Recent Developments in Detector Technology

for sub-mm Astronomy

Jochem Baselmans

on behalf of many others

SRON, Netherlands Institute for Space Research

CosmoNanoscience Group, Kavli Institute of Nanoscience, TU Delft

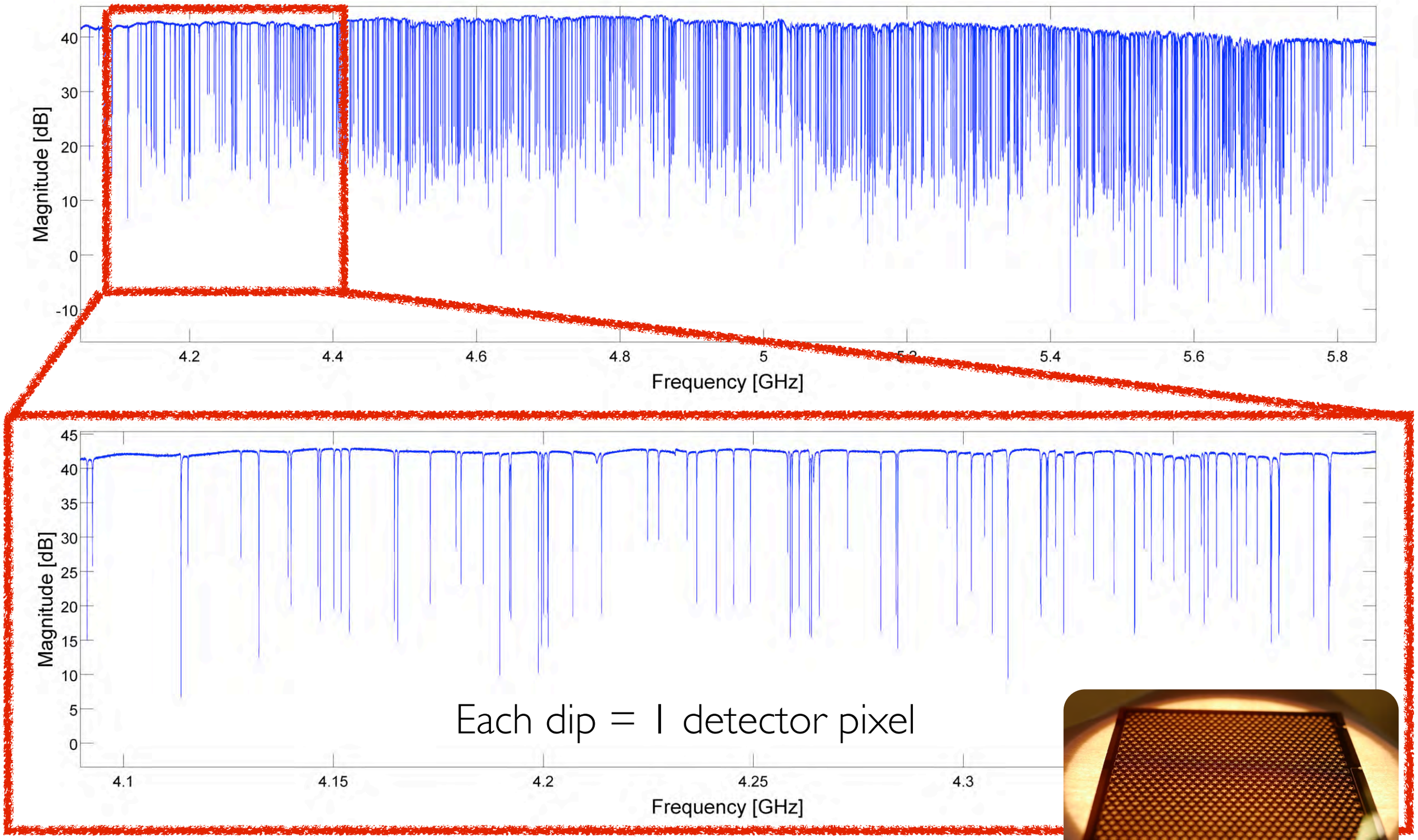
What will I be talking about

Kinetic Inductance Detectors

- Large imaging arrays
- On-chip Spectrometers
- Utra wideband THz-antenna

Large Imaging Arrays

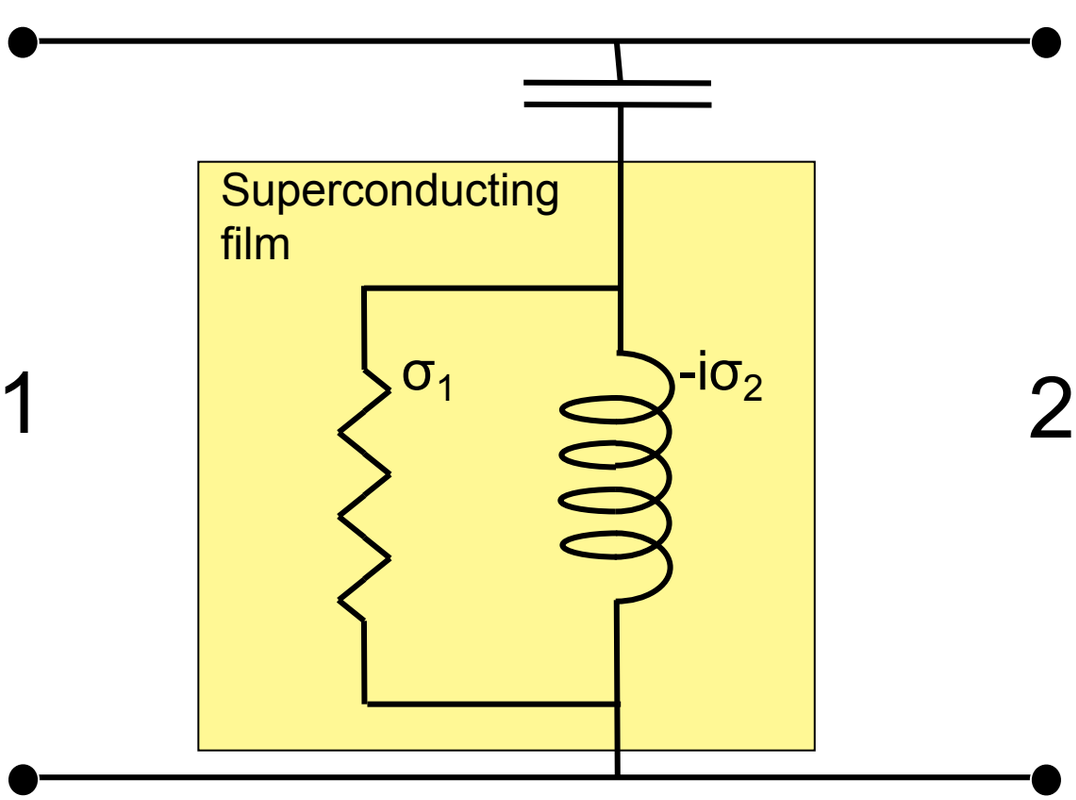
Science case: Many Pixels, > few 1000

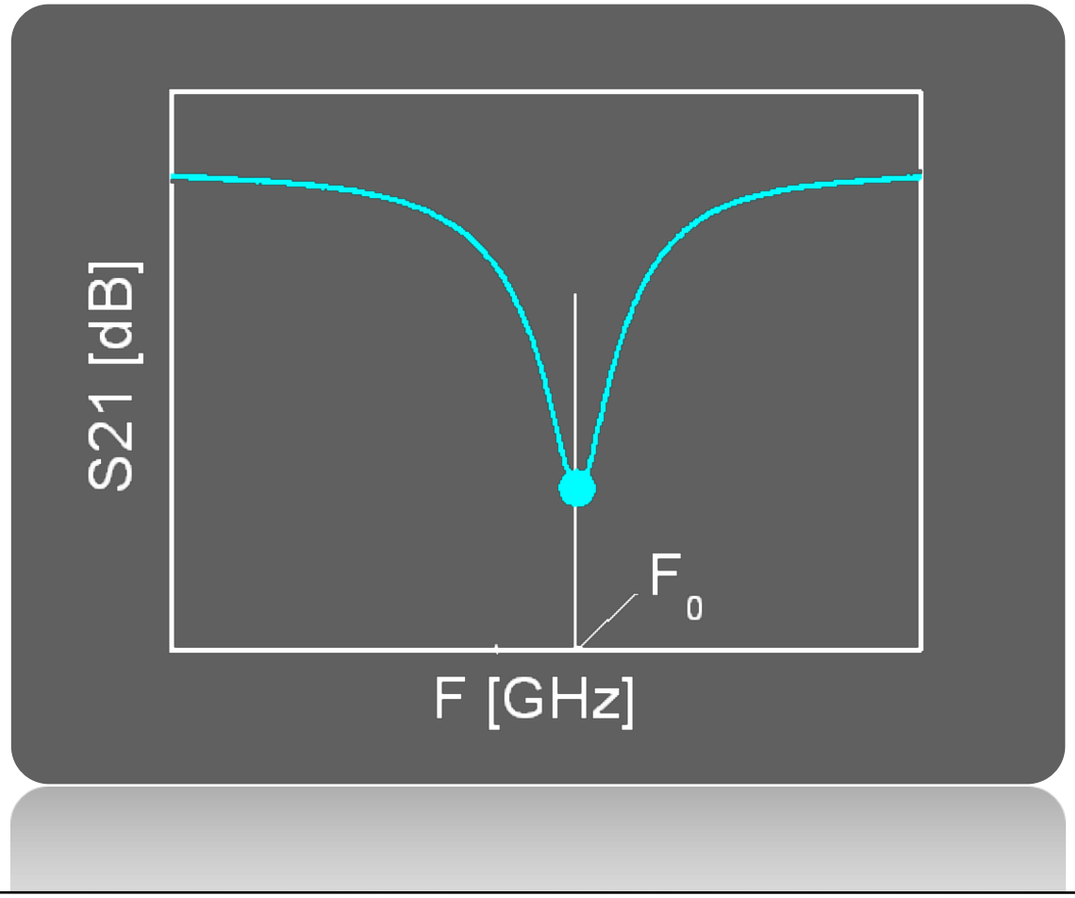


Each dip = 1 detector pixel

The Kinetic Inductance Detector

- Superconducting film
- Inside a microwave resonance circuit
- Capable of coupling to radiation
  - Q ~10^4 -10^6
  - F_o ~1-10 GHz



