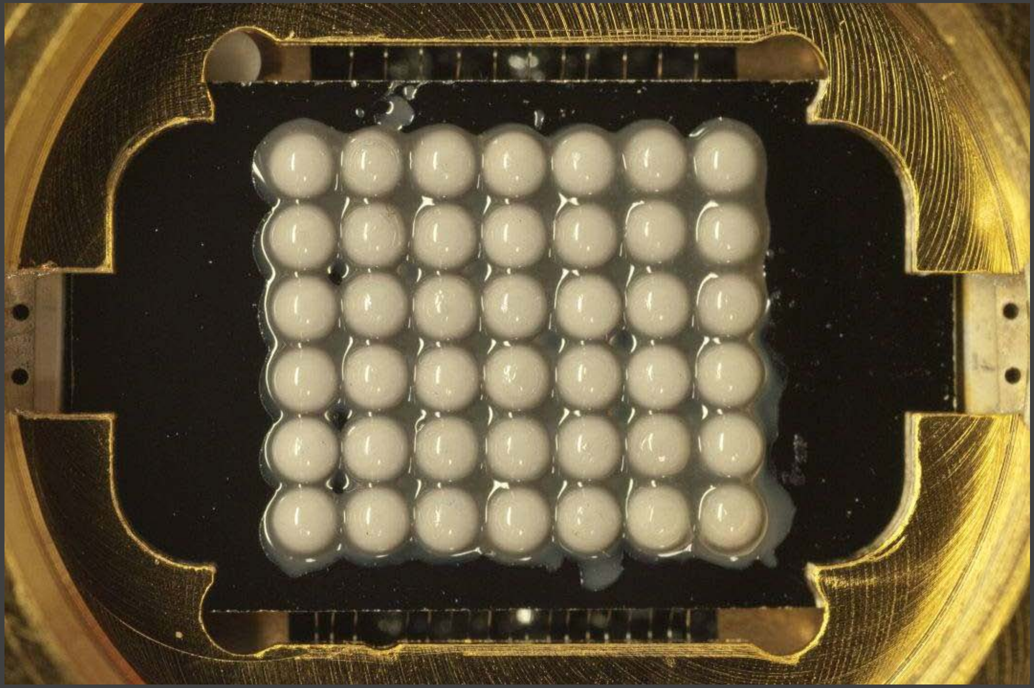
Antenna coupled Kinetic Inductance Detectors camera design and performance at IRAM 30m telescope

A. Baryshev



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TNO

TU Delft
Delft University of Technology

NÉEL institut

Max-Planck-Institut für Radioastronomie

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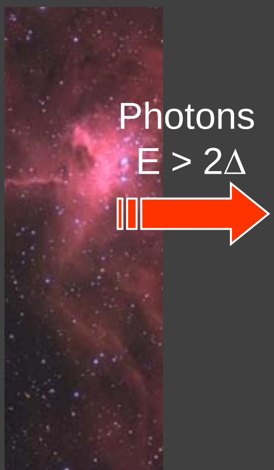
KID detector

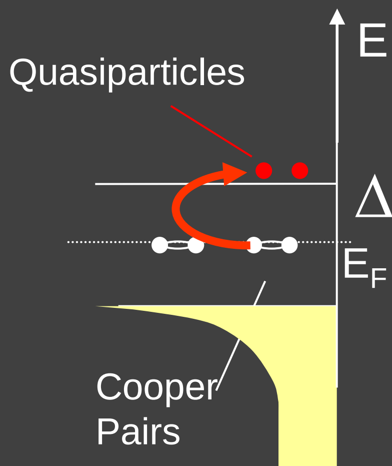
Principle

Sky signal



Pair breaking effect

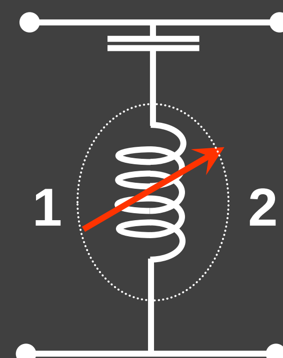
high frequency current creates qp excitations in superconductor



