National Aeronautics and Space Administration

Hierarchical Antennas for mm-wave Spectroscopy on a Chip

Principal Investigator: Andrew Beyer (389); Co-Investigators: Clifford Frez (389), Sunil Golwala (Caltech), Fabien Defrance (Caltech)

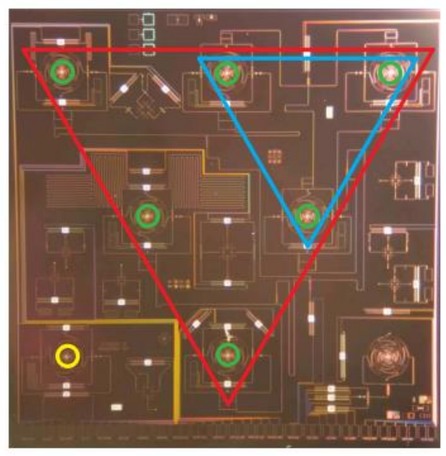
Program: FY22 R&TD Topics
Strategic Focus Area: Direct/Coherent Detectors and Arrays

Objectives:
To develop hierarchical, superconducting phased-array antennas for 3D mapping of universe over entire THz spectral band (0.1 THz-2 THz).
0.1-2 THz replete w/ molecular rotational, atomic fine-structure lines in star-forming environments from Milky Way to highest redshifts at which galaxies exist

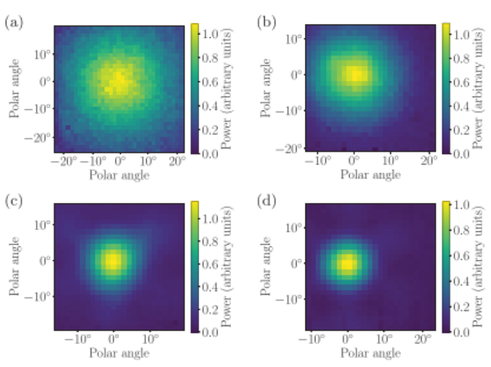
Background

THZ spectrometers: potential to map universe in 3D (good angular resolution on the sky and redshift depth).
-Fixed element receiving antenna limits efficiency w/ tight beam profile to ~half octave (v_{max}:v_{min} 1.65:1)→reduces 3D potential of detectors.
-Solution→ hierarchical antennas extend v_{max}:v_{min} to ~ 1:6.

State-of-the-art (SOA)



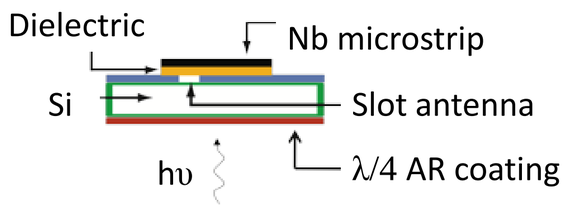
Both figs.: A. Cukierman,et.al. APL112, 132601 (2018)

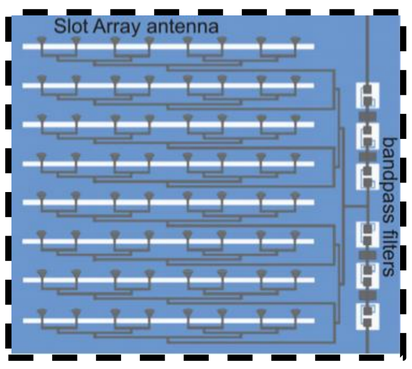


Beam maps at a) 90 GHz and b) 150 GHz, fixed element antenna vs. c) 90 GHz and d) 150 GHz w/ hierarchical-array antennas.

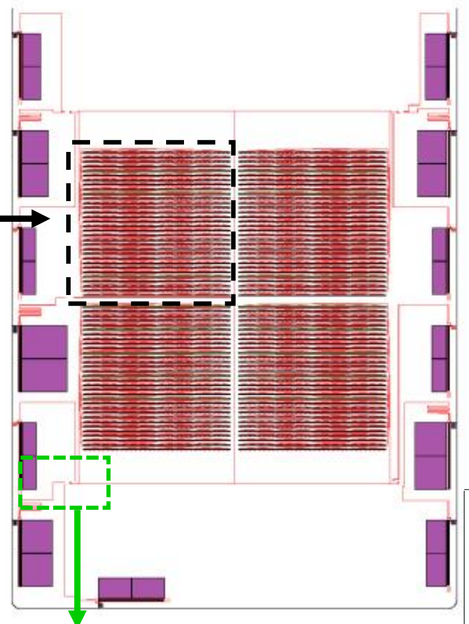
SOA issues: 1) Artifacts from inefficient filling of focal plane. 2) Our approach→ E-field uniform illumination and translational symmetry for expansion across a focal plane. 3) SOA requires lenslets. JPL: spectroscopic mapping; will not need lenslets. Bottom line→ Simpler: flat and no lenslet/wafer mating.