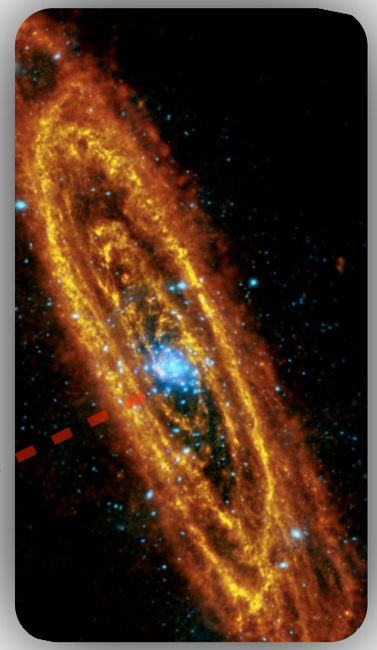


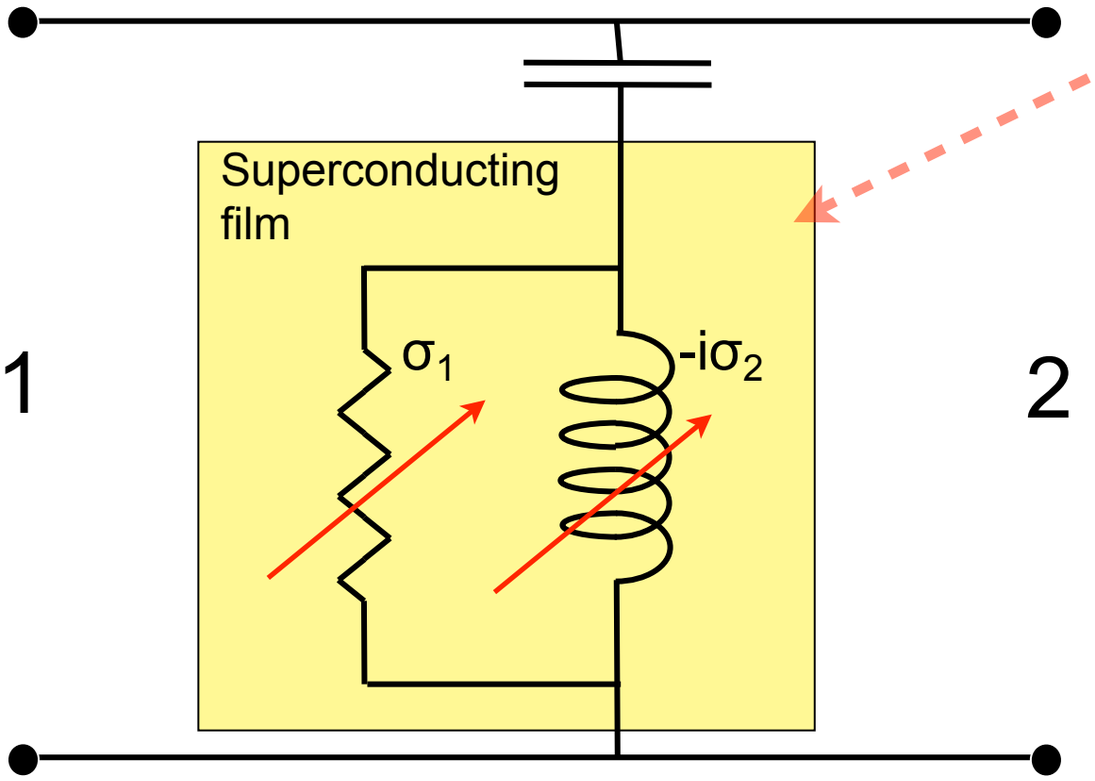
The Kinetic Inductance Detector

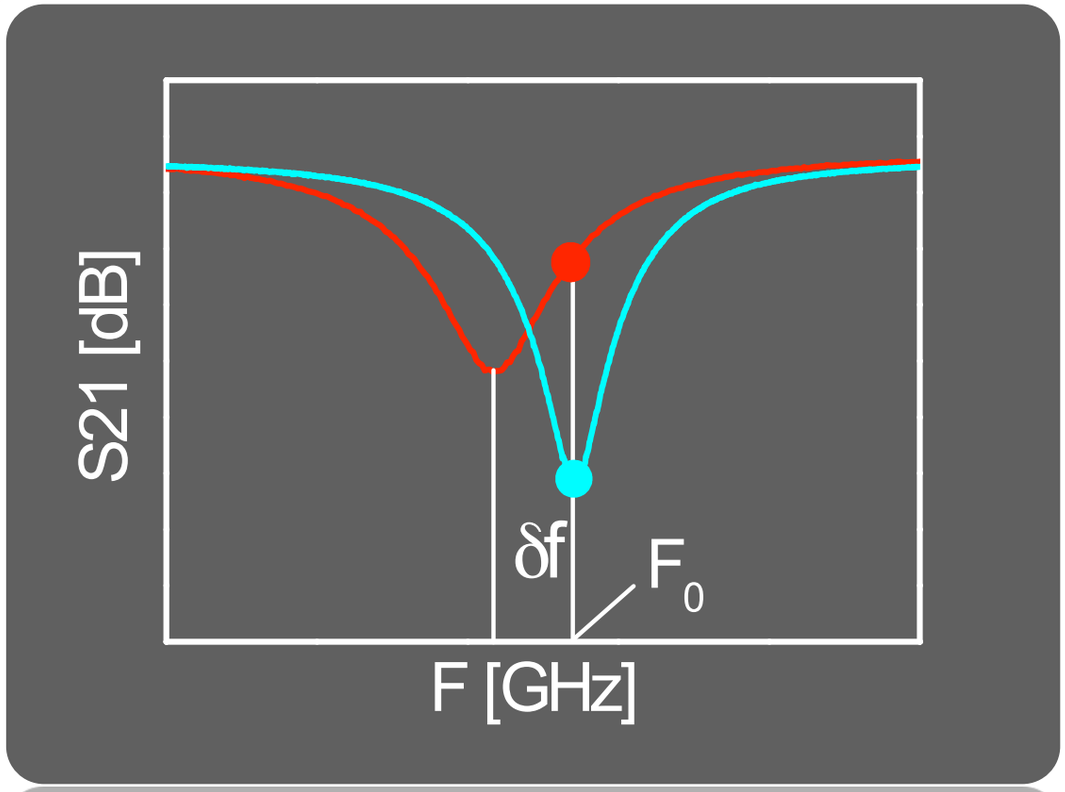
- Superconducting film
- Inside a microwave resonance circuit
- Capable of coupling to radiation

  $Q \sim 10^4 - 10^6$

  $F_o \sim 1 - 10$ GHz







Implementation

2

Transmission line

Lenses

1

CPW resonator

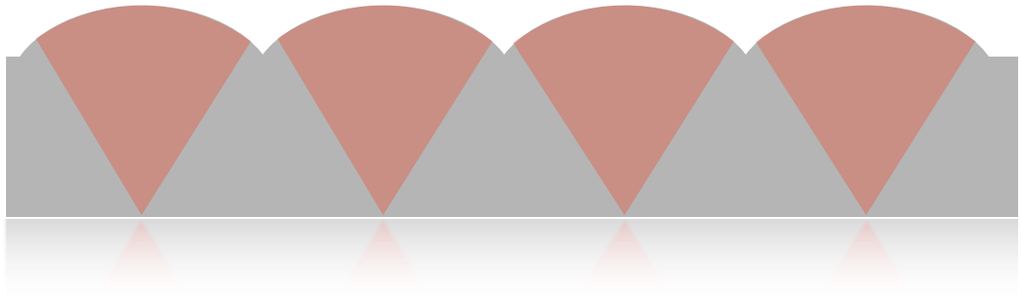
Antenna

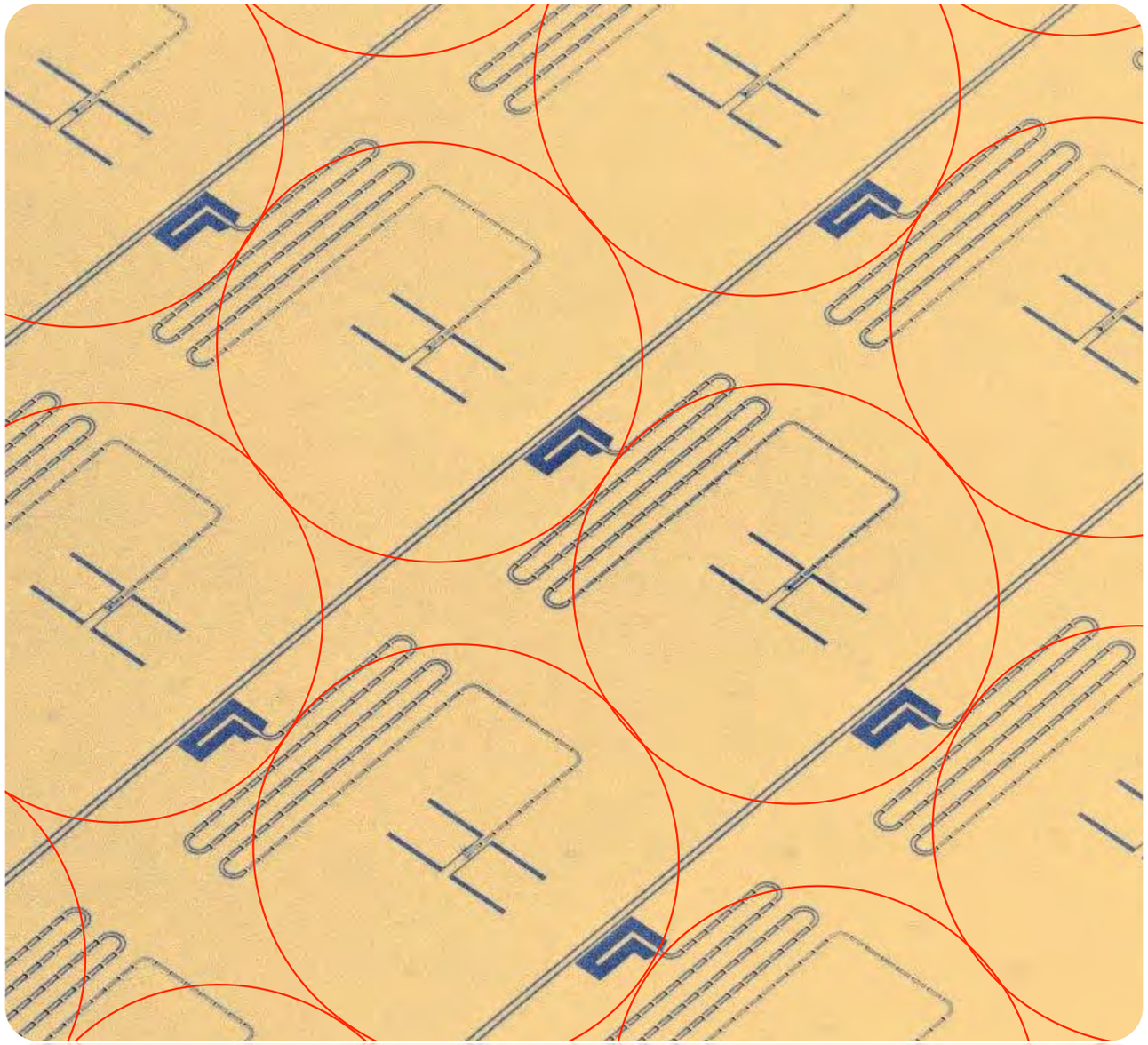
Al: $F_{2\Delta} \simeq 80$ GHz

200 µm

NbTiN: $F_{2\Delta} \simeq 1.2$ THz

KID Imaging Array





- Resonators coupled to 1 transmission line
- Resonators have different length - different resonance frequencies
- All antenna's are identical
- Covered with flies eye lens array

5 feedlines
5400 pixels
Si lens array

2 cm

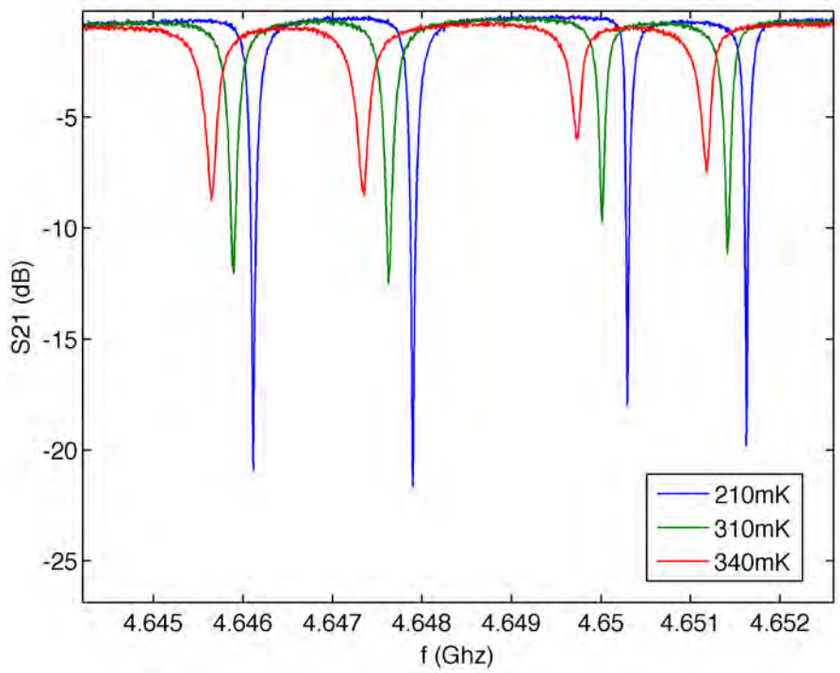
veldlaser
laser micro machining materials

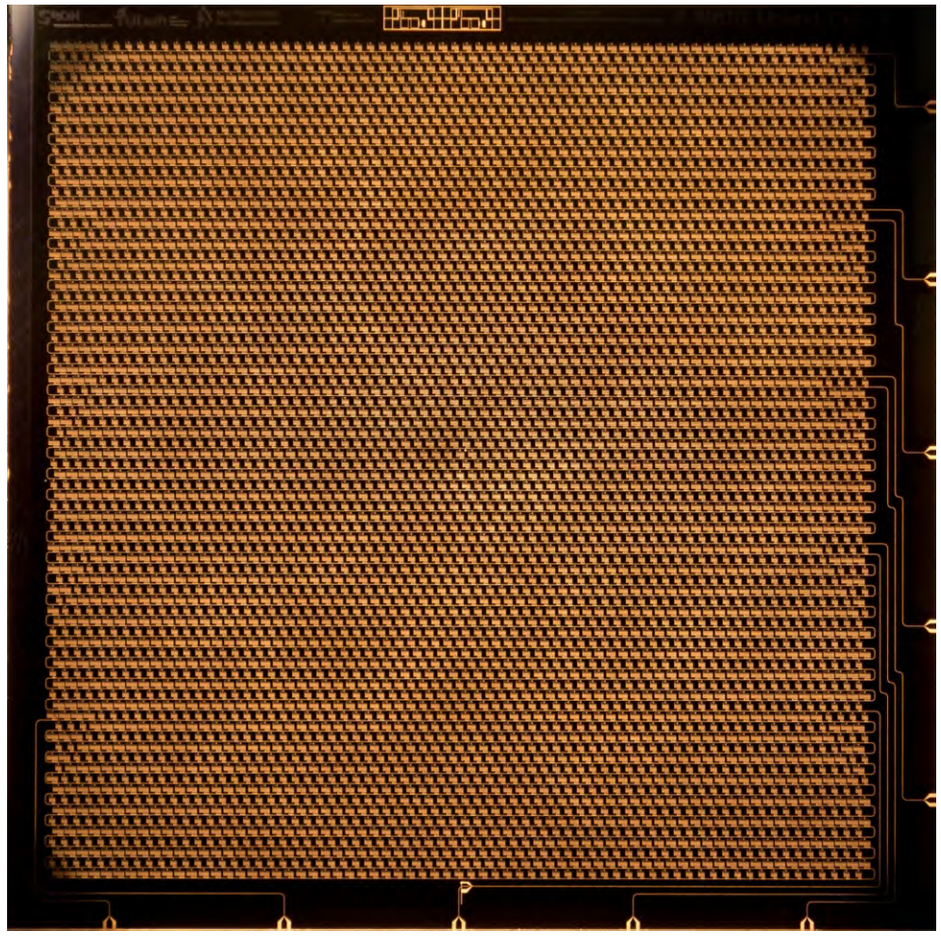
ASTRON Netherlands Institute for Radio Astronomy