KID

Superconductor

in resonance cirquit

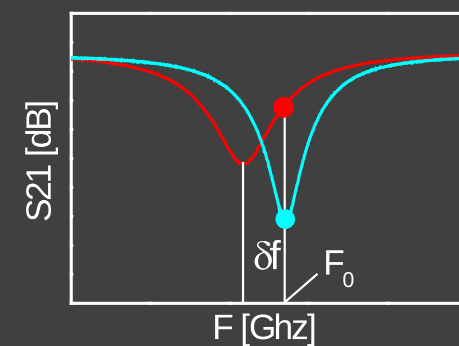


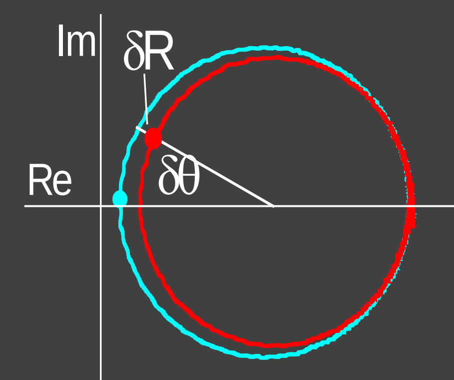
Readout

Resonance feature @F_0

shape depends on N_{qp}

can be read out with 1 tone

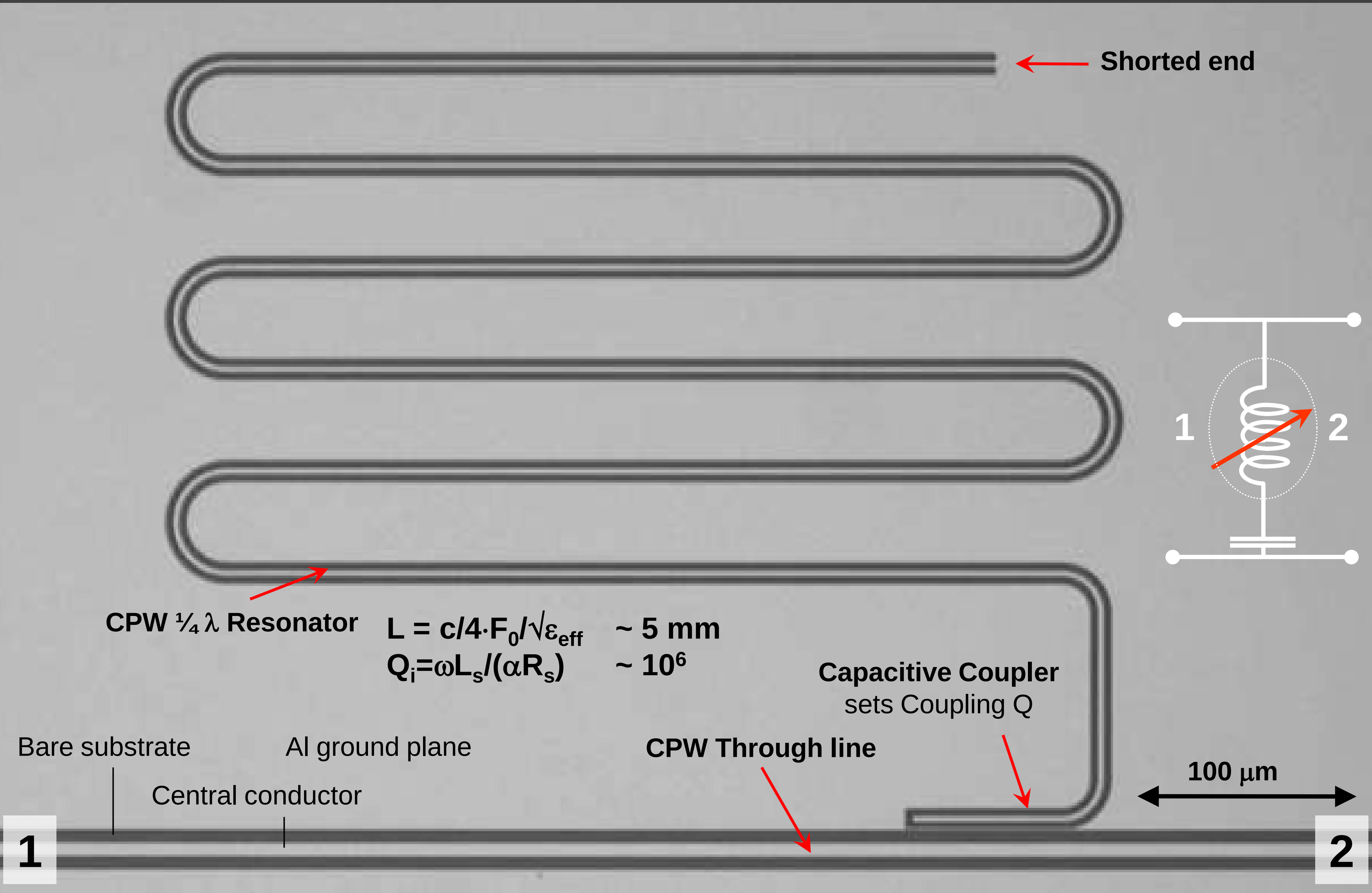




P. Day, et al., Nature 425, 817 (2003).

KID resonators

Capacitive Coupled Distributed resonator



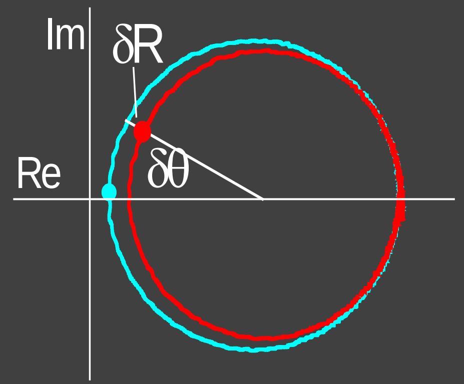
KID detector

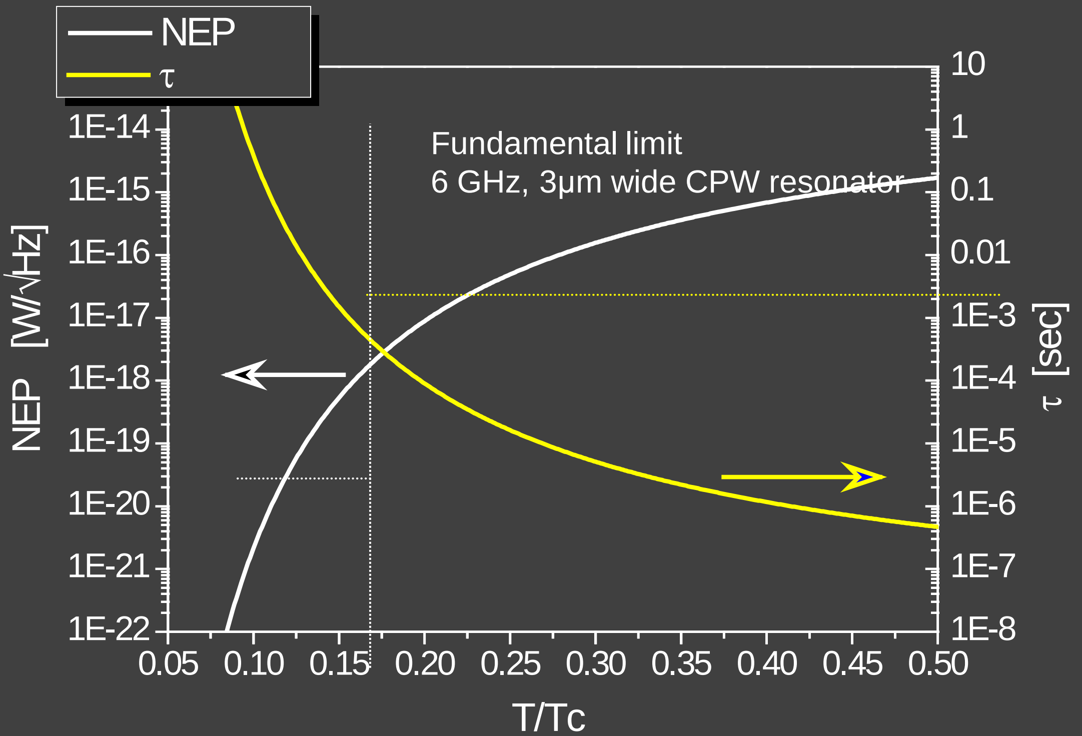
Fundamental and not so fundamental limits of KIDs

Noise Signal

$$NEP_x = \sqrt{S_x(\omega)} \cdot \left(\frac{\eta \tau_{qp}}{\Delta} \frac{dx}{dN_{qp}} \right)^{-1}$$

