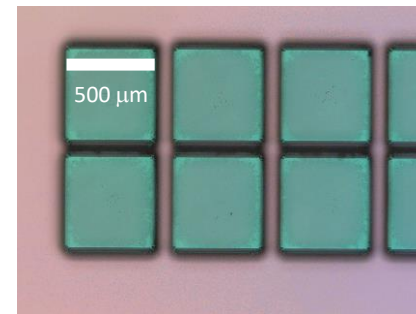
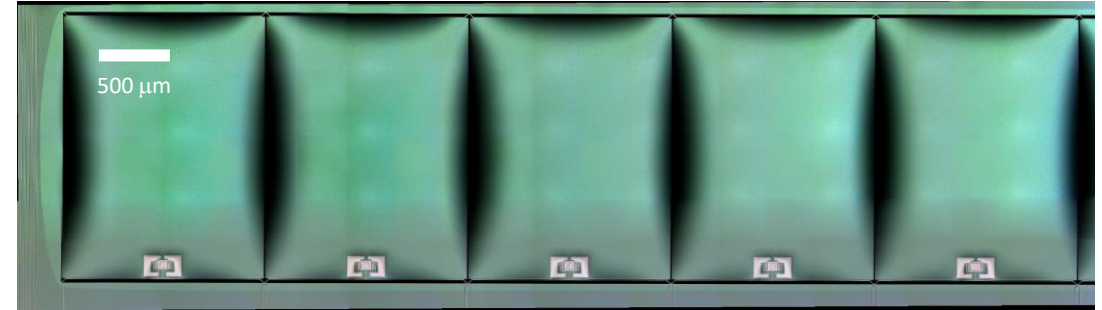
Advances in detector focal plane assemblies undertaken at Goddard

- TES bolometers – strategies for high filling factor, low noise-equivalent power (NEP) devices.
- Absorber coatings – broadband coatings with & without spectral filtering.
- Resonant backshorts – micromachined flat and wedged backshorts.
- Blackbody sources – micromachined, fast, *in situ* devices.
- Indium bump hybridization – depositing bumps on non-planar surfaces.

Strategies for fabricating high filling factor, ultrasensitive, TES bolometric detectors

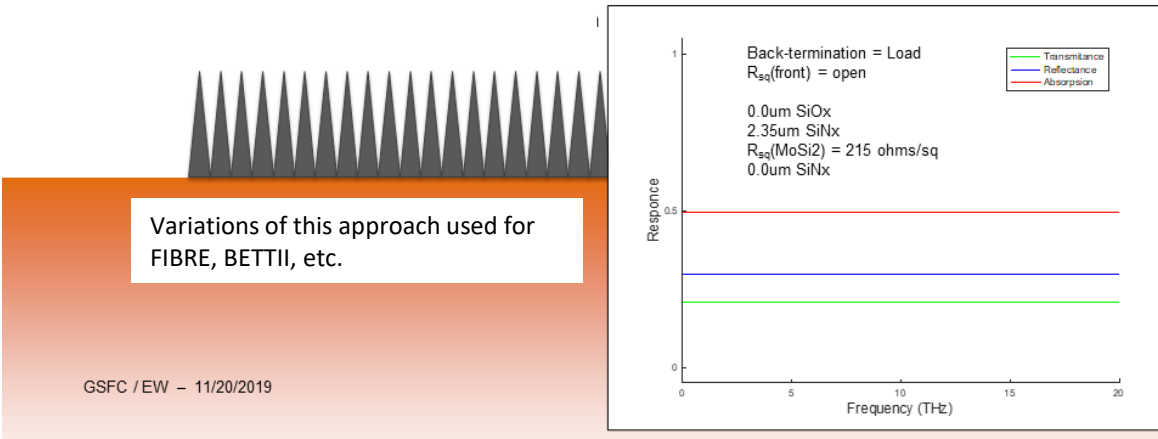
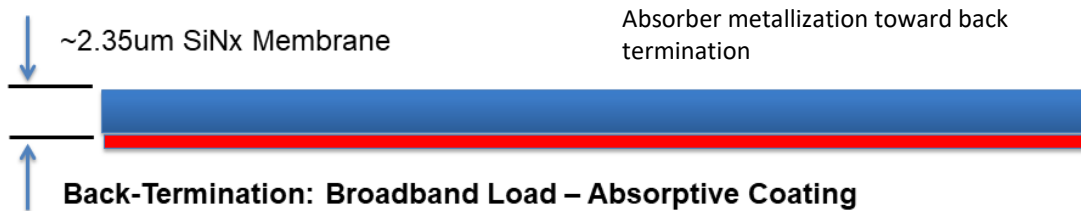
- Novel membrane release strategies for large, leg-isolated pixels¹.
- Novel back-etch strategies to enable fabrication of devices with narrow rigid frames between pixels.
- Development of perforated dielectric thermal isolation legs for reduction of thermal conductance².

1. A.D. Brown *et al.*, J. Low Temp. Phys, 2018;
A. D. Brown *et al.*, US Patent no. 11,101,158, 2021
2. K. Denis *et al.*, SPIE Proc., 2019