Approach

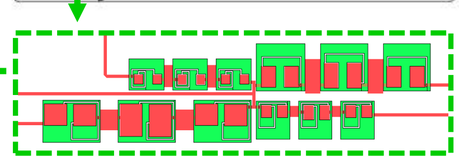




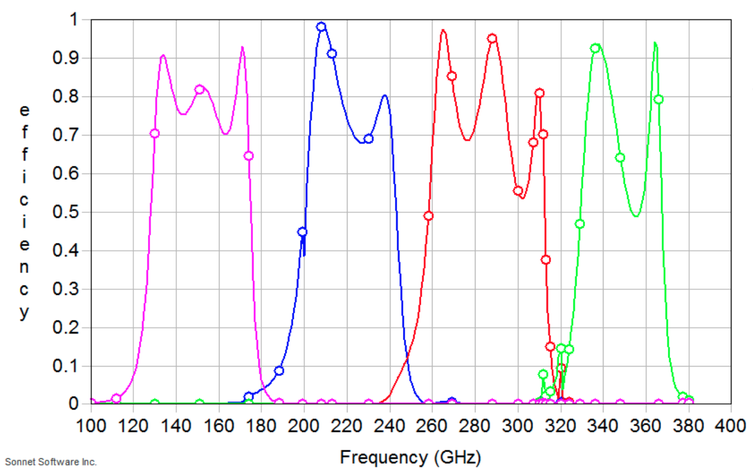
Above: Superconducting phased-array antenna components. Right: Fundamental array element schematic.



Actual design of **2-scale hierarchical antenna**, w/ four fundamental array elements & bandpass filters in μ-strip.

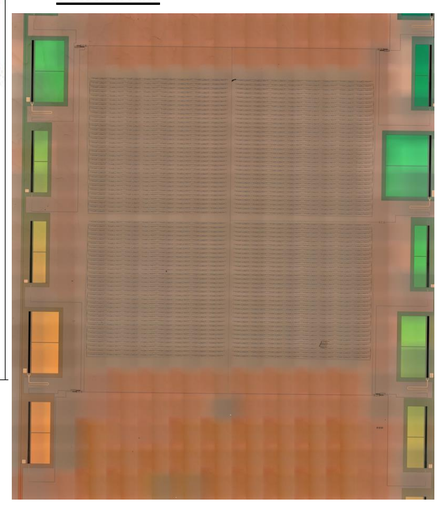


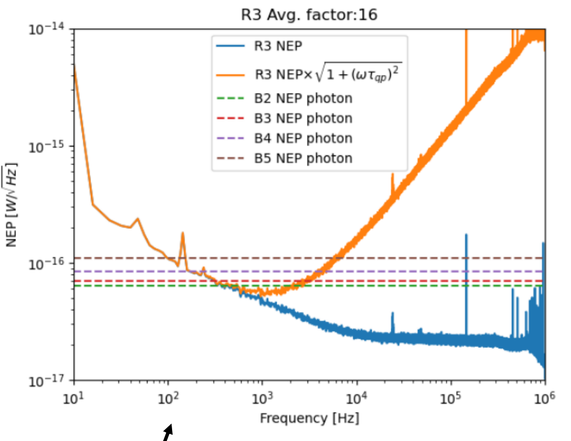
4 of the bandpass filters fed from μ-strip antenna elements



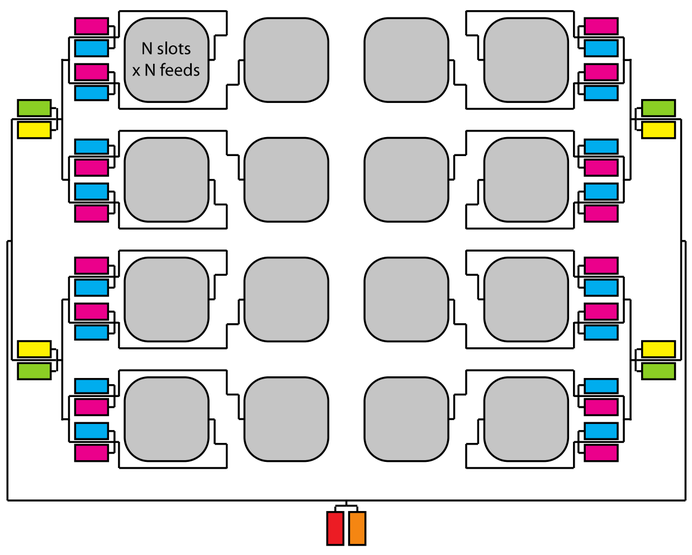
Transmission spectra of 4 filters, simulated from 2-scale full structure, showing high efficiency in each band simultaneously.