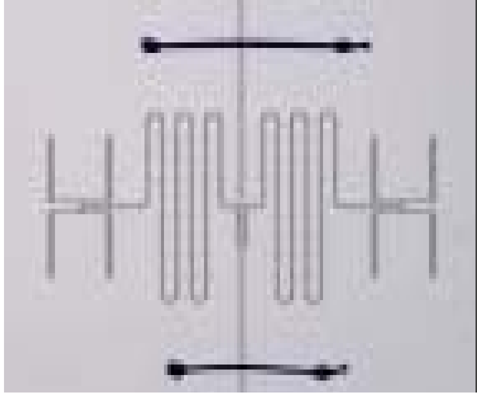
θ or R

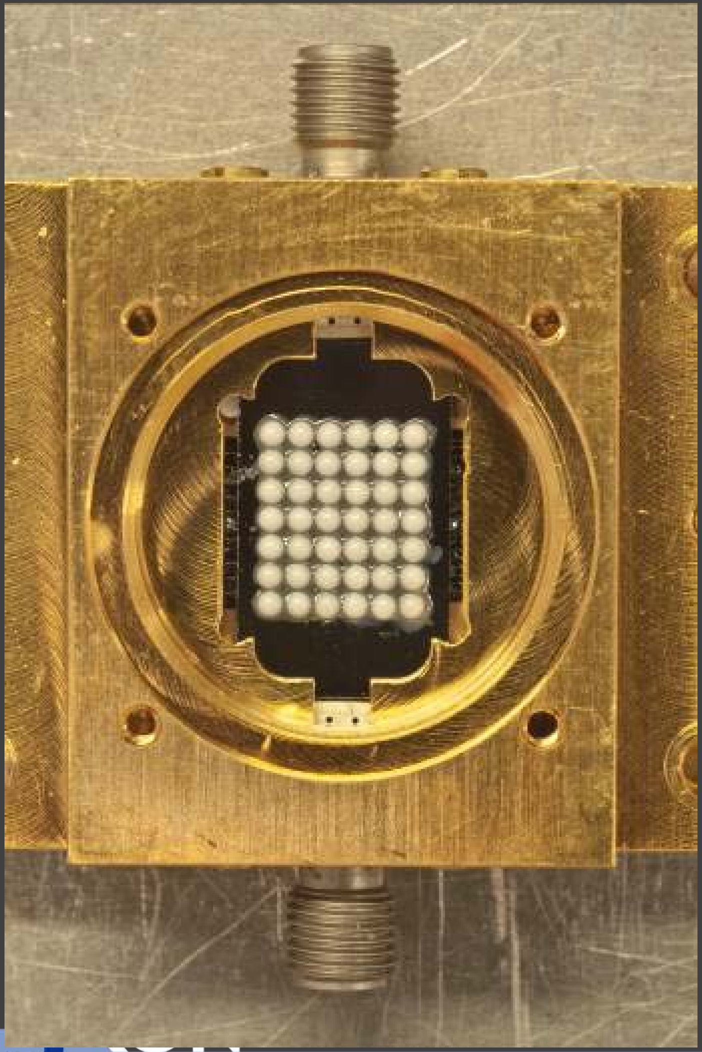


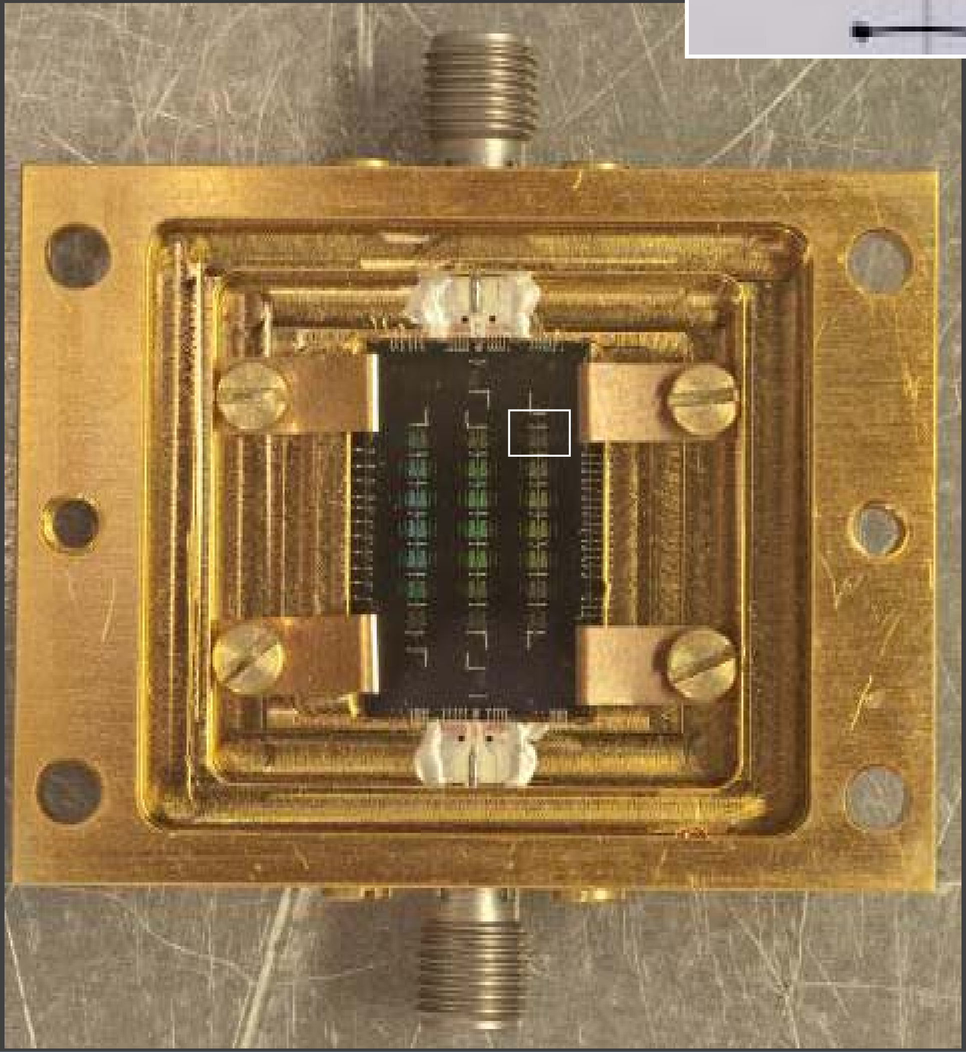


Array to NIKA

- 42 pixel antenna coupled array, Nyquist sampled
- home made Sapphire spherical lenses