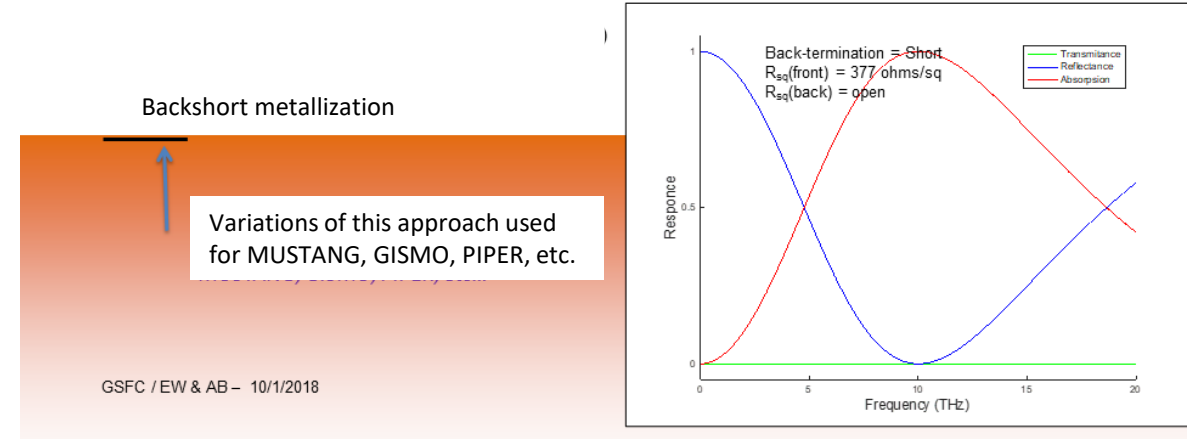
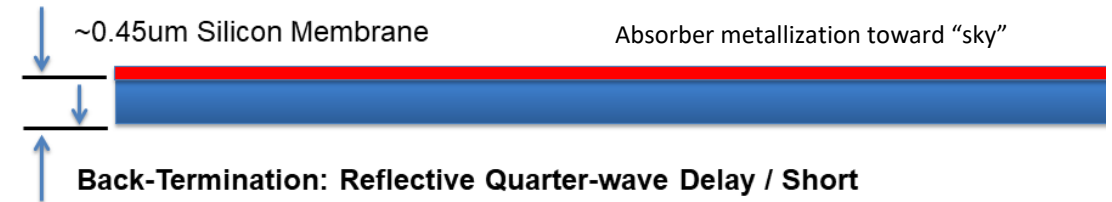


Impedance-matched absorber coatings

Frequency-independent/broadband (~**50% efficiency**)

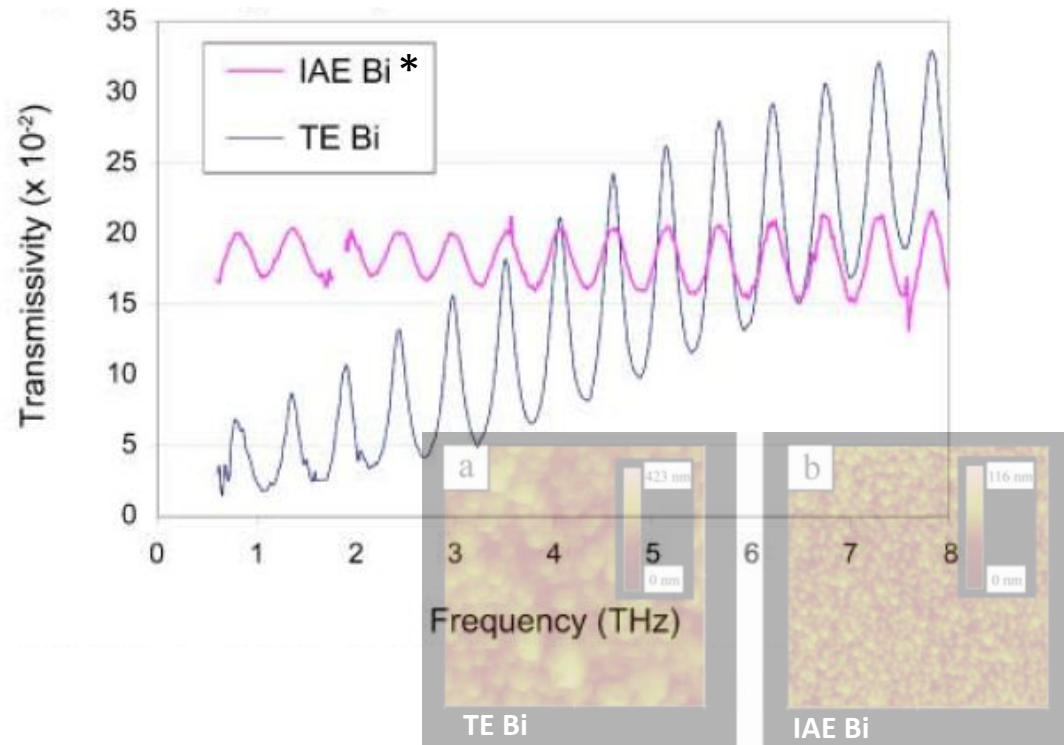


With reflective backshort (~**100% efficiency at narrow band**)