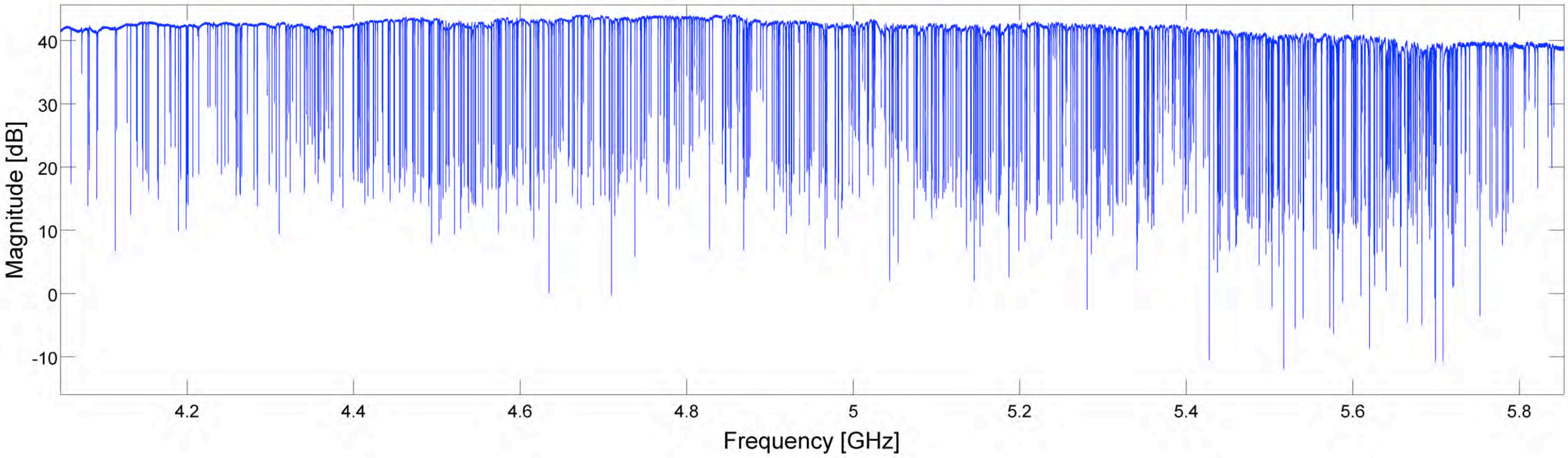
ceratec® Technical Ceramics BV

PHILIPS
Philips Lighting Uden

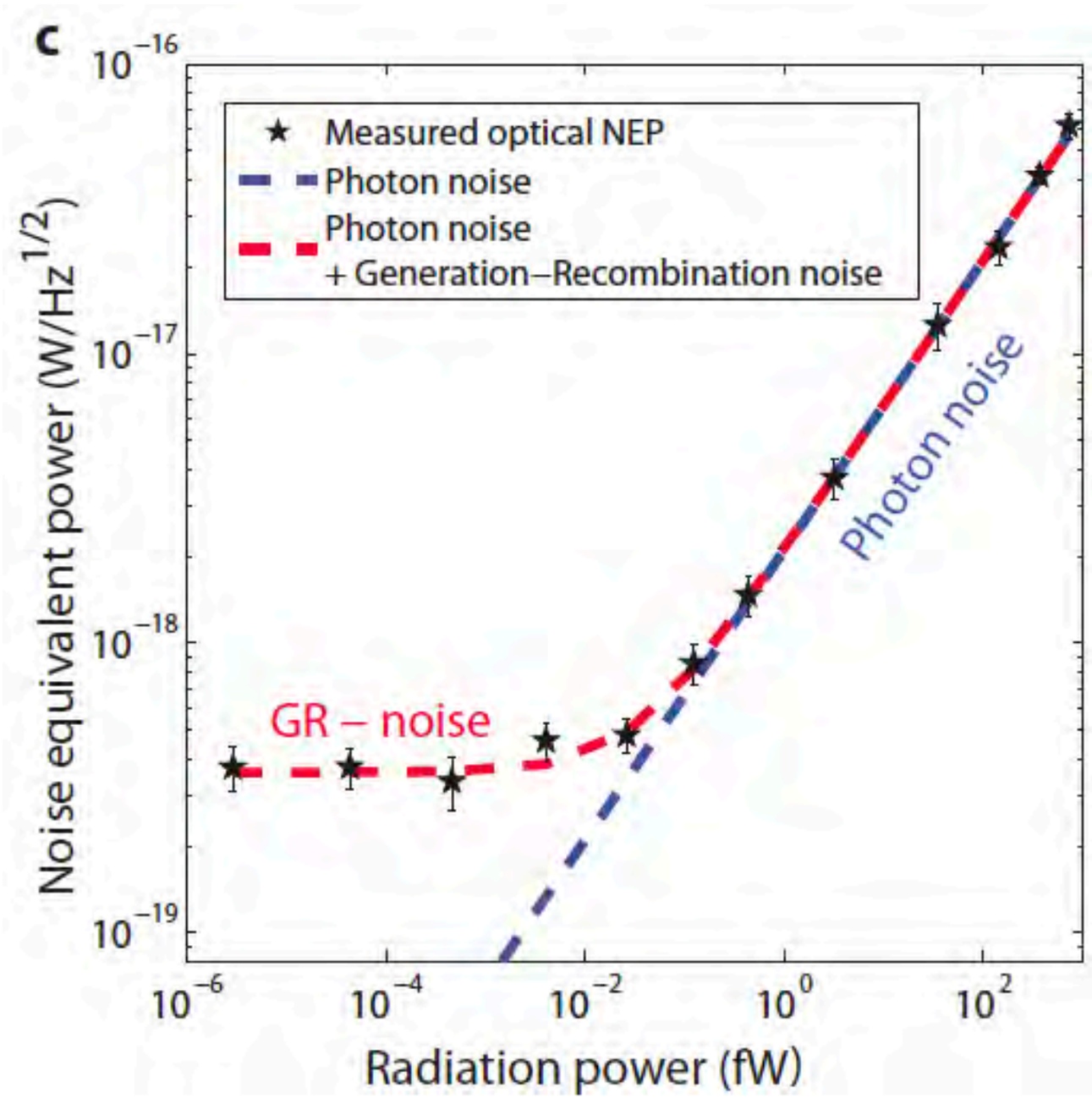
Readout ~1000 pixels / GHz





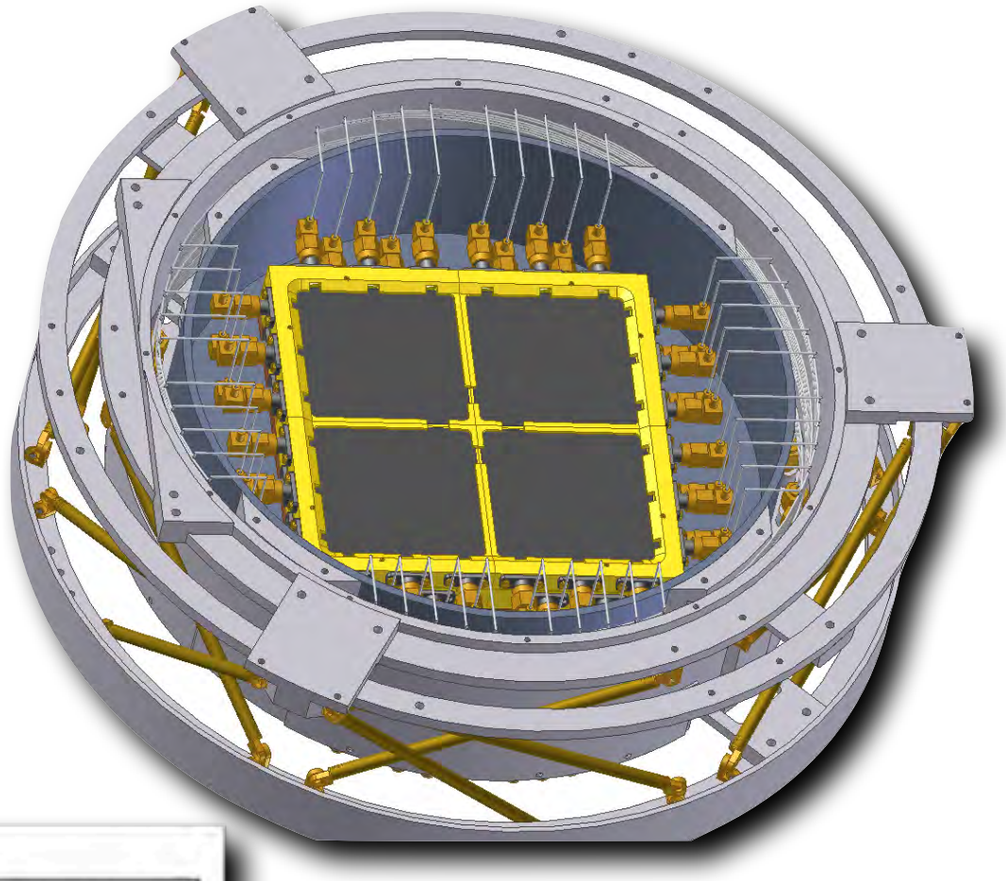


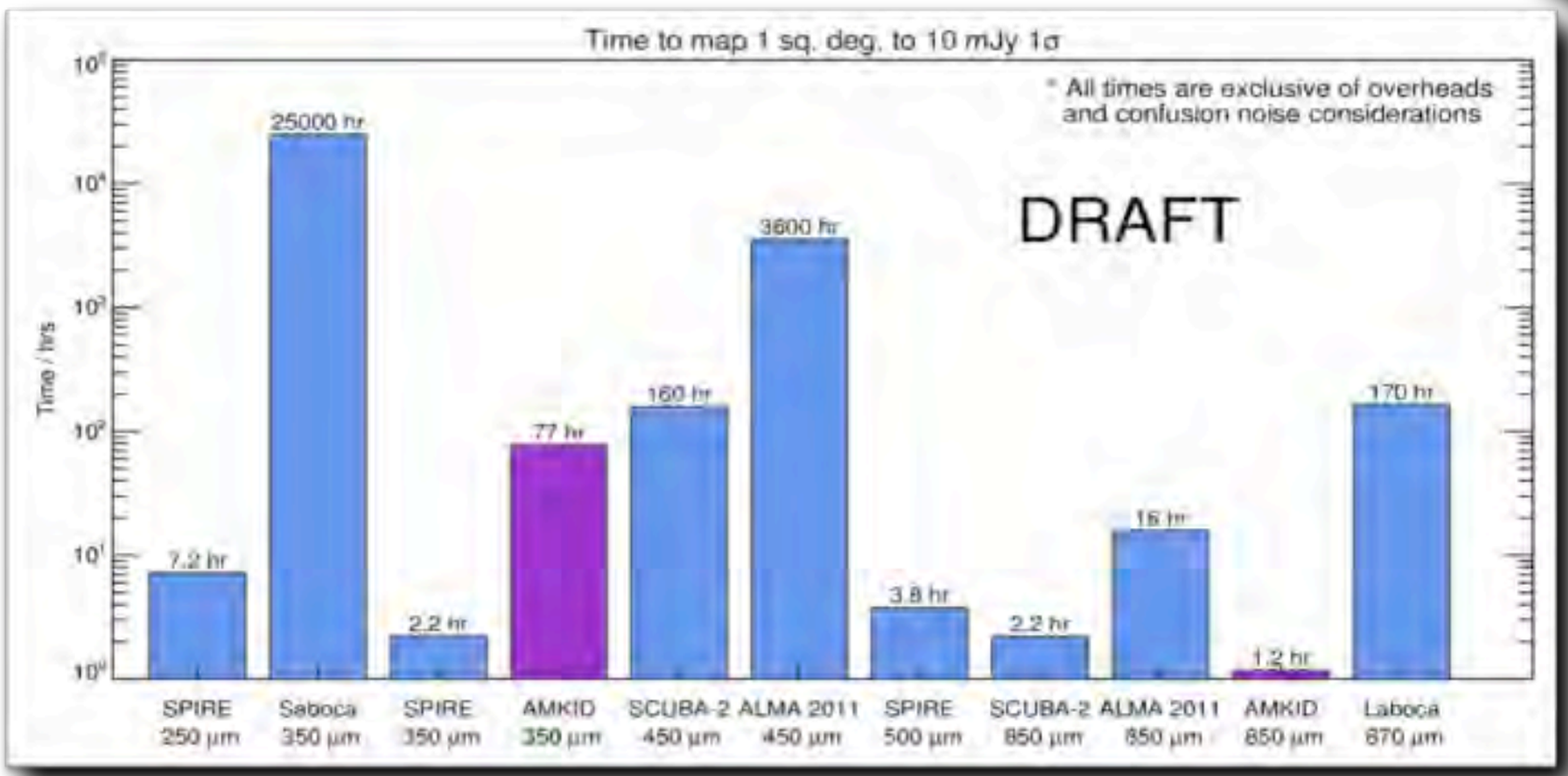
Sensitivity: Limited by noise in photon arrival rate