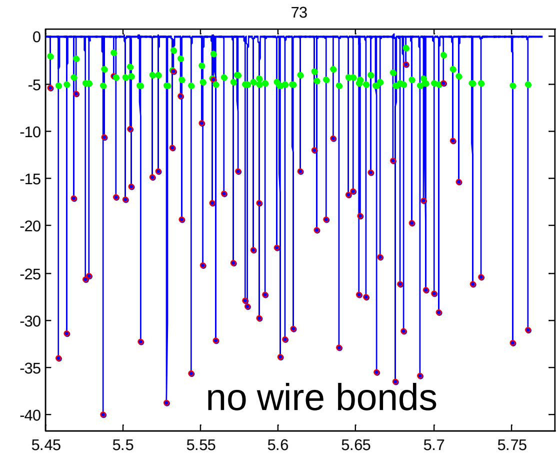


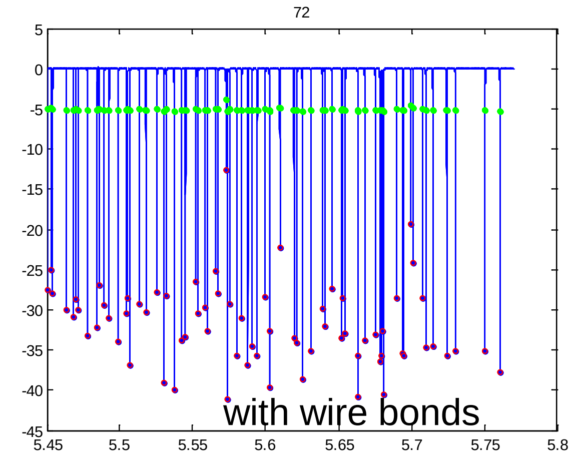


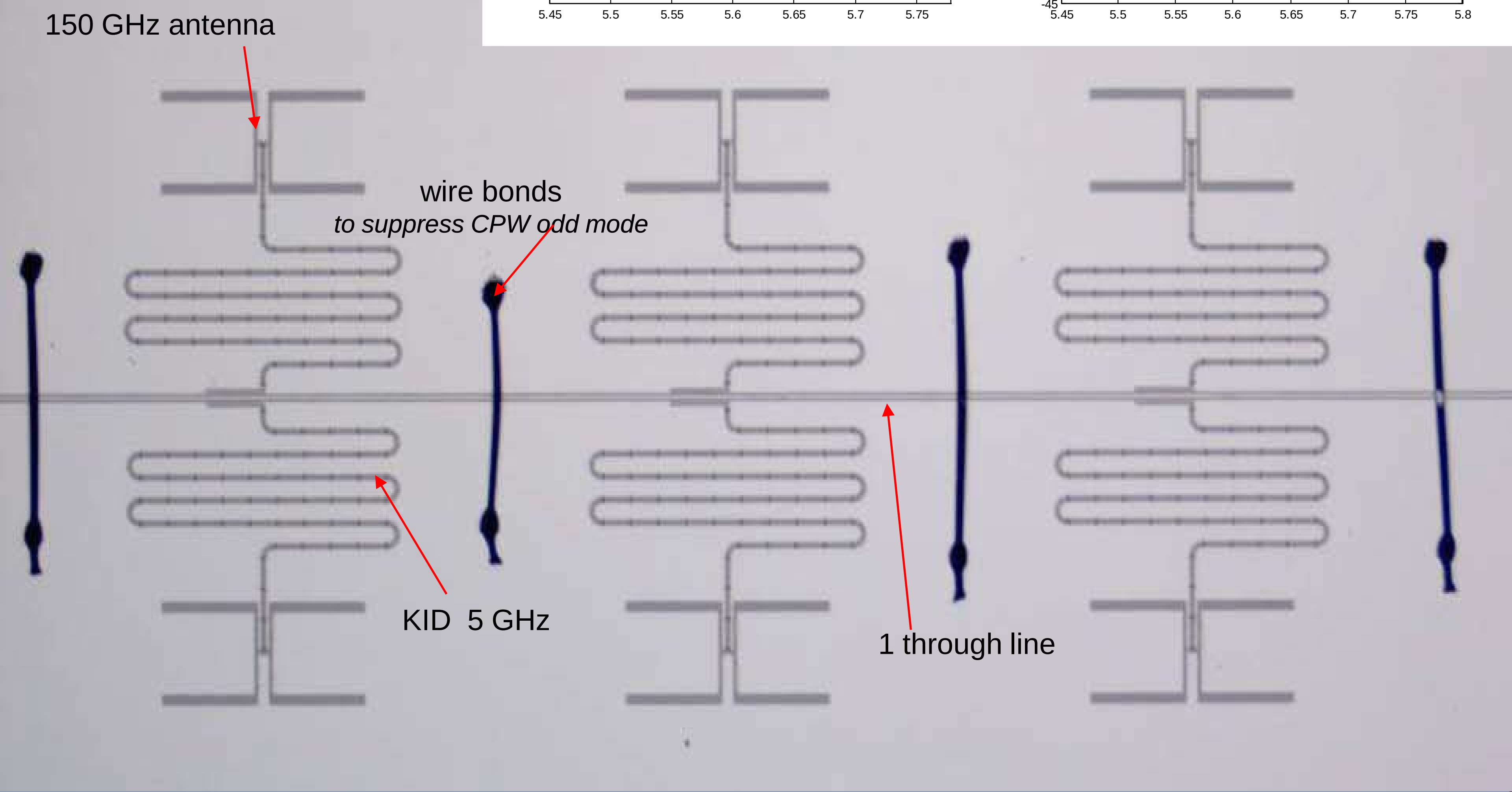


Array to NIKA

Design







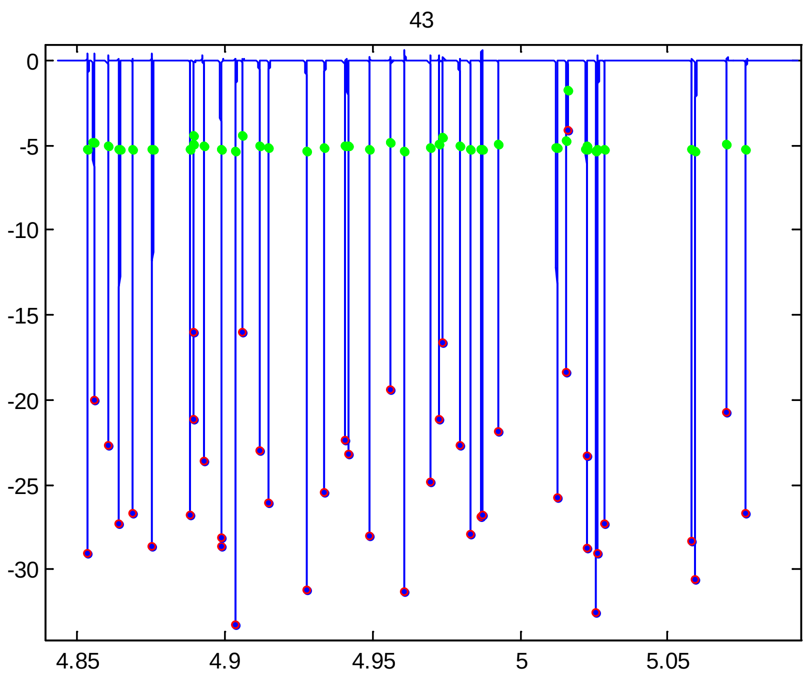
Array to NIKA

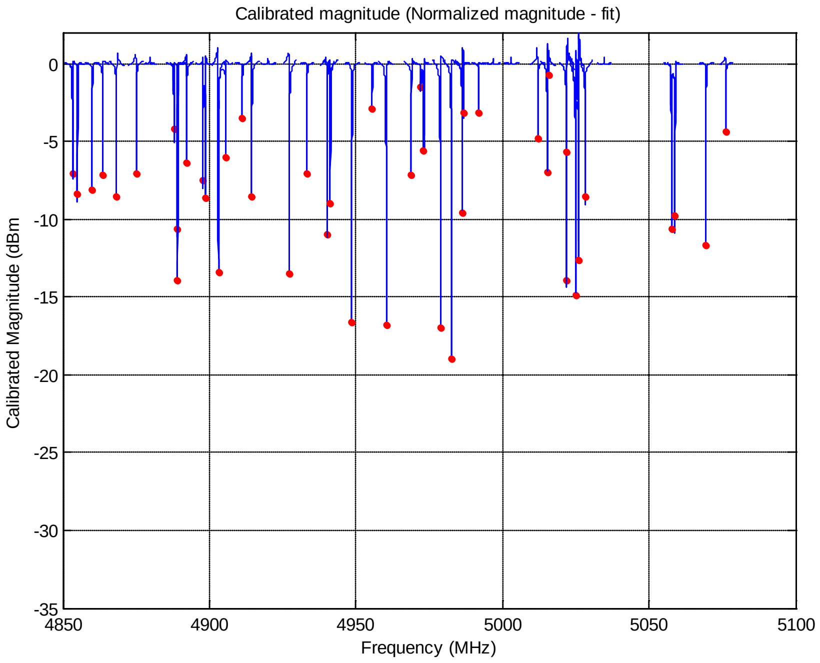
Q Design

- Q_{design} = 80.000 matched to expected sky load
- Q_i decreases with power loading
  - $S_{21,min} = Q/Q_i$