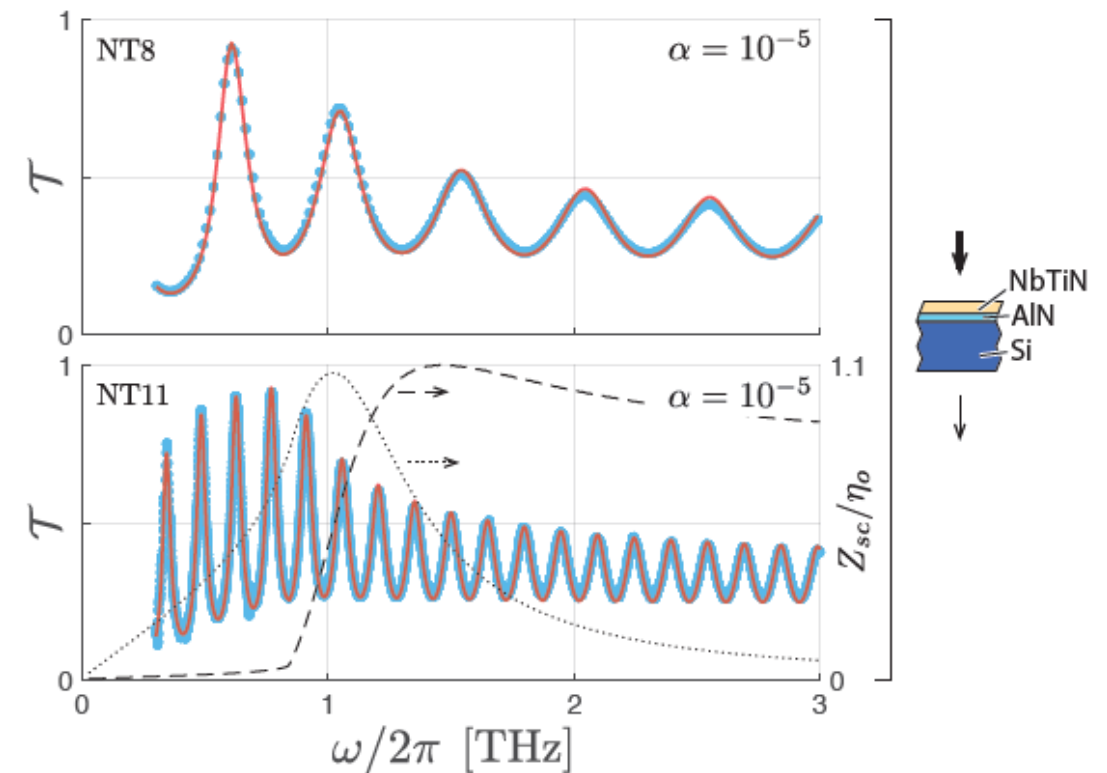


Impedance matched coatings considerations – spectral response

Impact of microstructure engineering¹



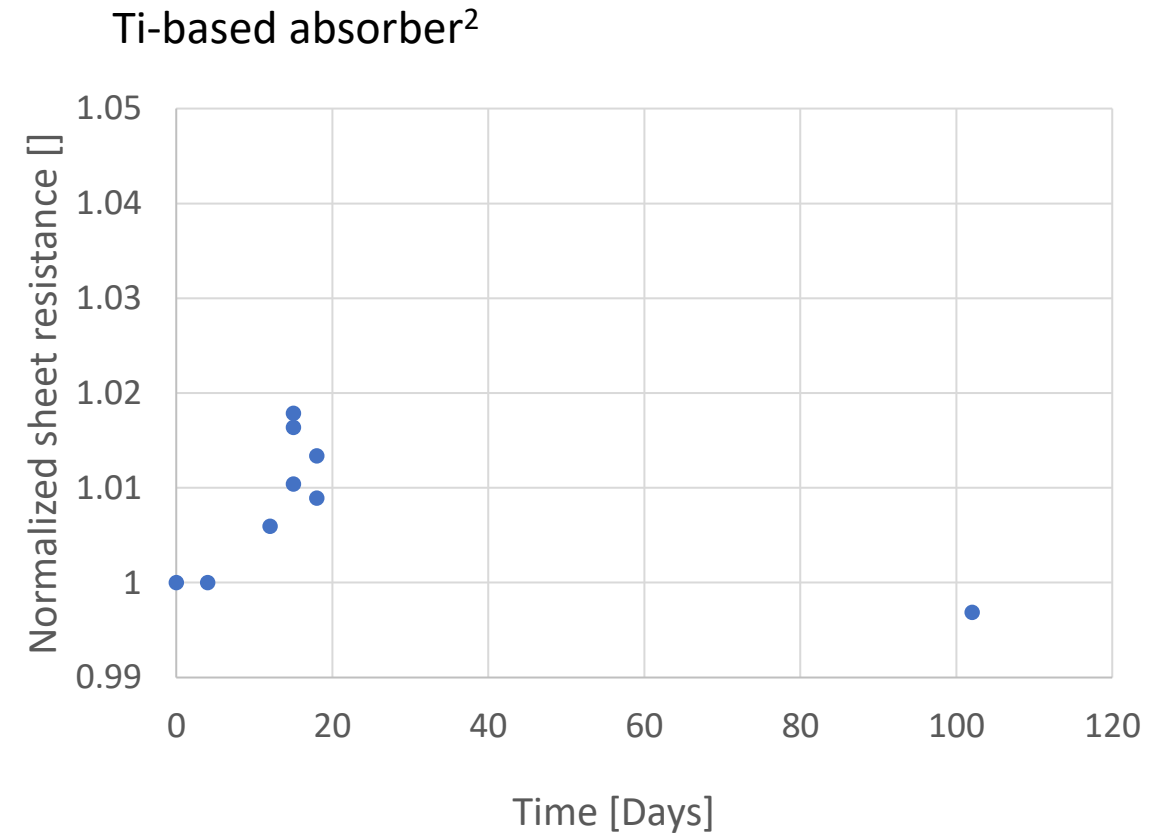
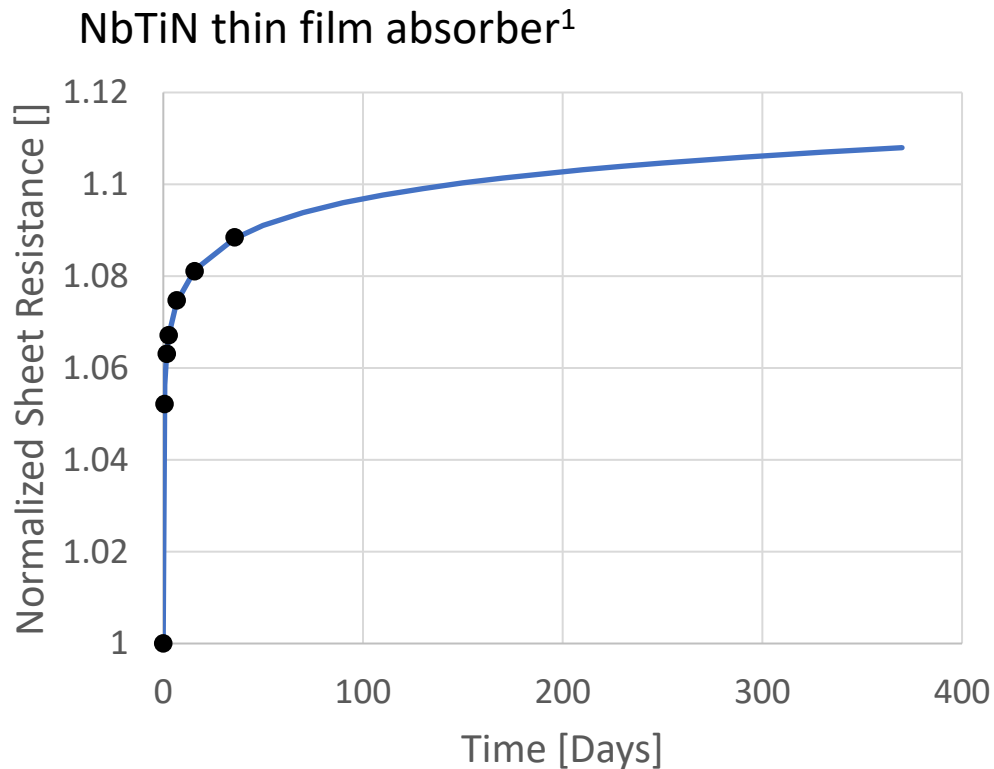
Spectral filtering by using superconducting film