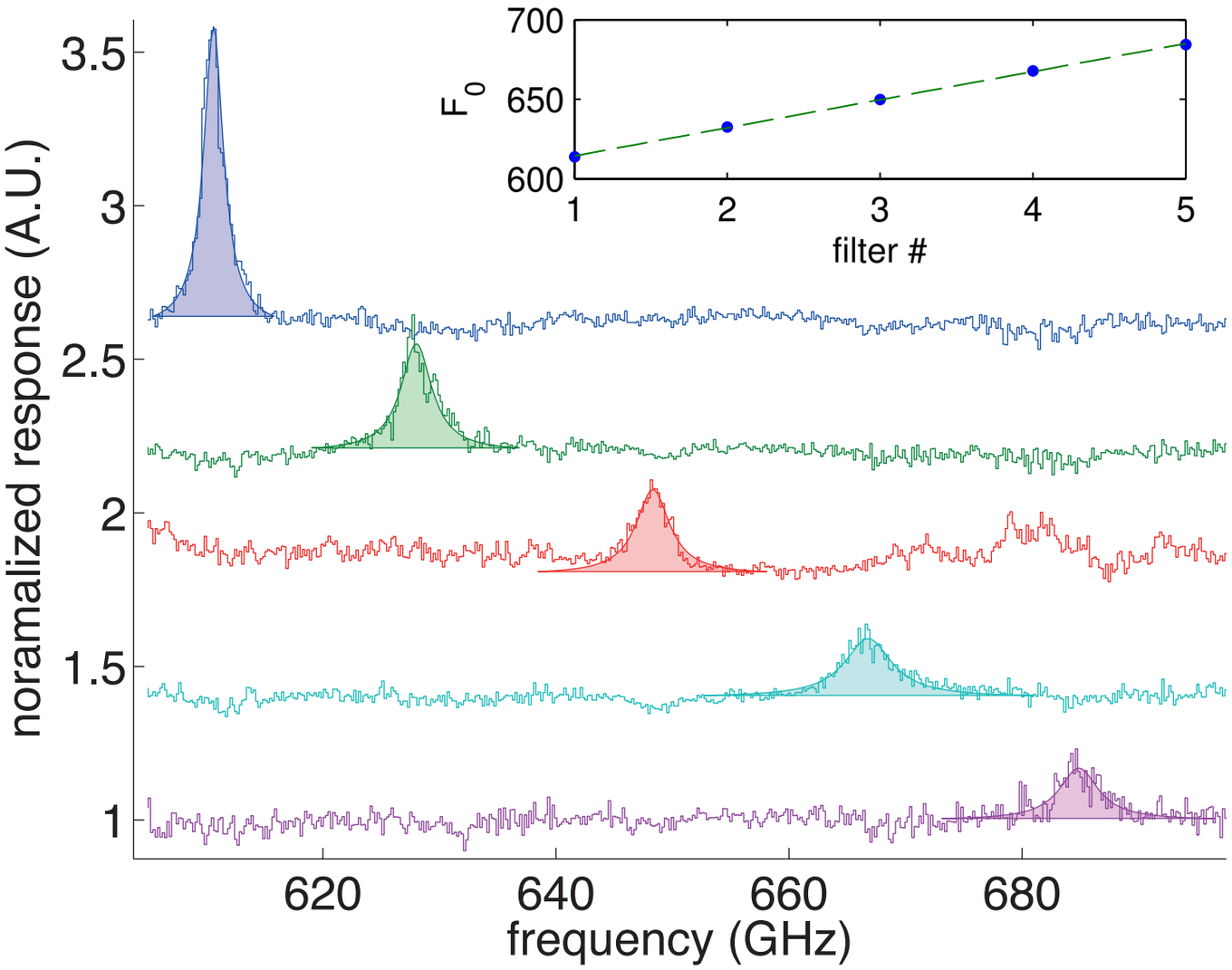
A-MKID

World's largest submm camera,
2x4 segments, 25120 MKIDs
FOV: 15 arcmin x 15 arcmin