Dark measurement without any light
Q_i = 3.7E6
S21 = -25 dB

Looking to the sky
Q_i = 0.13E6
S21 = -9.5 dB

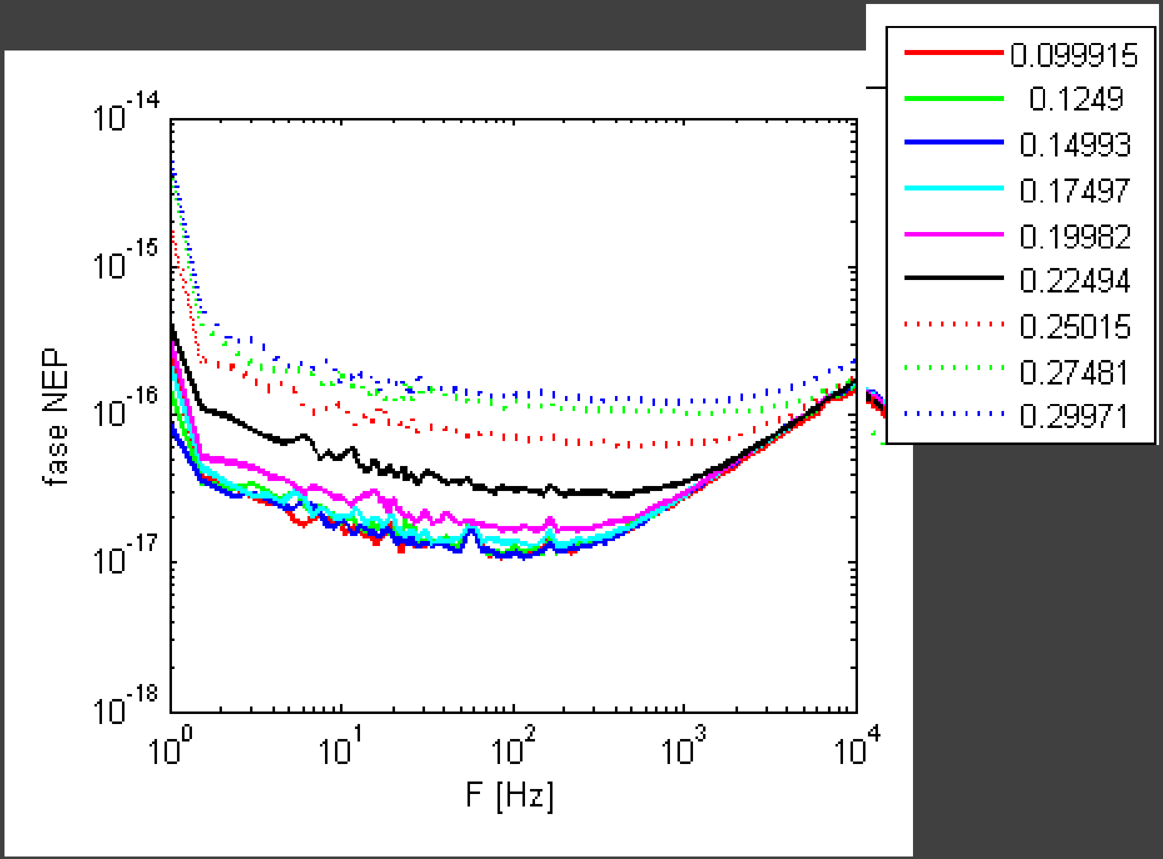




Array to NIKA

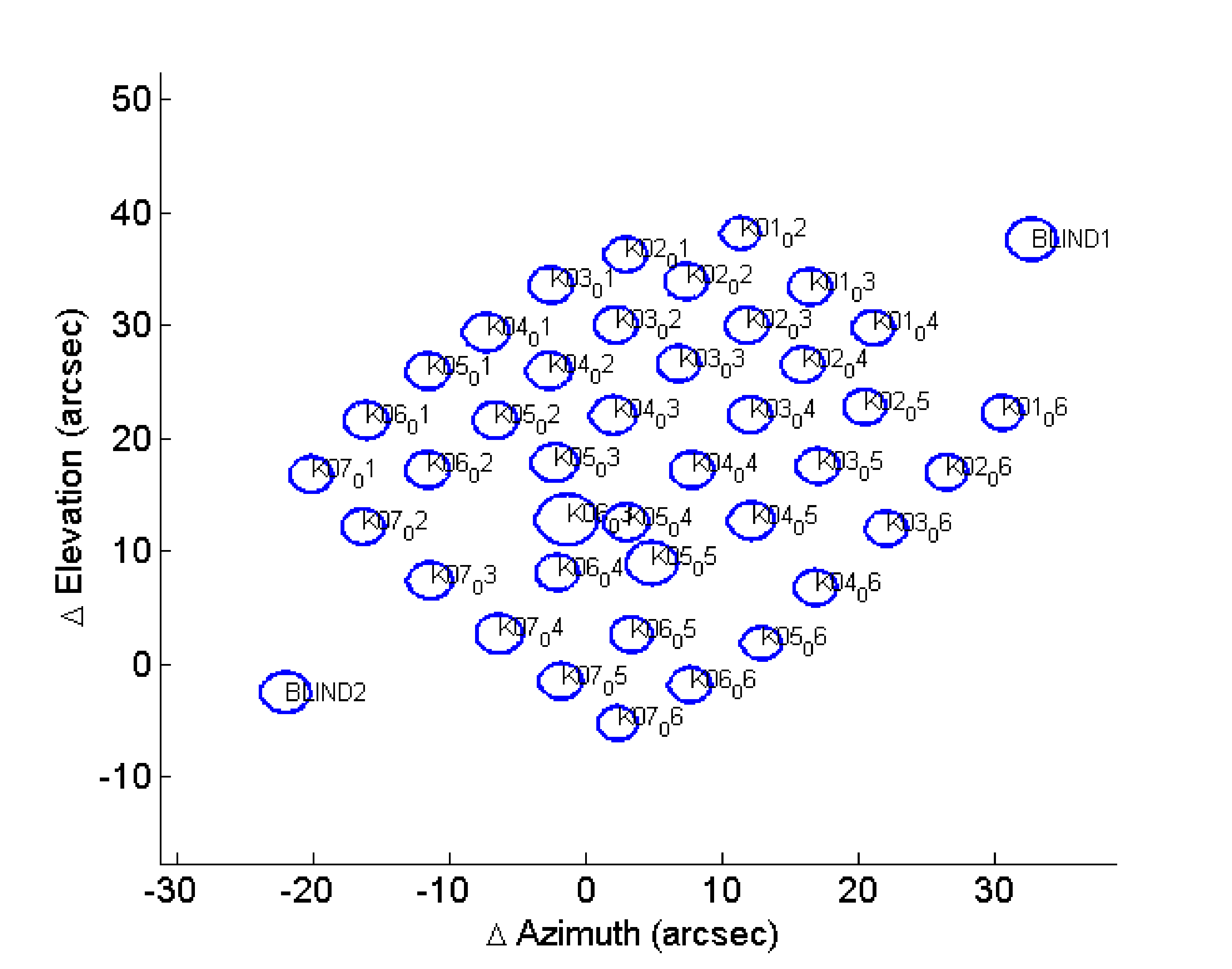
Testing sensitivity

- Sky loading simulated by temperature increase in dark environment
- NEP = NEP ~ $2{\cdot}10^{-16}$ W/√Hz for 100% radiation coupling (0.25K data)
- Expected sky NEP= $6{\cdot}10^{-15}$ W/√Hz per pixel
  - 10% pixel efficiency
  - 30% instrument efficiency