1. A.D. Brown *et al.*, AIP Conf. Proc., 2009

* IAE Bi= ion assisted evaporated bismuth; TE Bi = thermally evaporated bismuth

Impedance matched coatings considerations - aging

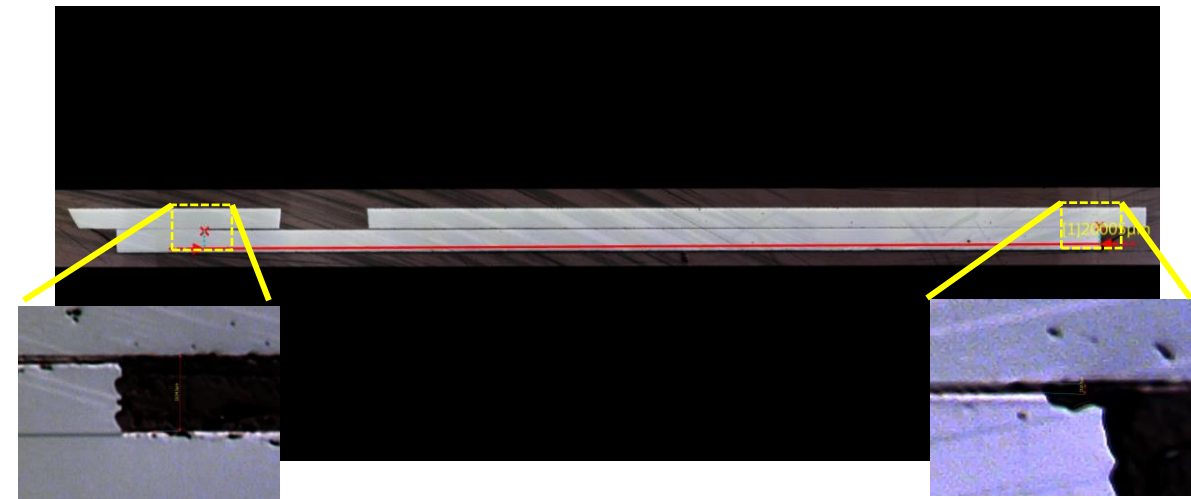
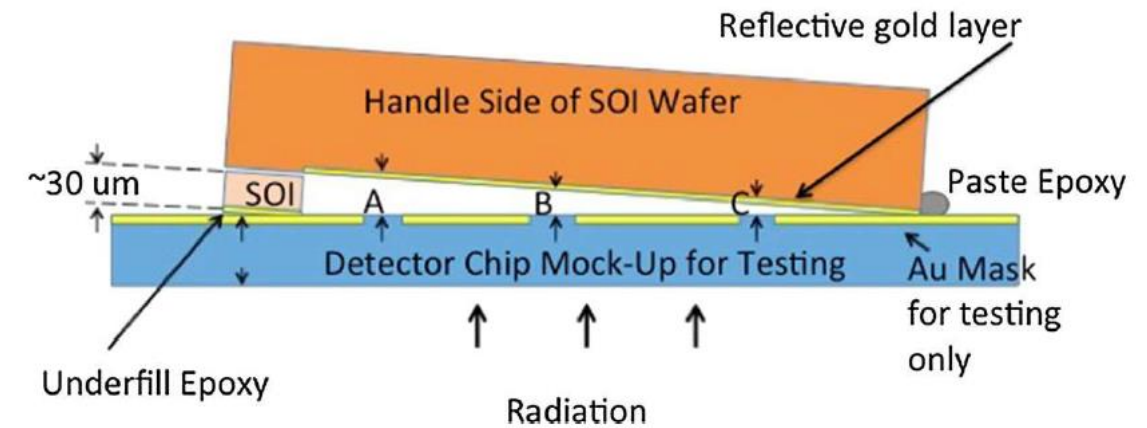