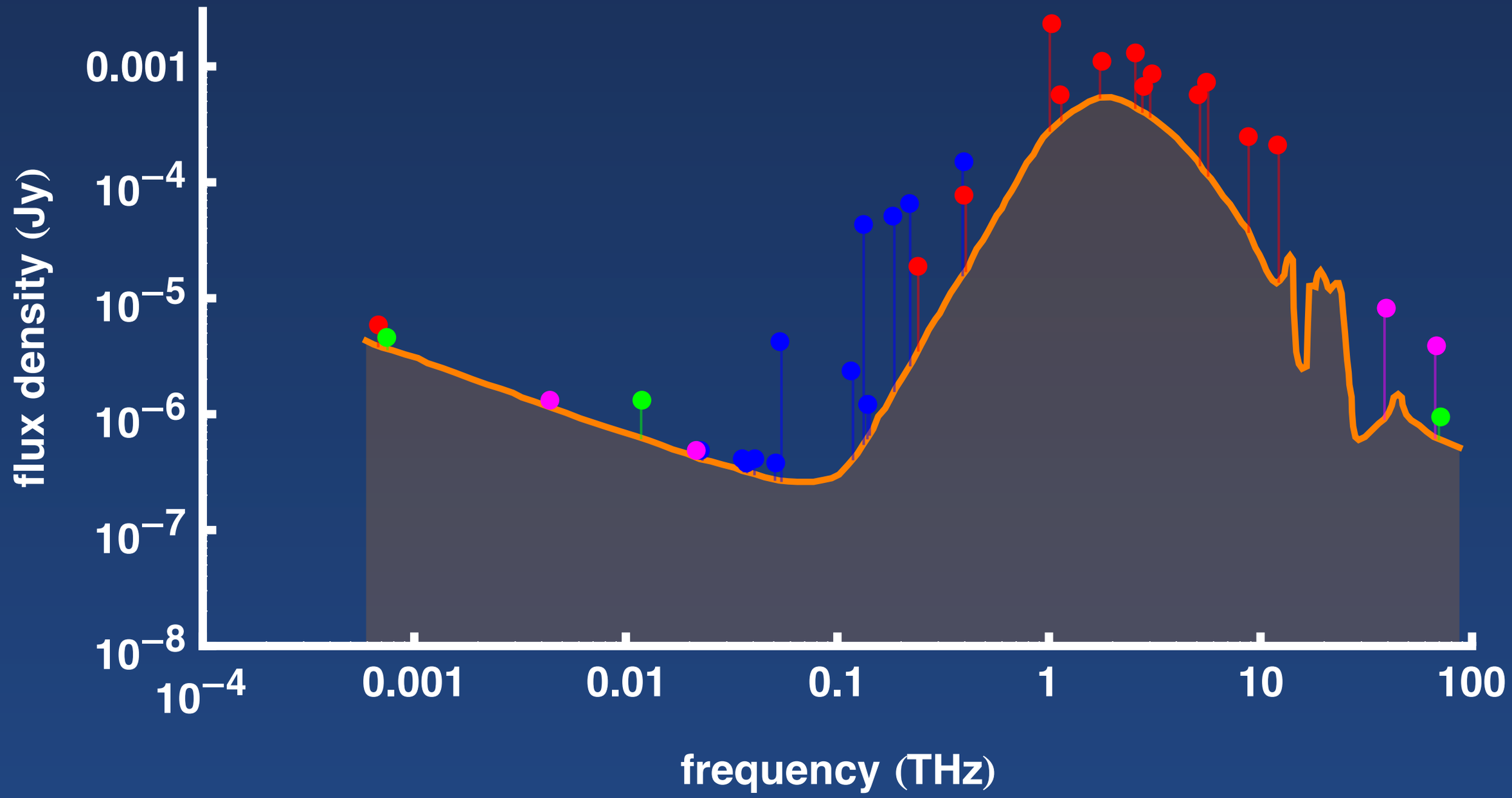




An On-Chip Spectrometer: Deshima

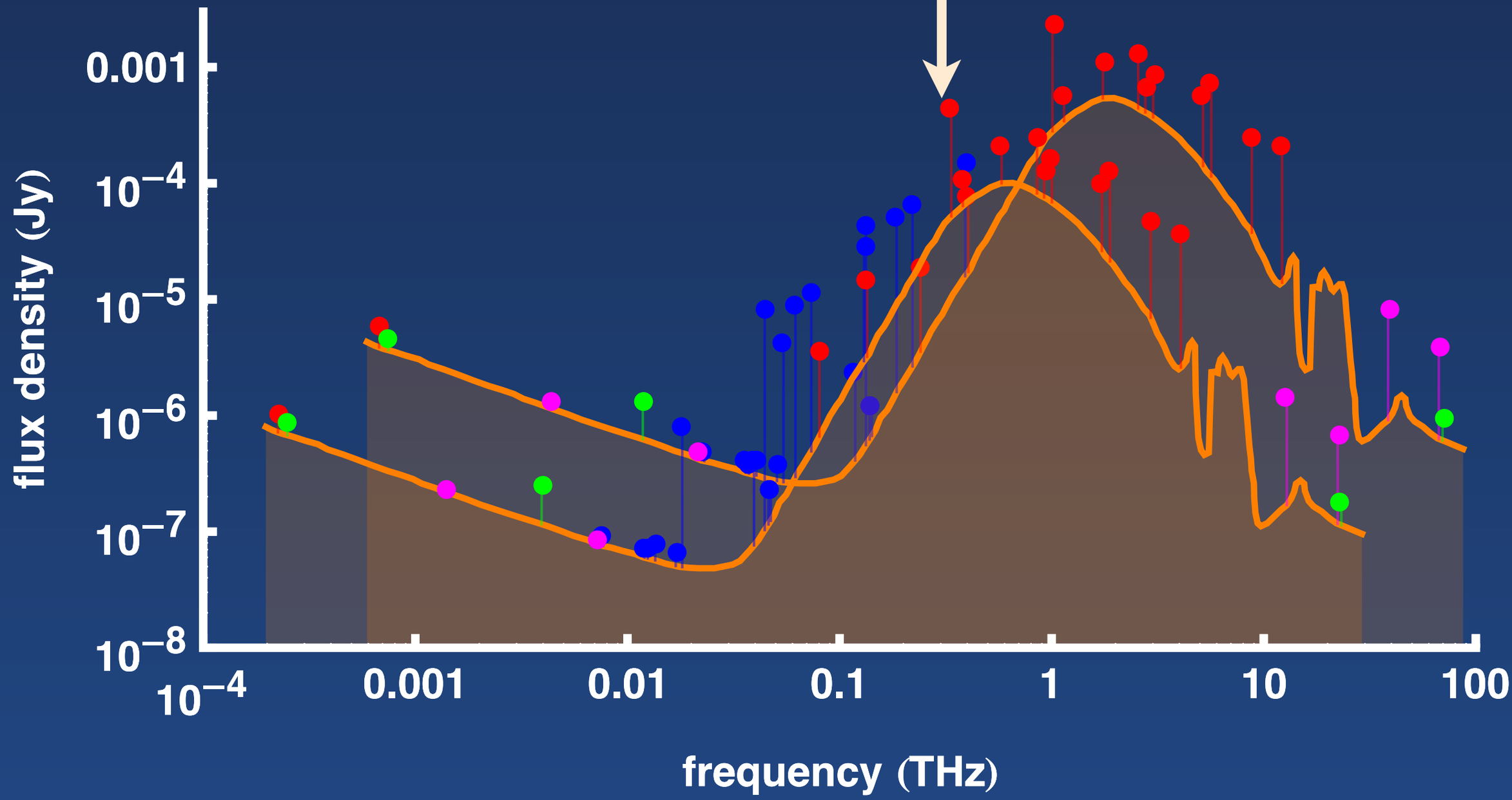


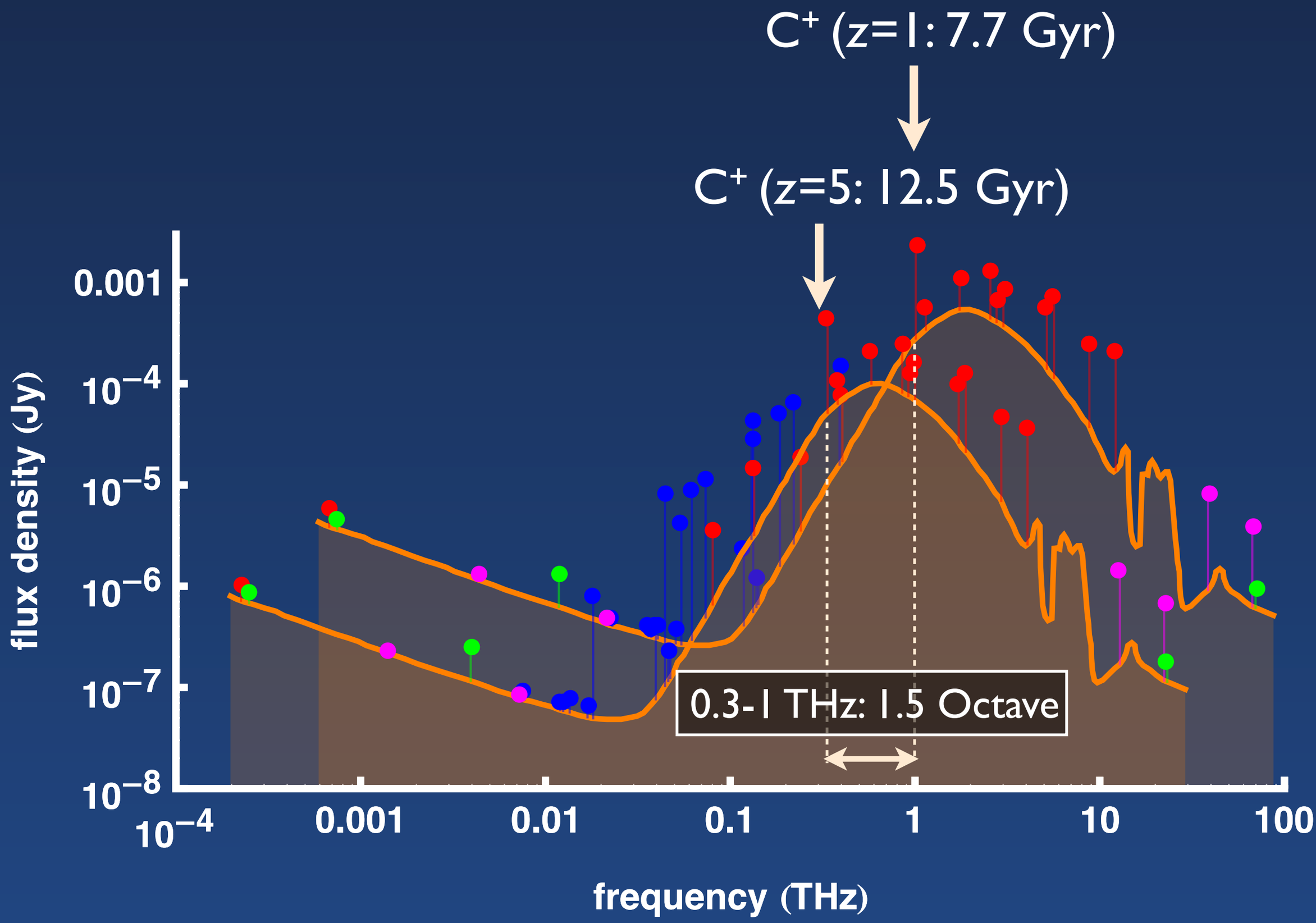
C^+ (z=1: 7.7 Gyr)


0.001
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
flux density (Jy)
10^{-4}
0.001
0.01
0.1
1
10
100
frequency (THz)

C^+ (z=1: 7.7 Gyr)

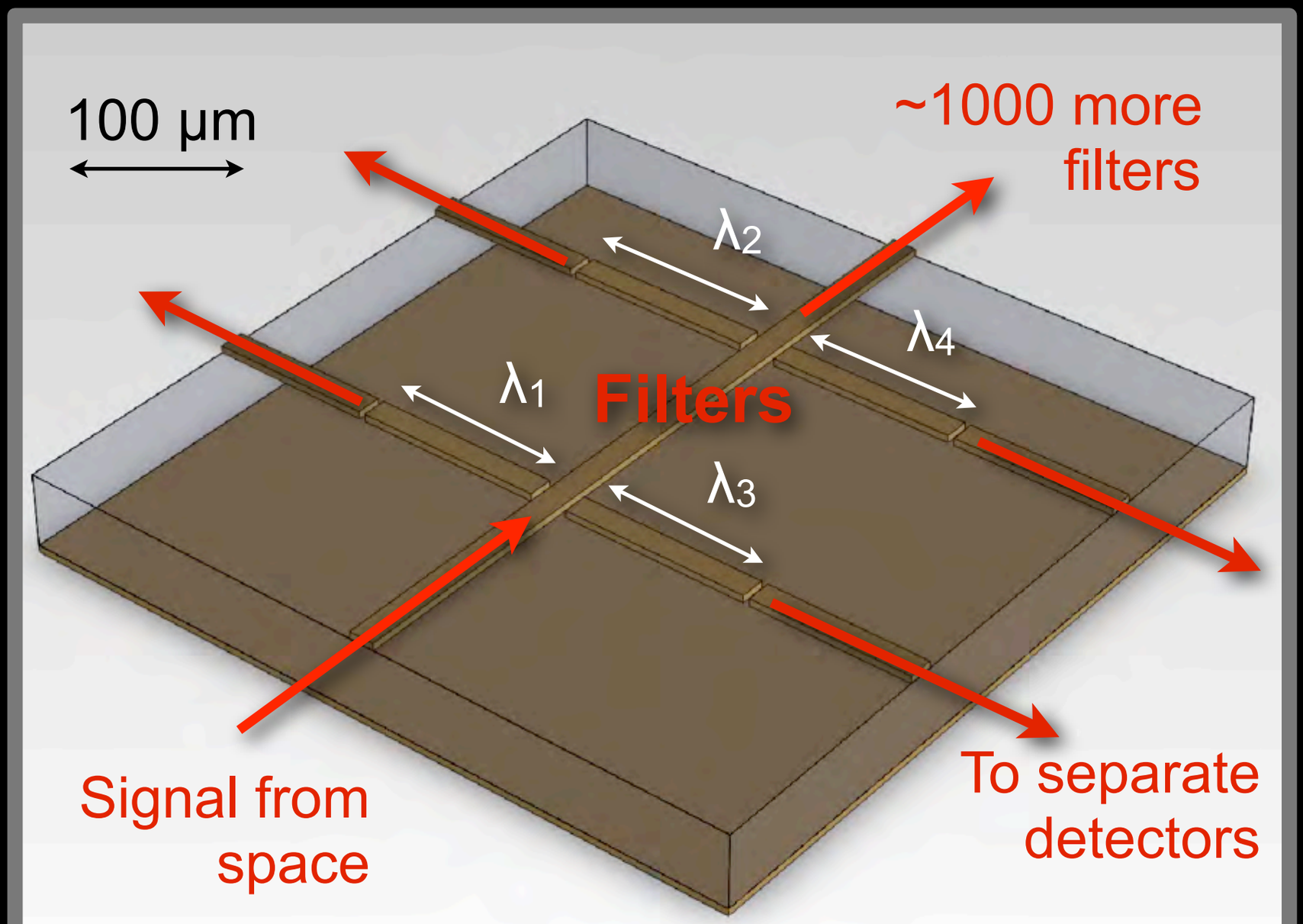
C^+ (z=5: 12.5 Gyr)

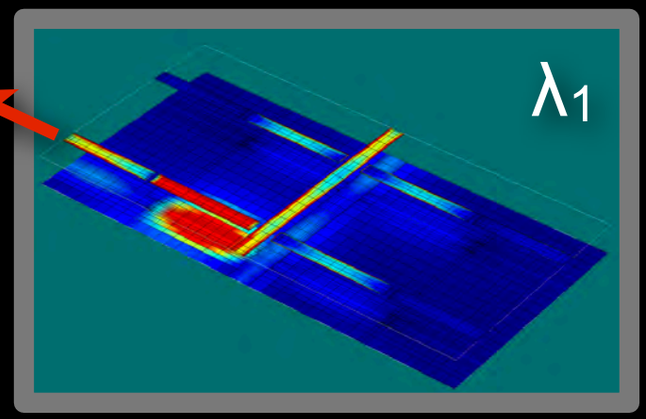


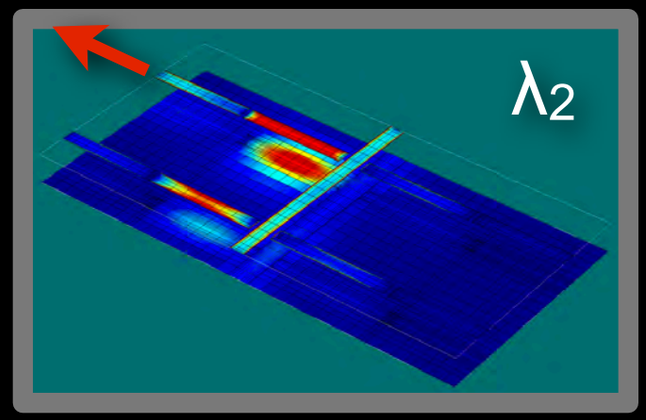

C+ (z=1: 7.7 Gyr)
C+ (z=5: 12.5 Gyr)
0.3-1 THz: 1.5 Octave
flux density (Jy)
0.001
10−4
10−5
10−6
10−7
10−8
10−4
0.001
0.01
0.1
1
10
100
frequency (THz)

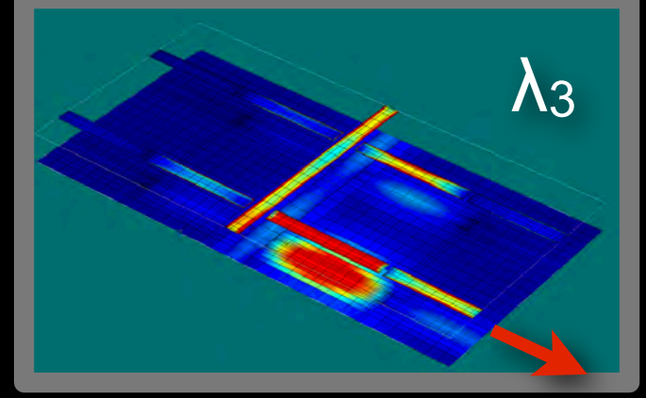
A Microwave Trick:

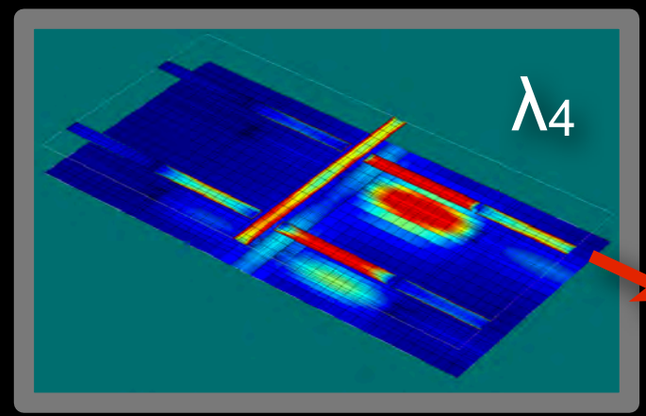
Photon sorting with superconducting micro-filters