Array to NIKA

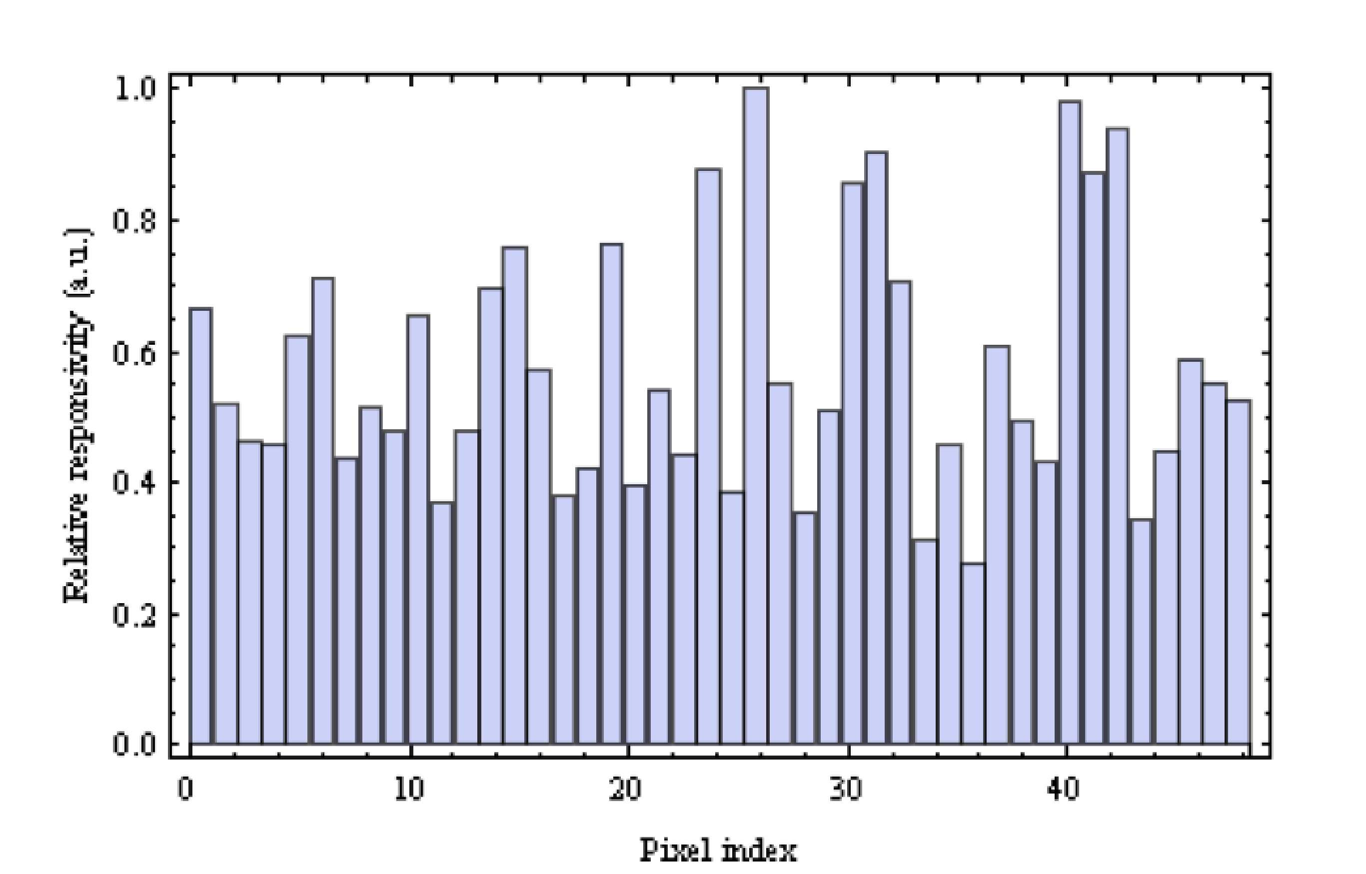
Finding the pixels in the focal plane



First Light

Constructing an image

- Use sky noise to calculate individual pixel gain



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NET of the system

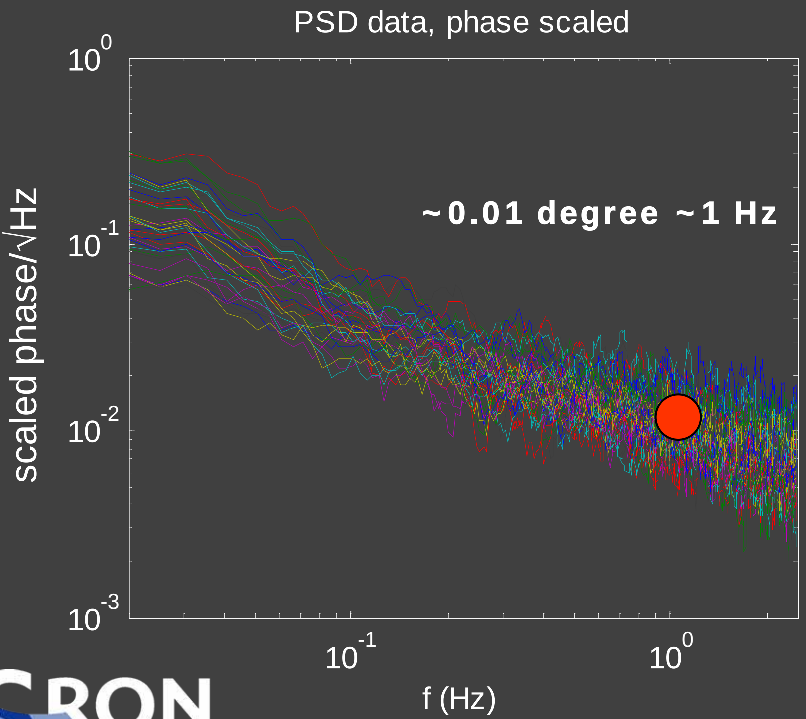
from Mars data

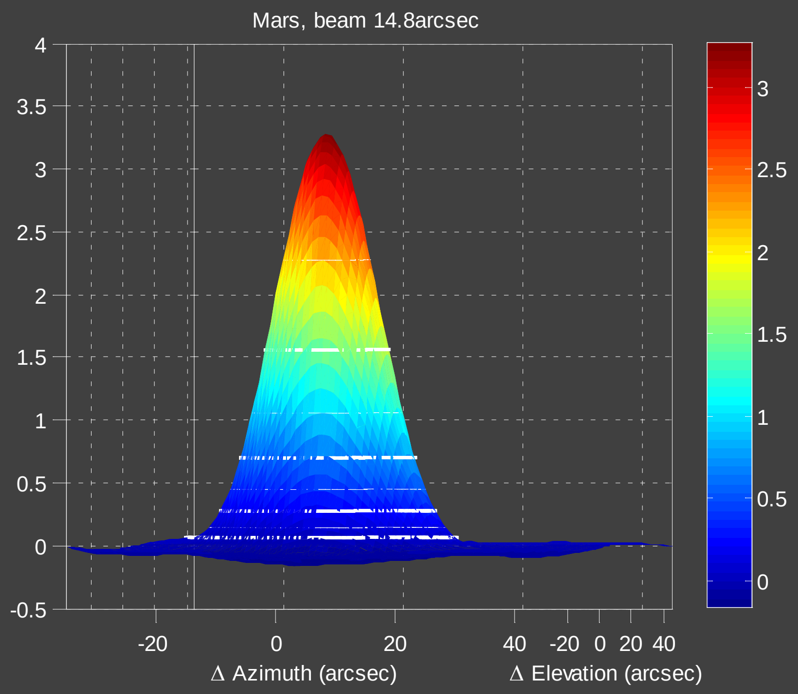
- SNR = 330/√Hz @ 1 Hz
- NET=T_{source}/SNR
- T_{source}=9K per pixel