1. A.D. Brown *et al.*, US Patent no. 10,458,853, 2019;
2. A.D. Brown *et al.*, New Technology Report GSC-19068-1

Resonant backshorts for enhanced optical coupling

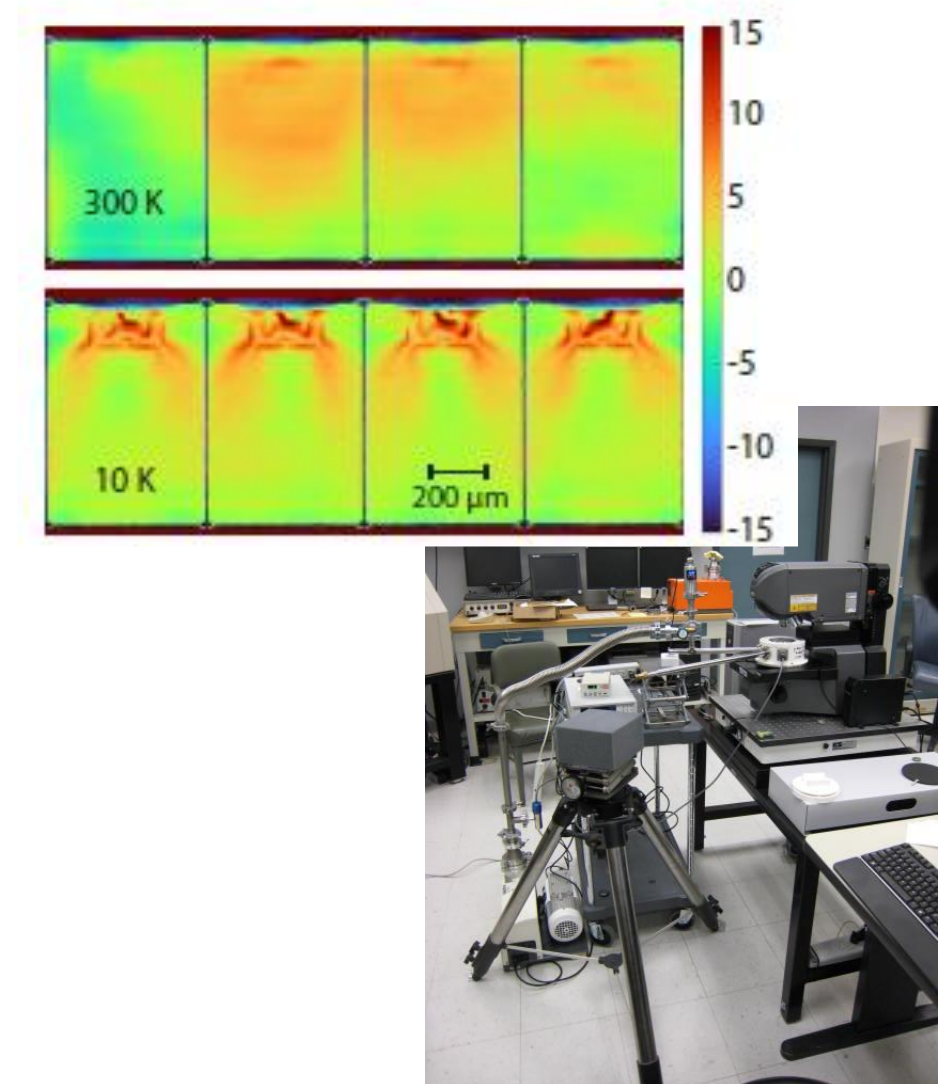
- Micromachined resonant backshort from a silicon on insulator wafer¹.
- Extremely tight control over electrical delay by specifying SOI device layer thickness and die dimensions.
- No CTE mismatch-related issues.

1. T. M. Miller *et al.*, J. Low Temp. Phys, 2018



Resonant backshort considerations

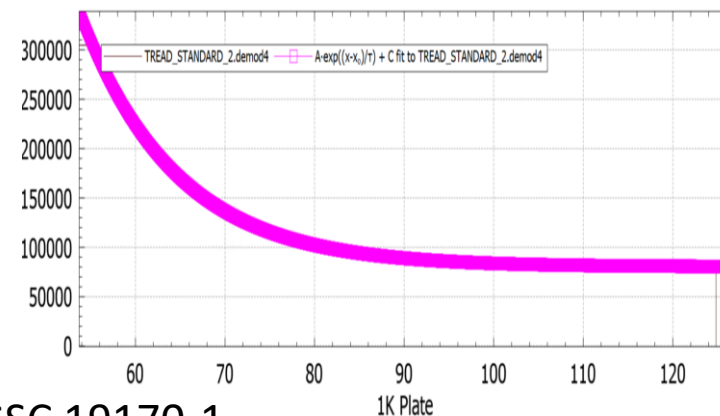
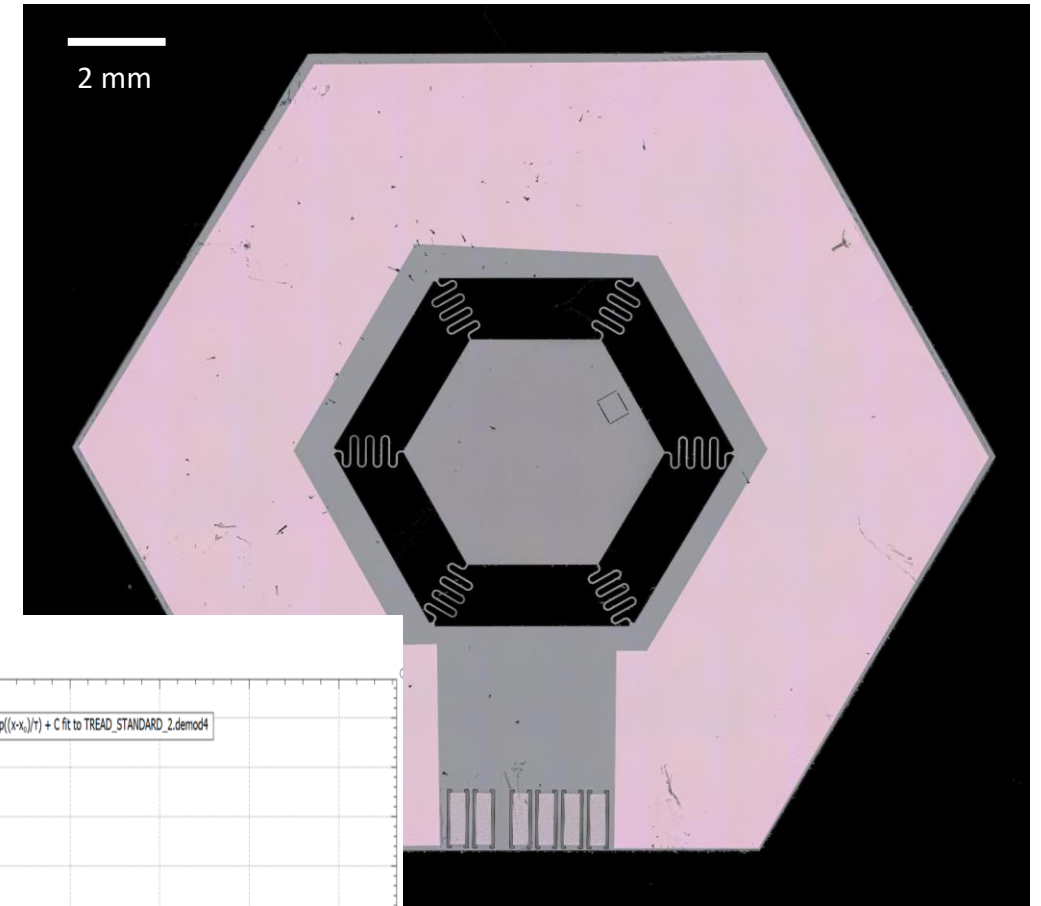
- Electrical delay impacted by pixel curvature.
- On account of CTE mismatch between metallic TES and dielectric membrane, a strategy for measuring pixel curvature a cryogenic temperature has been developed¹.