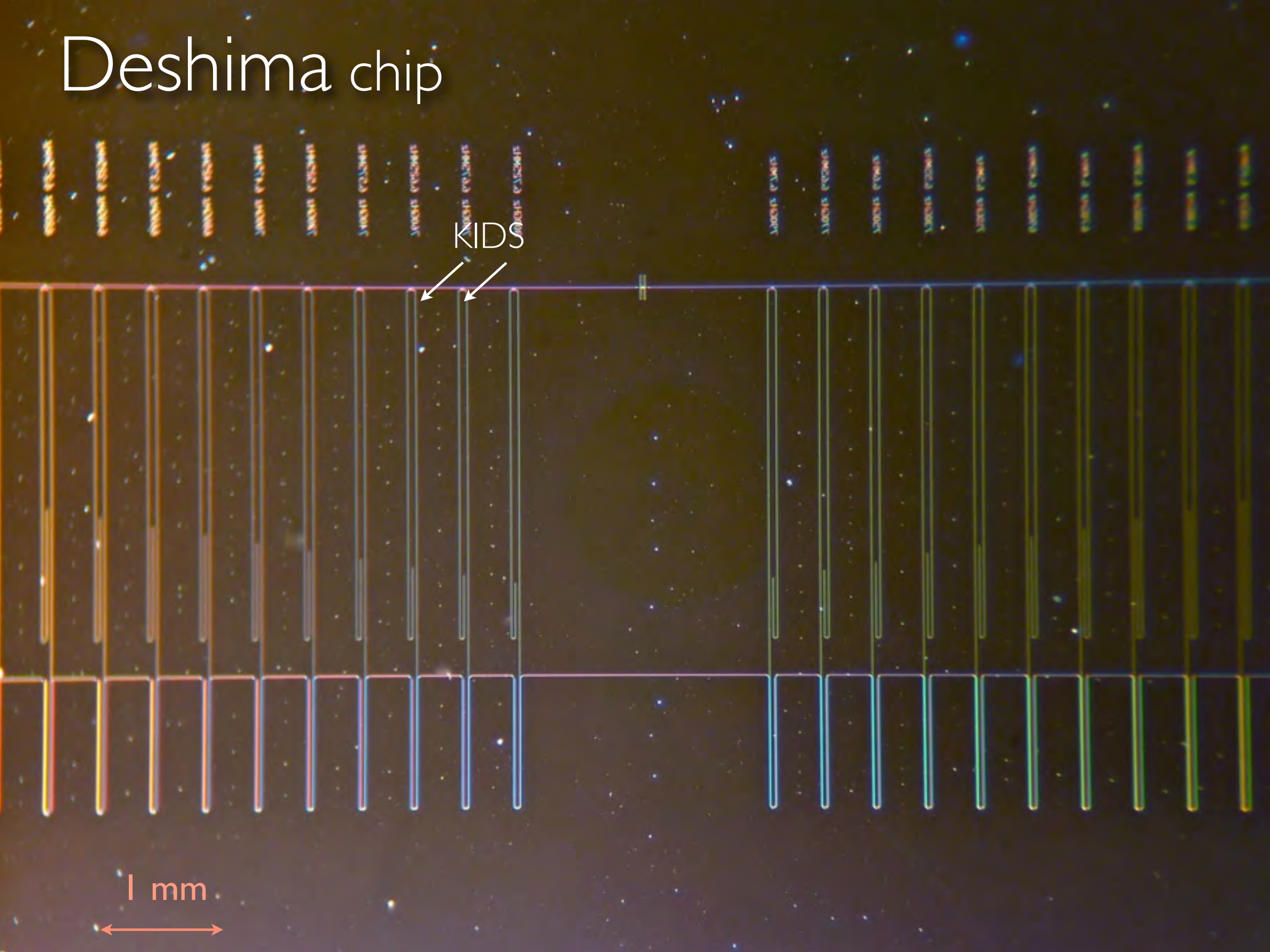




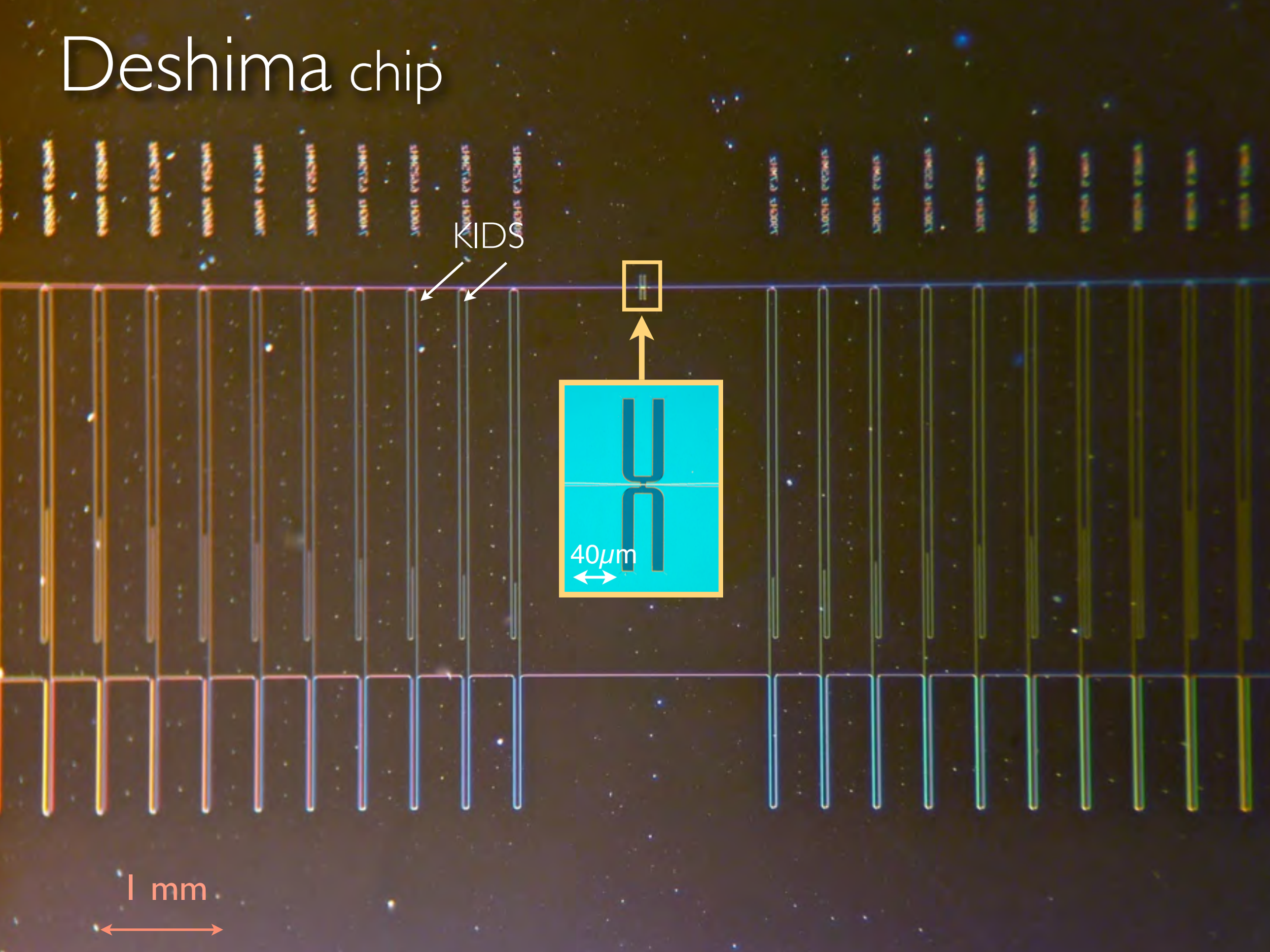




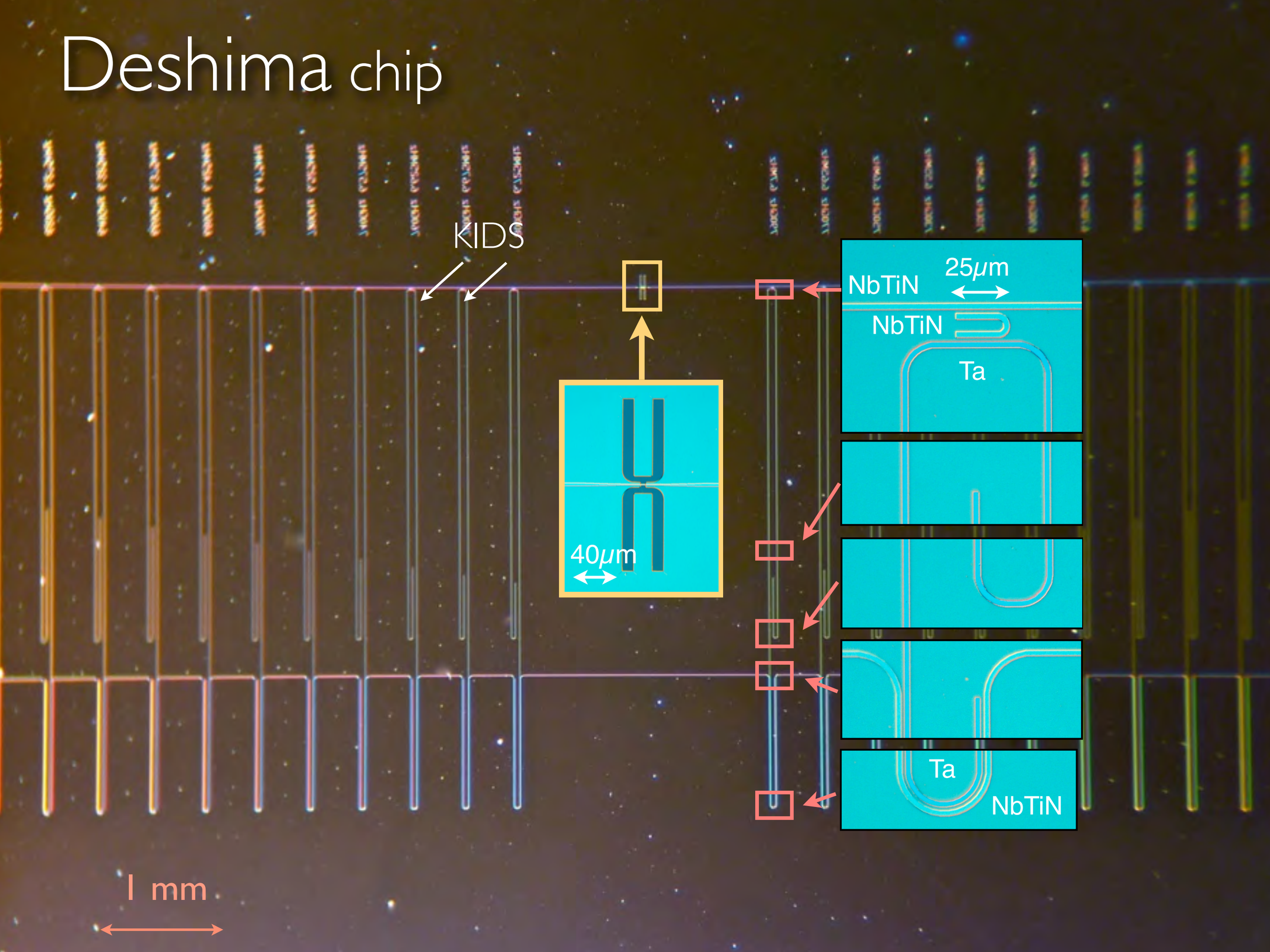
Deshima chip



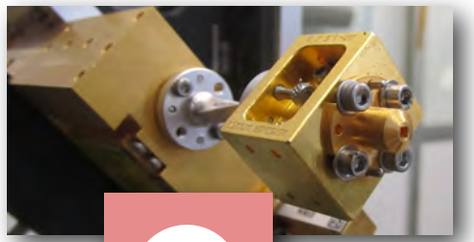
Deshima chip



Deshima chip



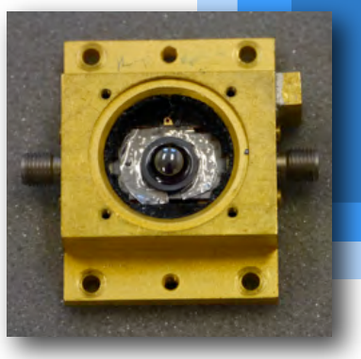
First laboratory demonstration:
Spectroscopy with an On-chip Filterbank