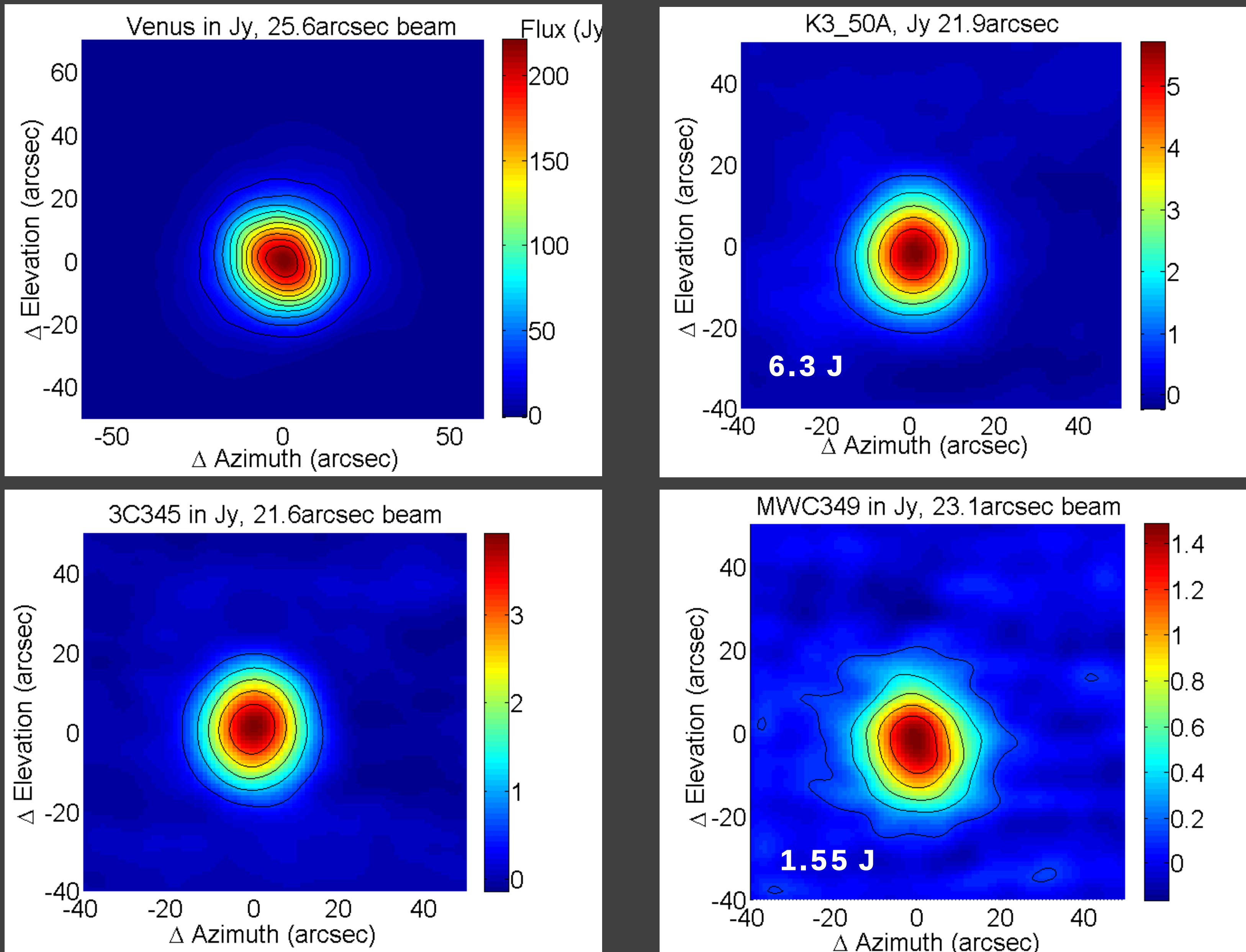
•$NET_{sys,pixel}$ = 27mK/√Hz

•$NEP_{sys,pixel}$ = 1.6 · 10^{-14} W/√Hz

•$NEP_{array,pixel}$ = ~3 · 10^{-15} W/√Hz



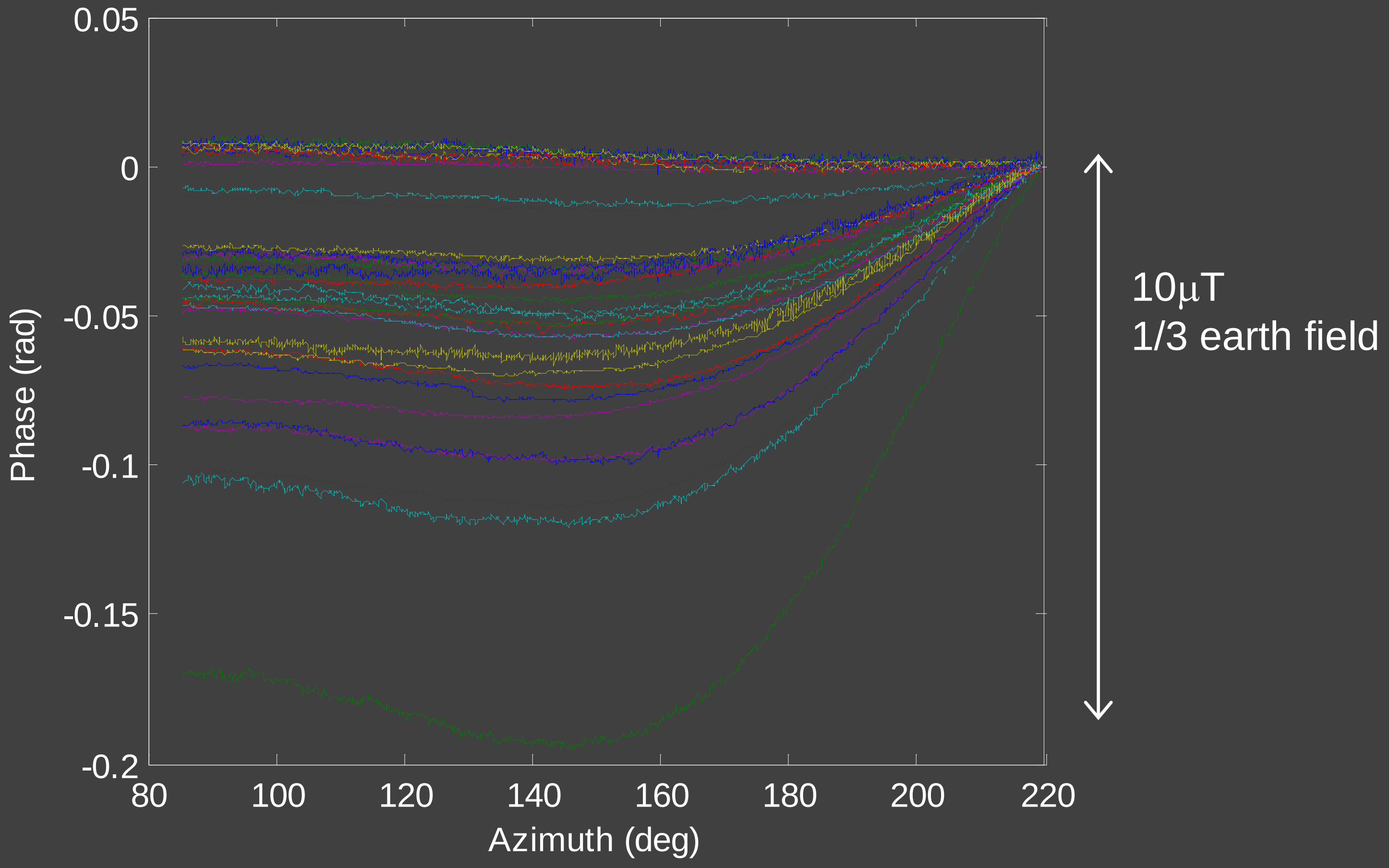




NEP 1E-14 sky, 3..5E-15 W / Hz$^{0.5}$

Magnetic Field effect

- Only marginal shielding
- Clearly visible on telescope slew, max 10° phase shift/80 degree azimuth
- within instrument noise during raster scans
- will cause drift << sky 1/f noise during long integrations (earth rotation)



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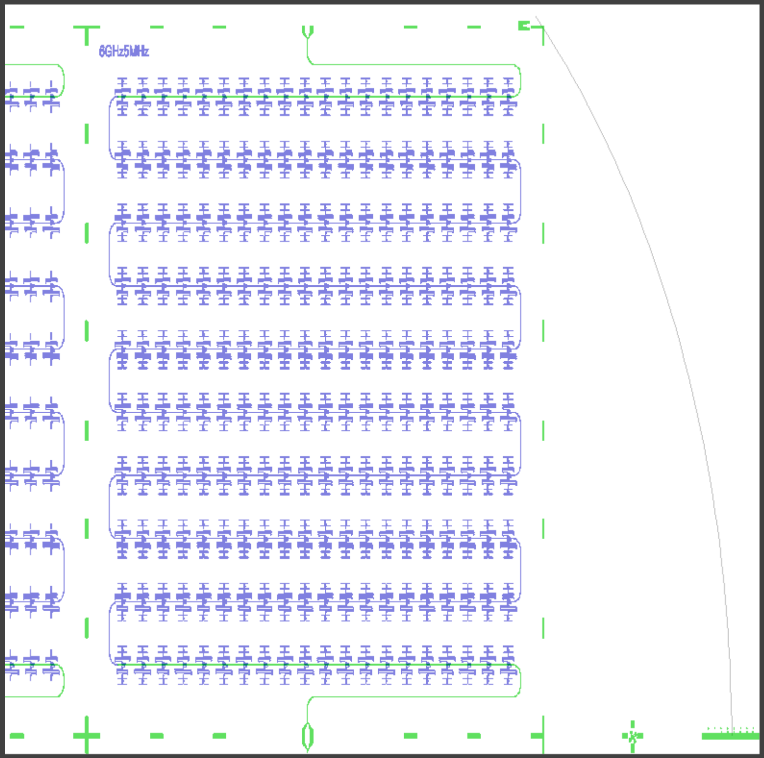
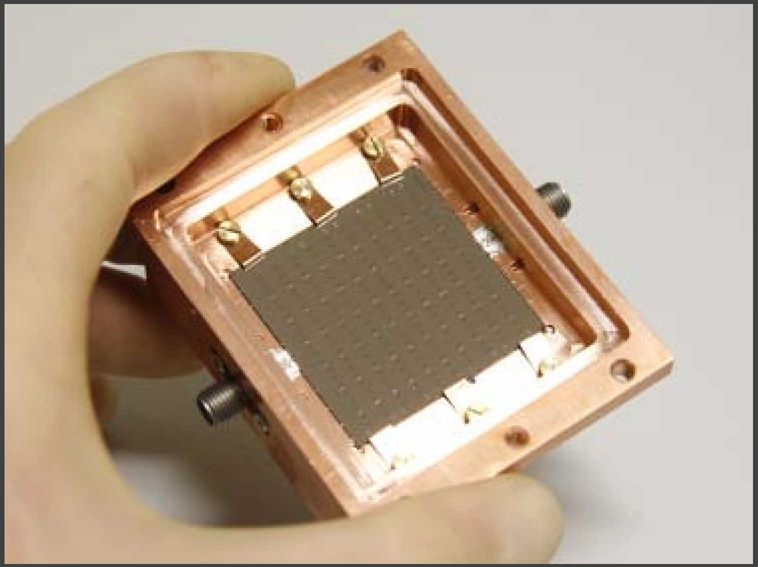
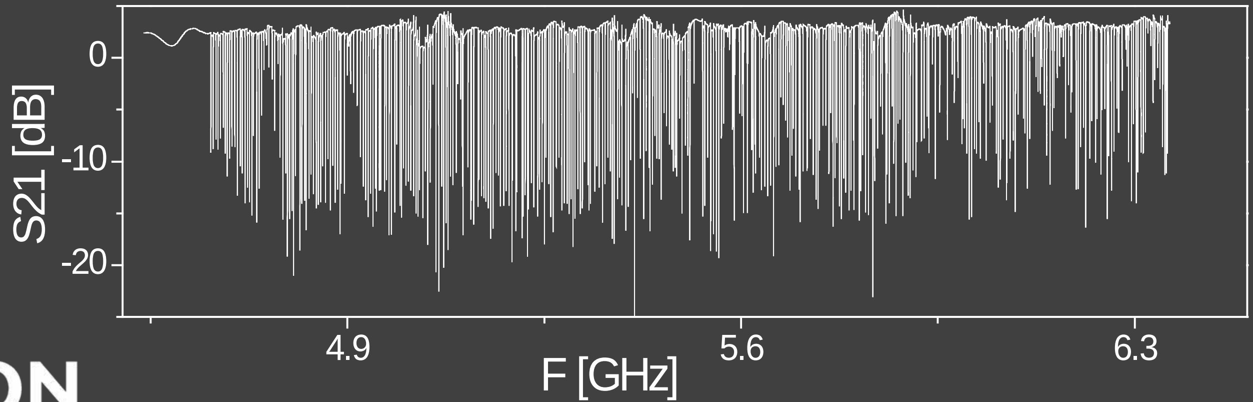
Larger arrays