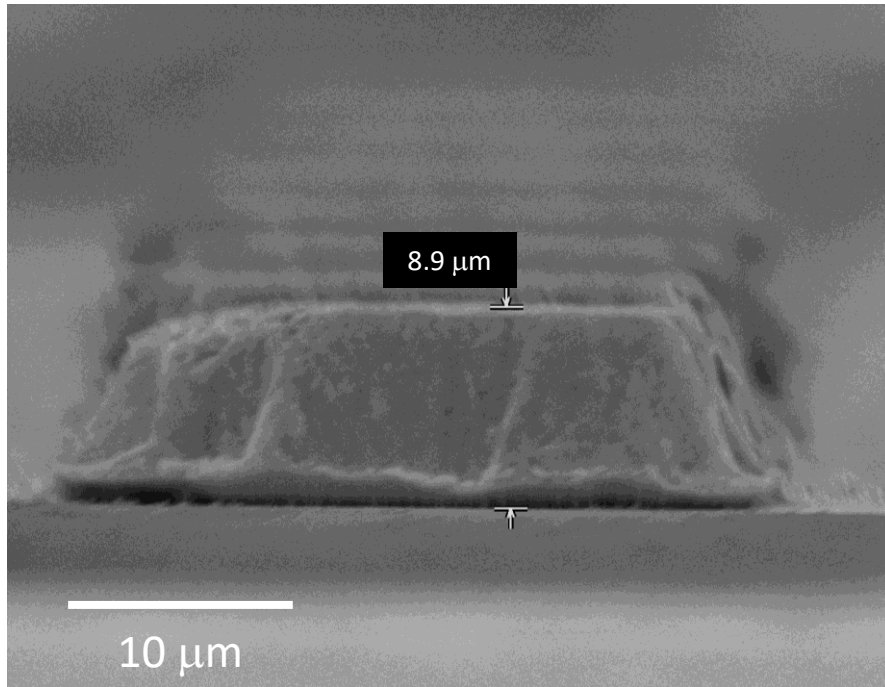
1. K. Rostem *et al.*, Rev. Sci Instru., 2023

Blackbody THz sources for laboratory detector characterization

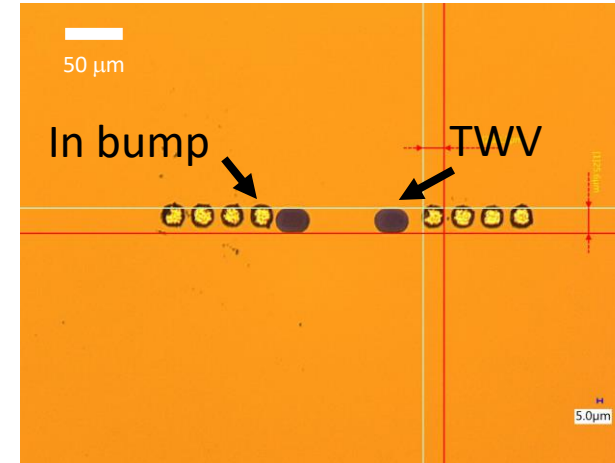
- Compact, fast, blackbody source, fabricated on silicon-on-insulator wafer.
- Uses implanted Si heater and thermistor. High emissivity (impedance-matched) coating deposited on one side of device.