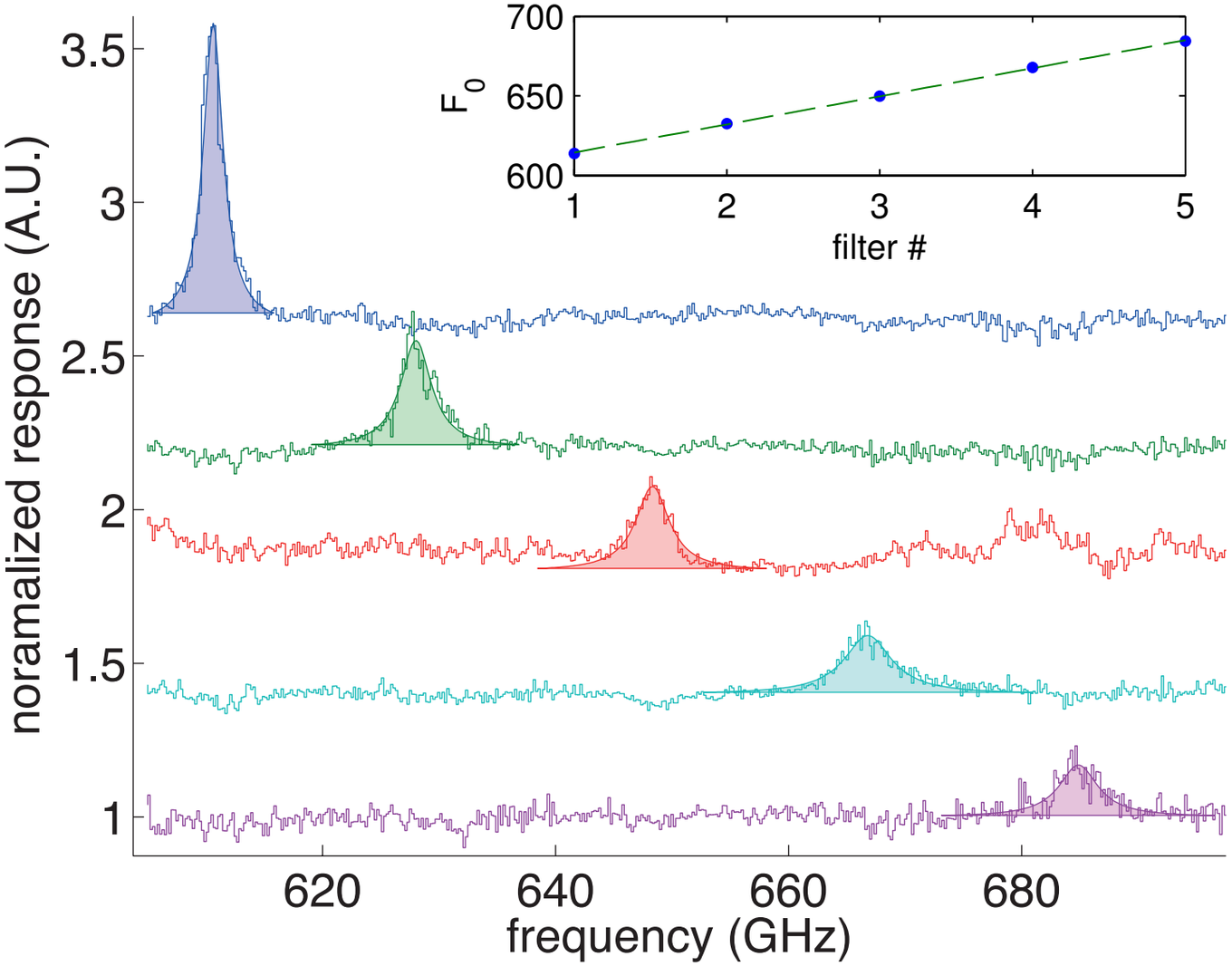


600-700 GHz
tunable source

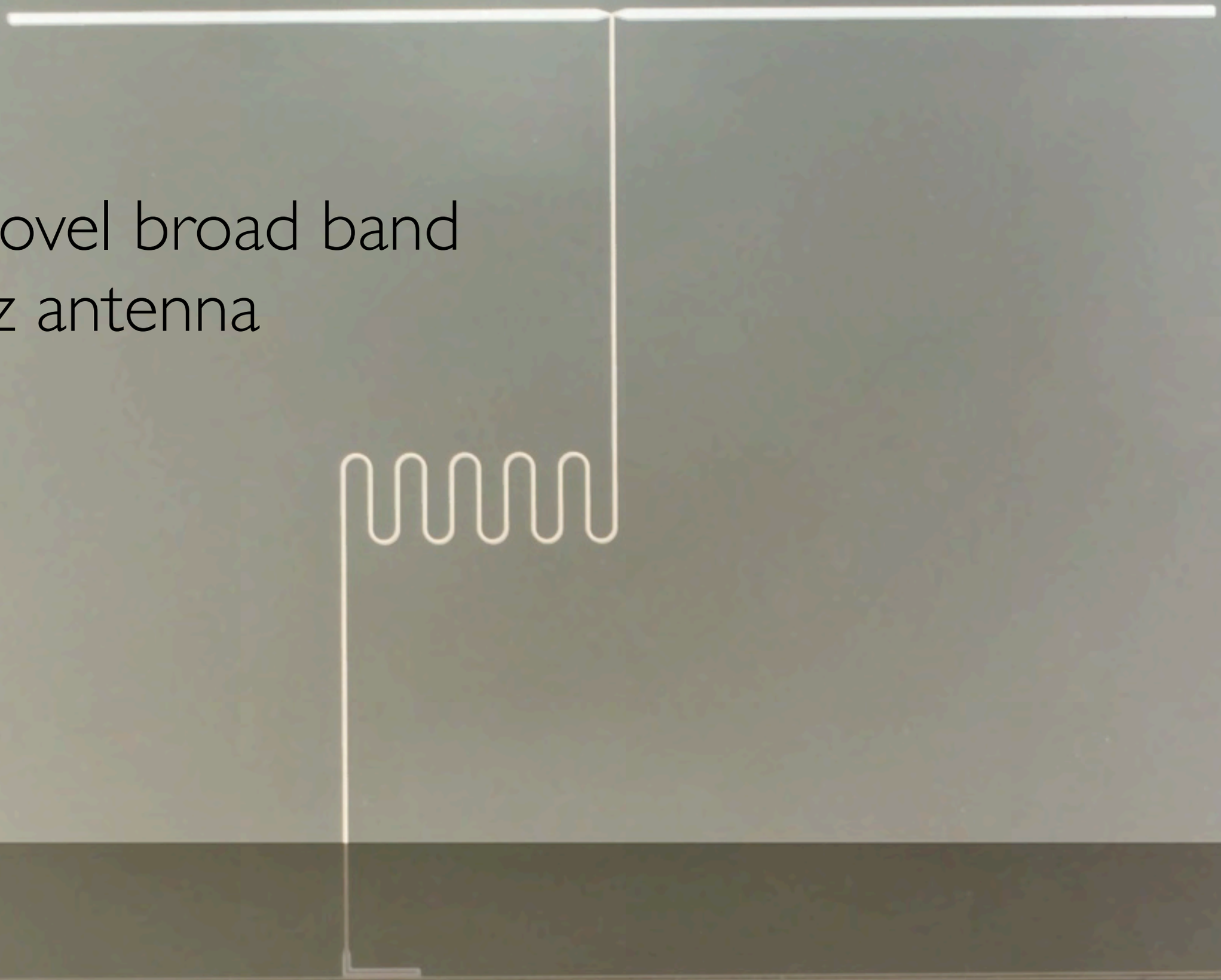
1.1 THz
lowpass filter

chip behind lens
@ 300 mK



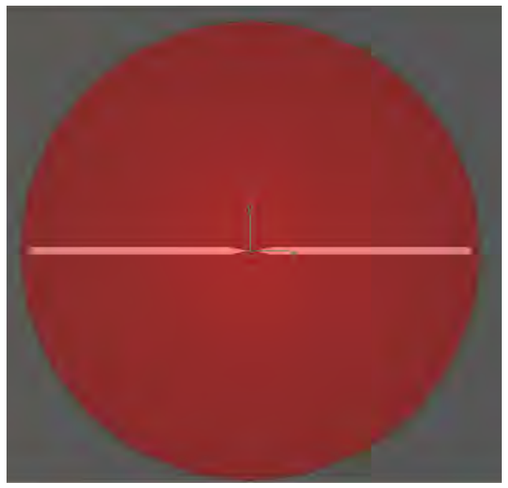


A novel broad band
THz antenna



0.5 mm

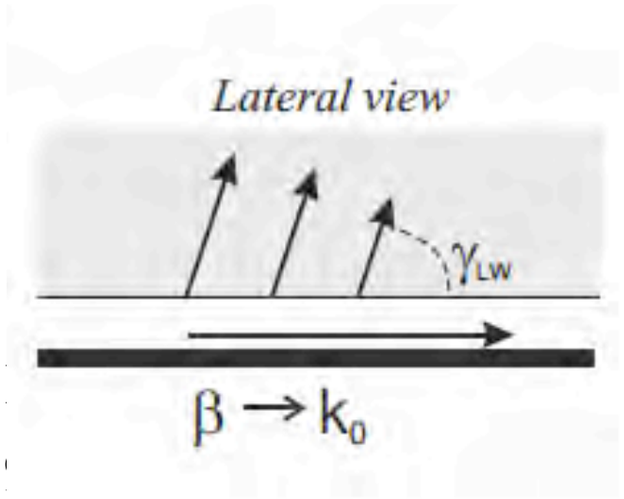
The leaky lens antenna

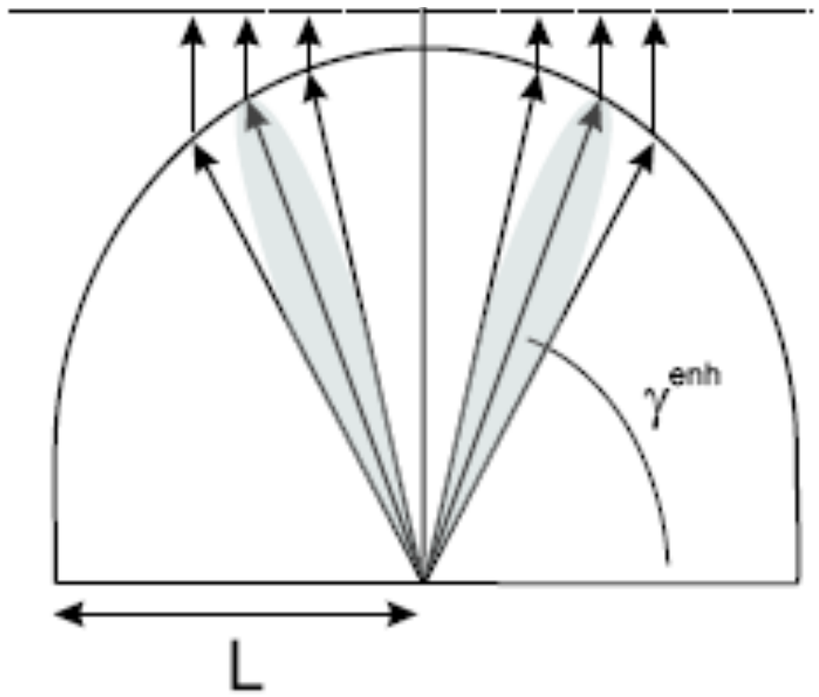


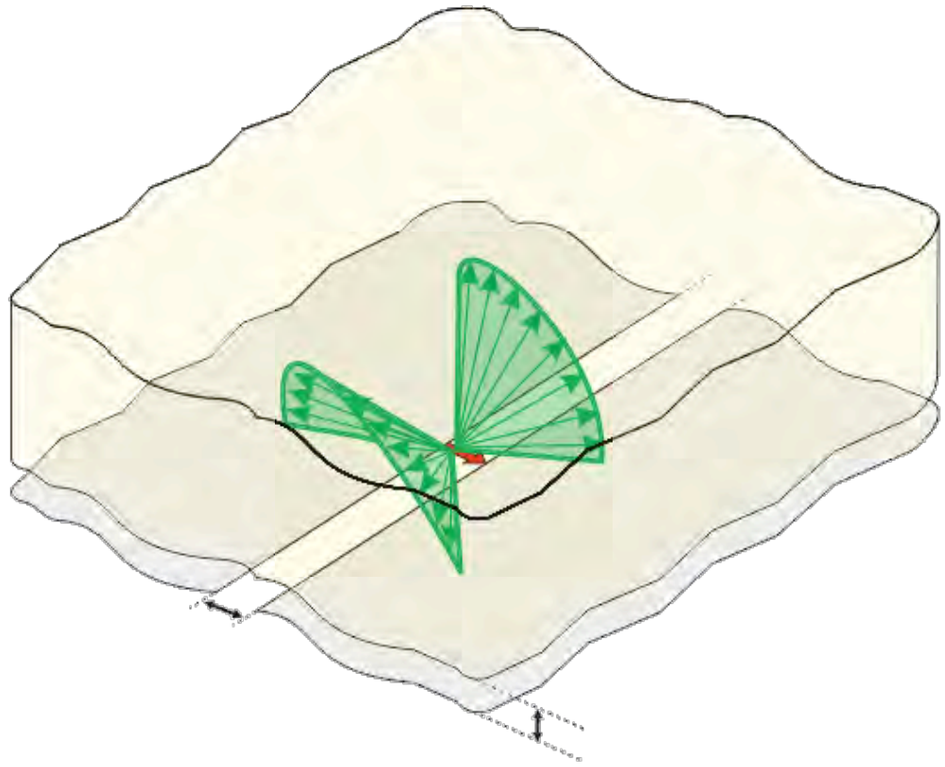
Wide Band

Stable directive patterns

Stable phase centers.