Results





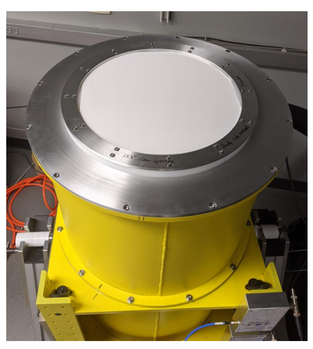
- Detectors 89% yield and designed sensitivity.



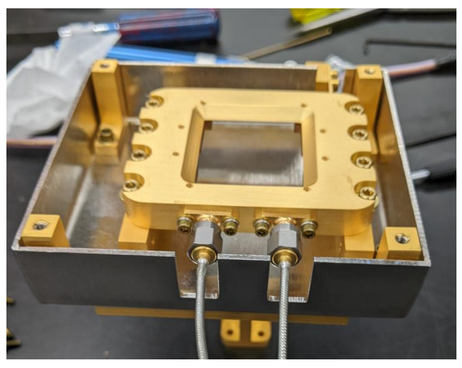
Above: 3-scale antenna for Y2. Each grey square indicates one fundamental element. Colored rectangles indicate bandpass filters. 2-scale antenna consists of one quadrant of the 3-scale antenna.

Microscope image of **2-scale hierarchical antenna**. Fabricated in the Microdevices Laboratory (MDL).

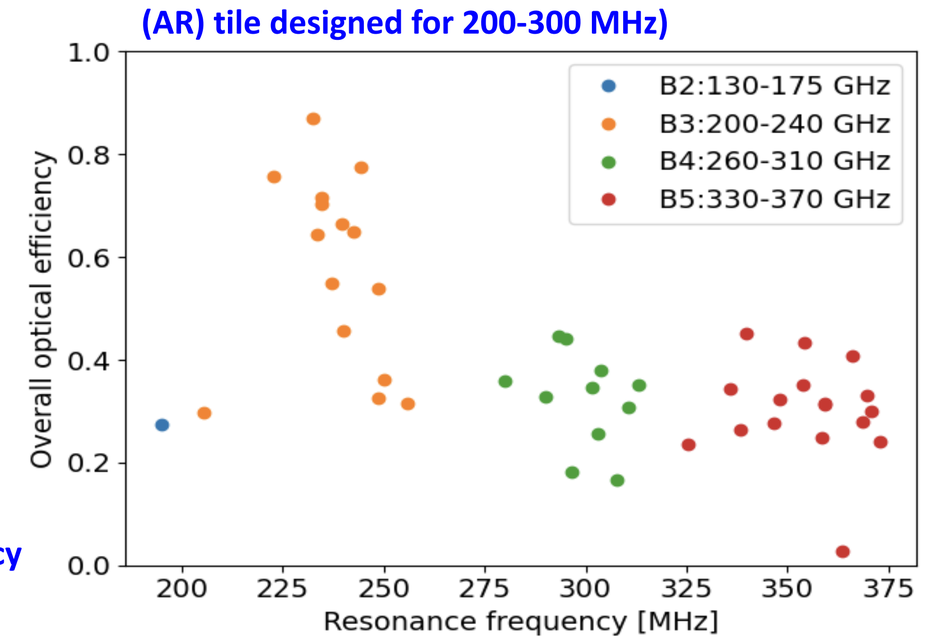
Cryostat upgrades to verify performance: New optical windows installed for beam and bandpass measurements



New device fixture for optimal efficiency collection (backshorts, AR, etc.), beam measurement out to 40-45 deg off-axis



Good optical efficiency (B3 is best as anti-reflection (AR) tile designed for 200-300 MHz)



Significance/Benefits to JPL and NASA:

Instrument infusion into a SuperSpec-based upgrade of the TIM balloon payload. The long-term targets are to assist PRIMA, a long-term flagship FIR mission.

PI/Task Mgr. Contact Information:
Email: Andrew.D.Beyer@jpl.nasa.gov

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

Clearance Number: CL#
Poster Number: RPC#R22122