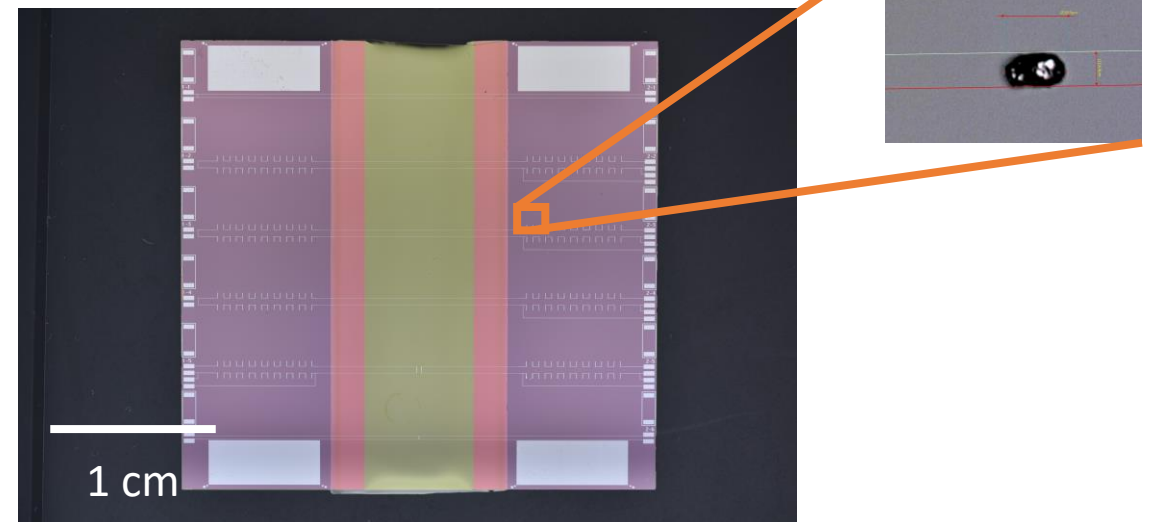
Indium bumps on non-planar surfaces



In bumps near through-wafer vias (TWV)¹

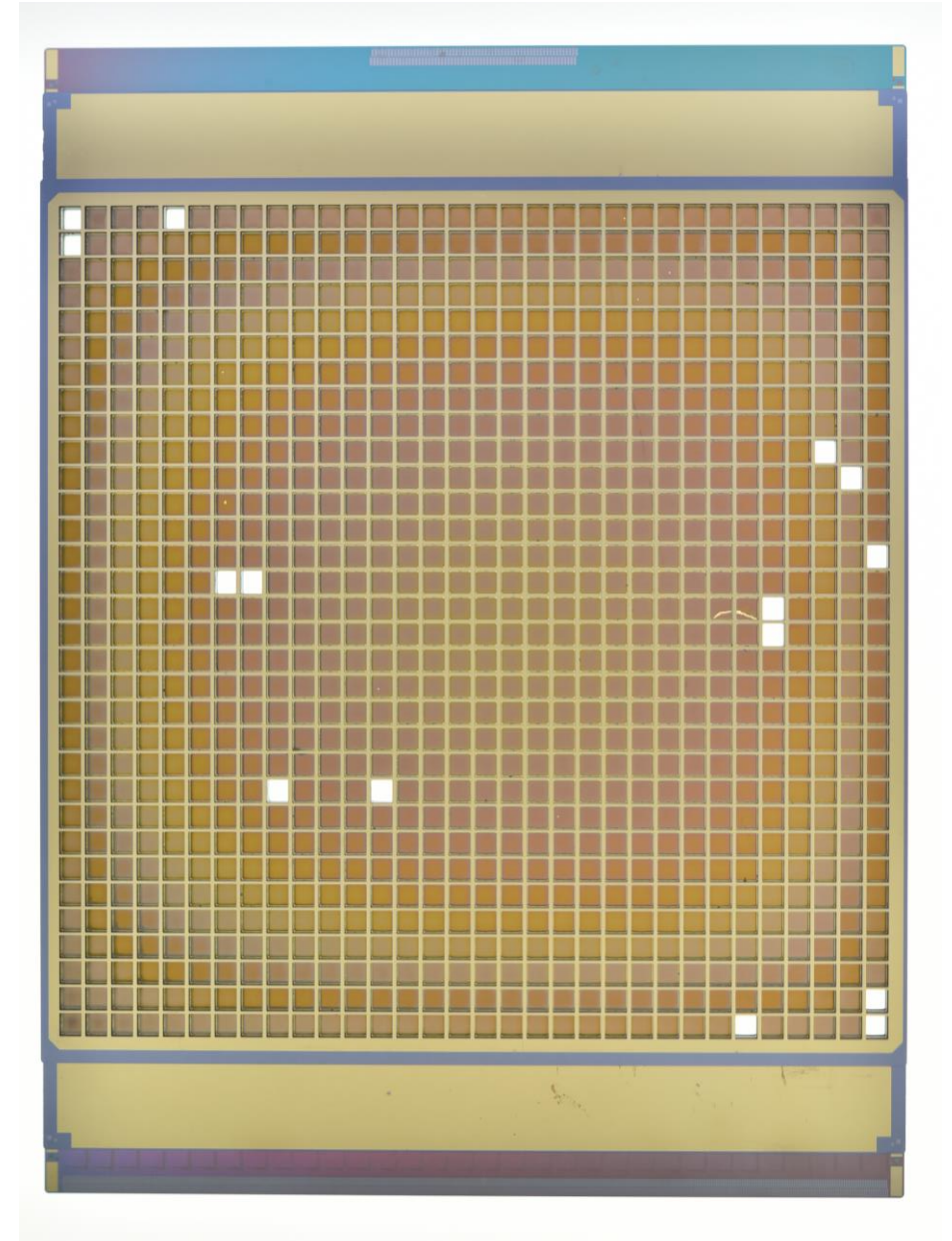
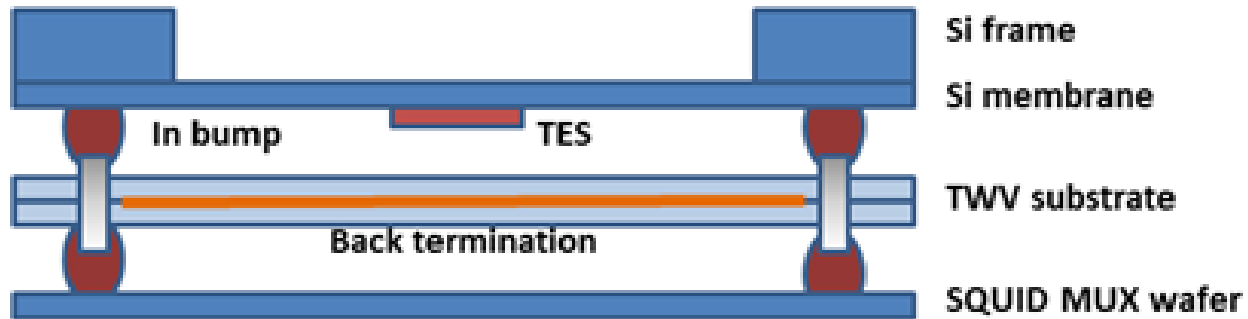