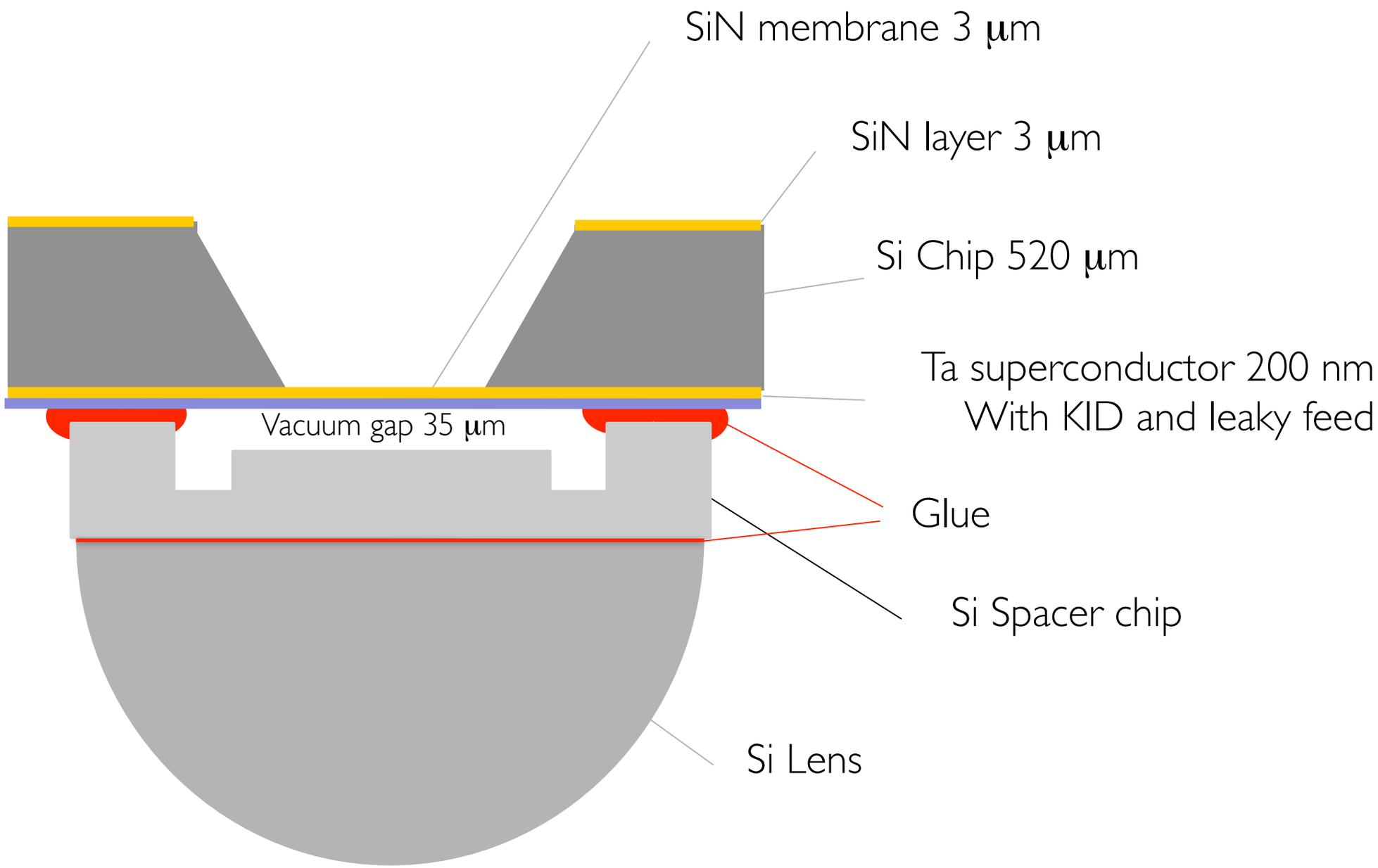




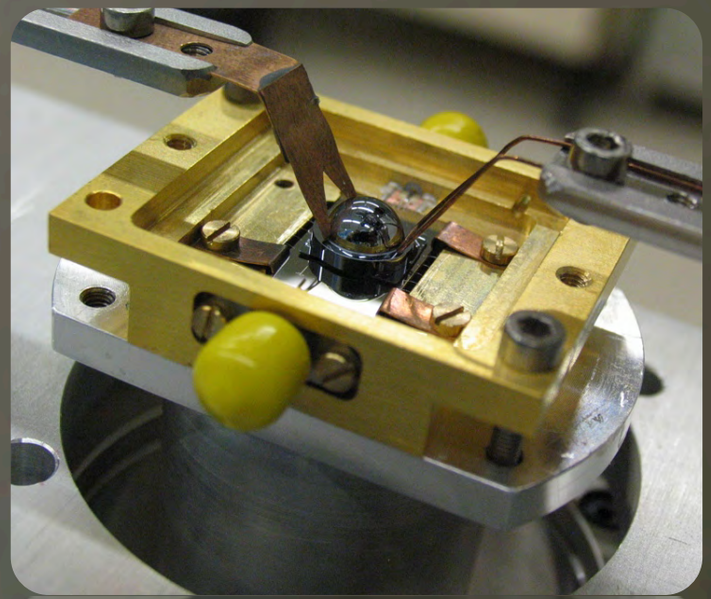


A. Neto, et al. July 2010 IEEE Trans. on Antennas and Propagation

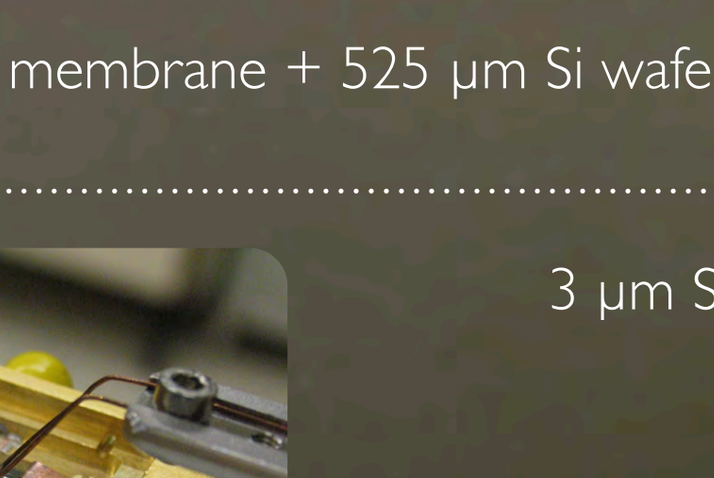
Making the THz leaky



3 μm SiN membrane + 525 μm Si wafer



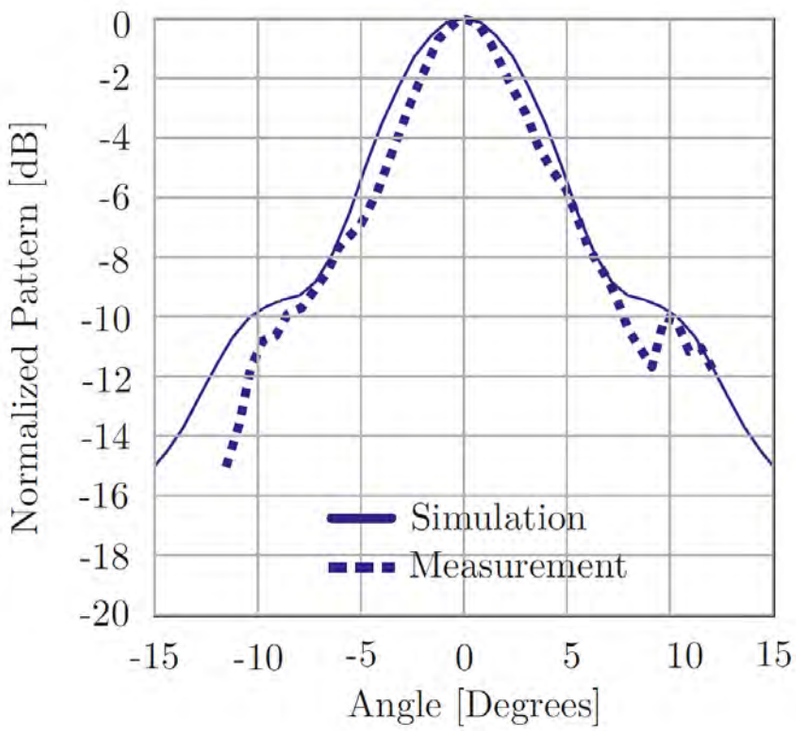
3 μm SiN membrane



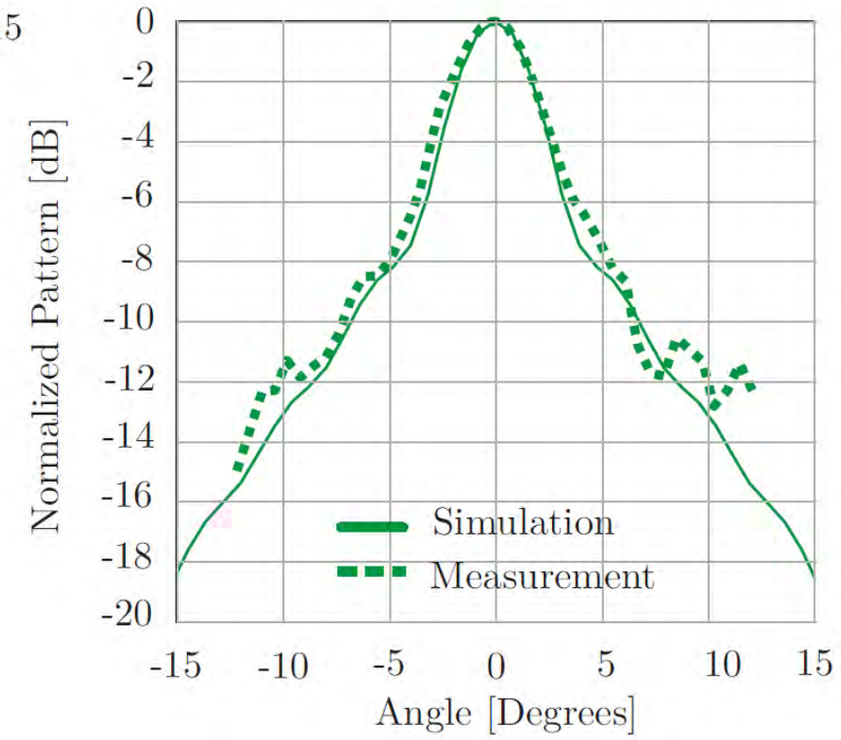
0.5 mm

RADIATION PATTERNS

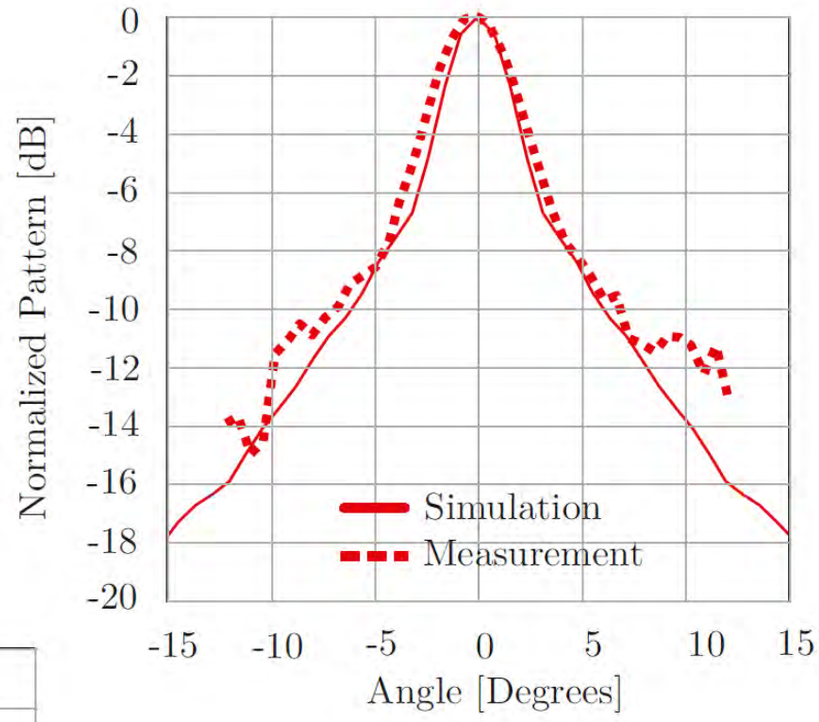
350 GHz



650 GHz



850 GHz



Frequency dependent response