In bumps near polyimide features^{2,3}



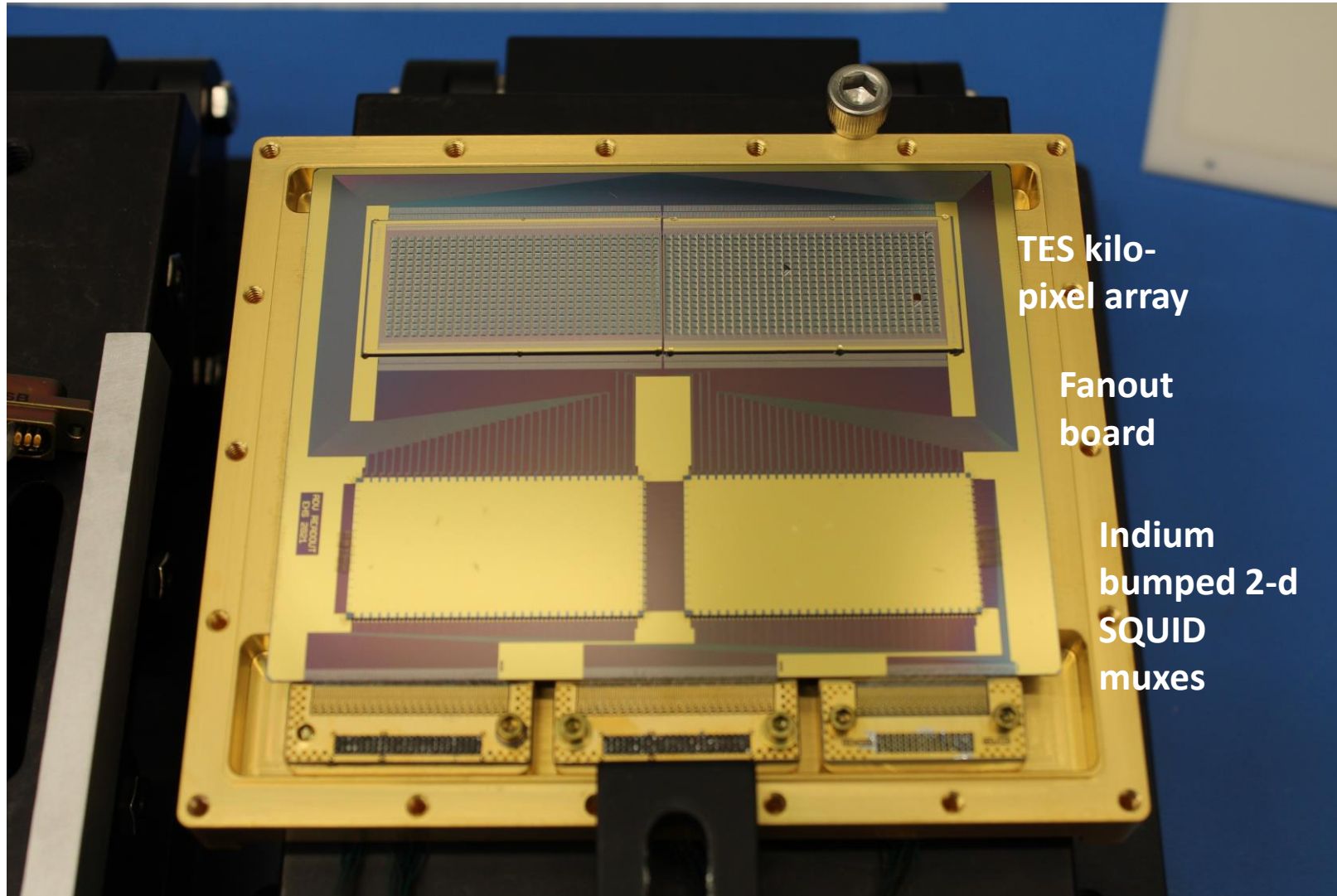
1. A.D. Brown and V. Mikula, US Patent no. 10,923,446, 2021
2. A.D. Brown, *et al.*, NASA New Technology Report 19192-1
3. J. Staguhn, *et al.*, J. Low Temp. Phys. *In press*

“Triple-stack” prototype¹



1. J. Staguhn *et al.*, J. Low Temp. Phys, 2022

Completed focal plane assembly



THz source shown on previous slide will be used to illuminate pixels soon.

Summary

- NASA Goddard, with outside partners, is working on a myriad of different technologies to advance bolometric detector focal plane assemblies.
- Some of our focus areas include:
 - Low noise, high filling fraction, transition edge sensors
 - FIR coupling schemes
 - FIR radiation sources
 - Indium bump hybridization

Contributors

- NASA GSFC:
 - Vilem Mikula
 - Karwan Rostem
 - Johannes Staguhn
 - Edward Wollack
 - Archana Devasia
 - Kevin Denis
 - Ryan Kent
 - Stephen Lebair
 - Felipe Colazo-Petit
 - Nicholas Costen
 - Frederick Wang
 - Elmer Sharp
 - Dale Fixsen
 - Samelys Rodriguez
 - Ian Schrock
 - Timothy Miller
 - Manuel Quijada
 - Kevin Miller
 - Jessica Patel
 - Alexander Kutyrev
 - Regis Brekosky
 - James Chervenak
 - Sang Yoon
- NIST-Boulder:
 - Shannon Duff
 - Gene Hilton
 - Michael Vissers
- Princeton University:
 - Bert Harrop
 - Suzanne Staggs