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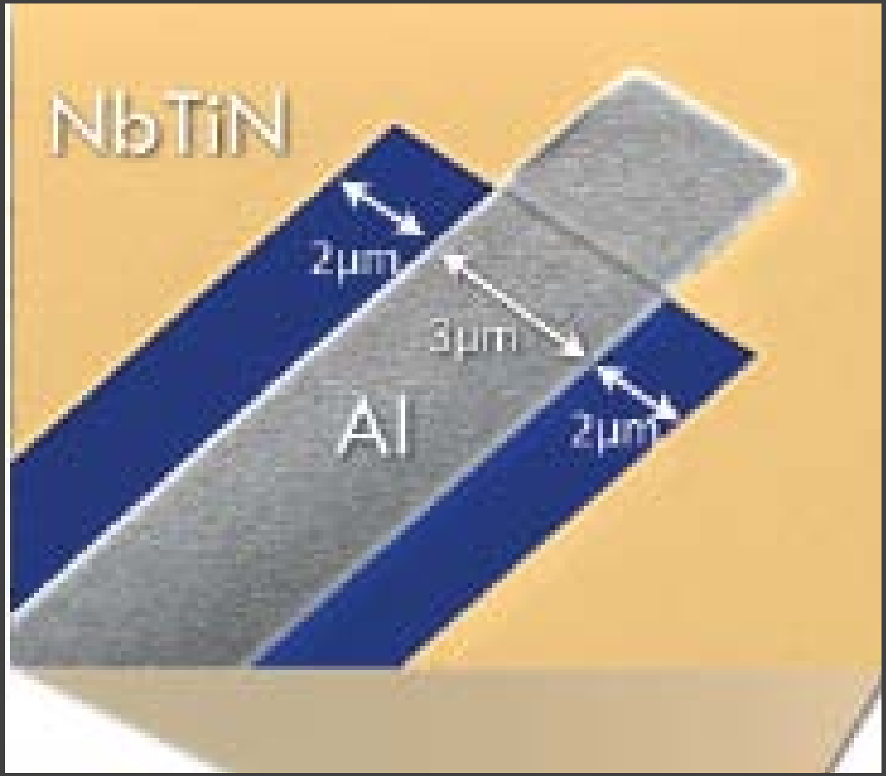
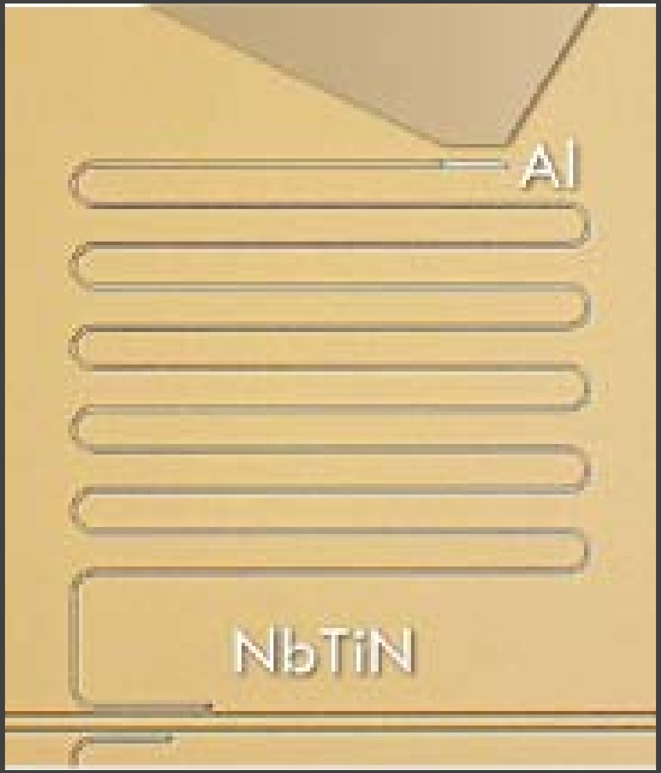
This Run

- 256 central core pixels (16x16) 324 total pixels (18x18)
- +- Spiral core distriution, 4MHz spacing 1 GHz BW (1.2 GHz for 324 pixels)
- Optical coupling: optimized double slot antenna with Si lens array
- Hybrid NbTiN-Al technology
- Air bridges





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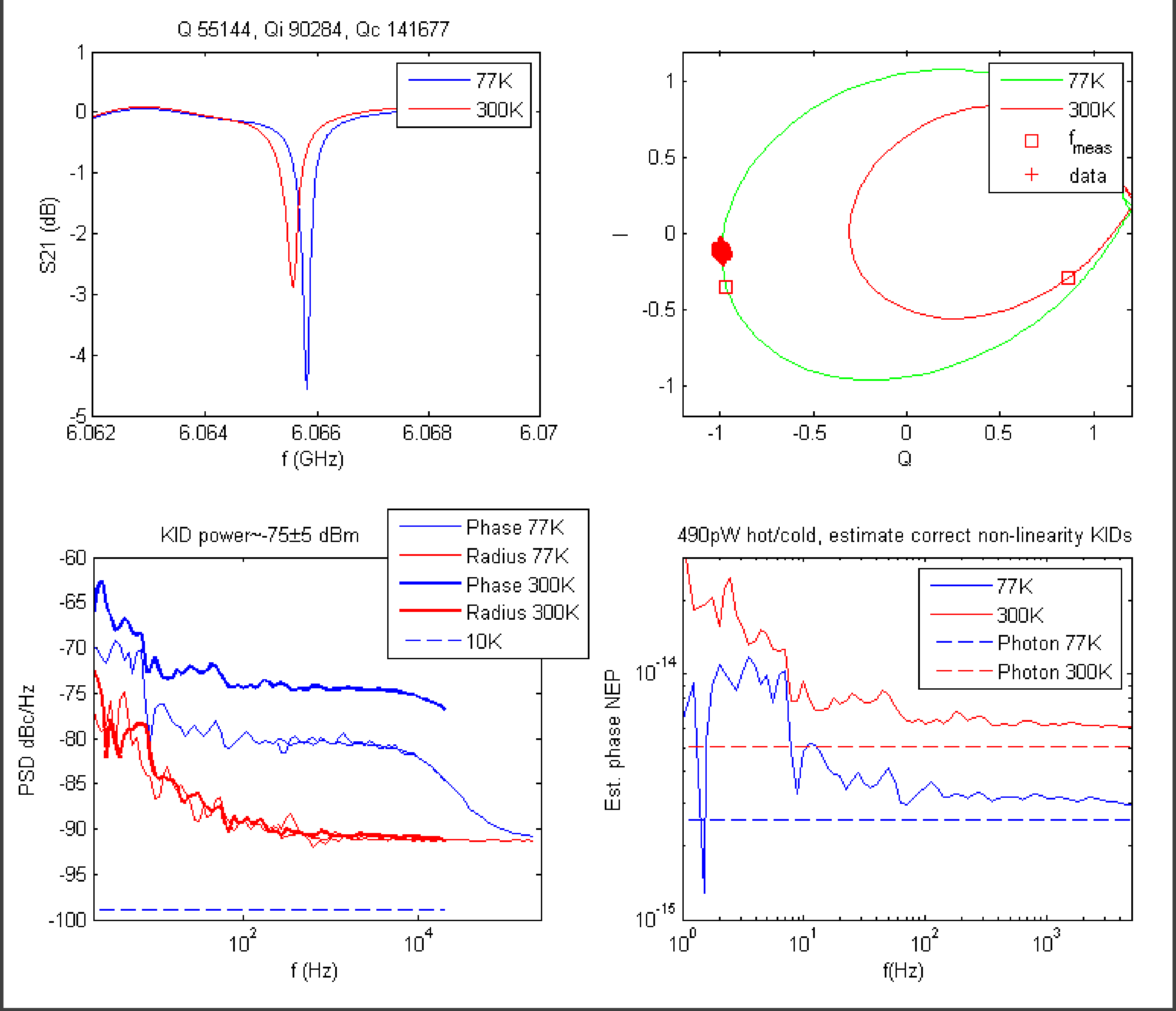
Batch H8 test results at 350 GHz (not optimal system)

With Bridges
Optical NEP 3E-15
KID NEP – 3E-17

Preliminary



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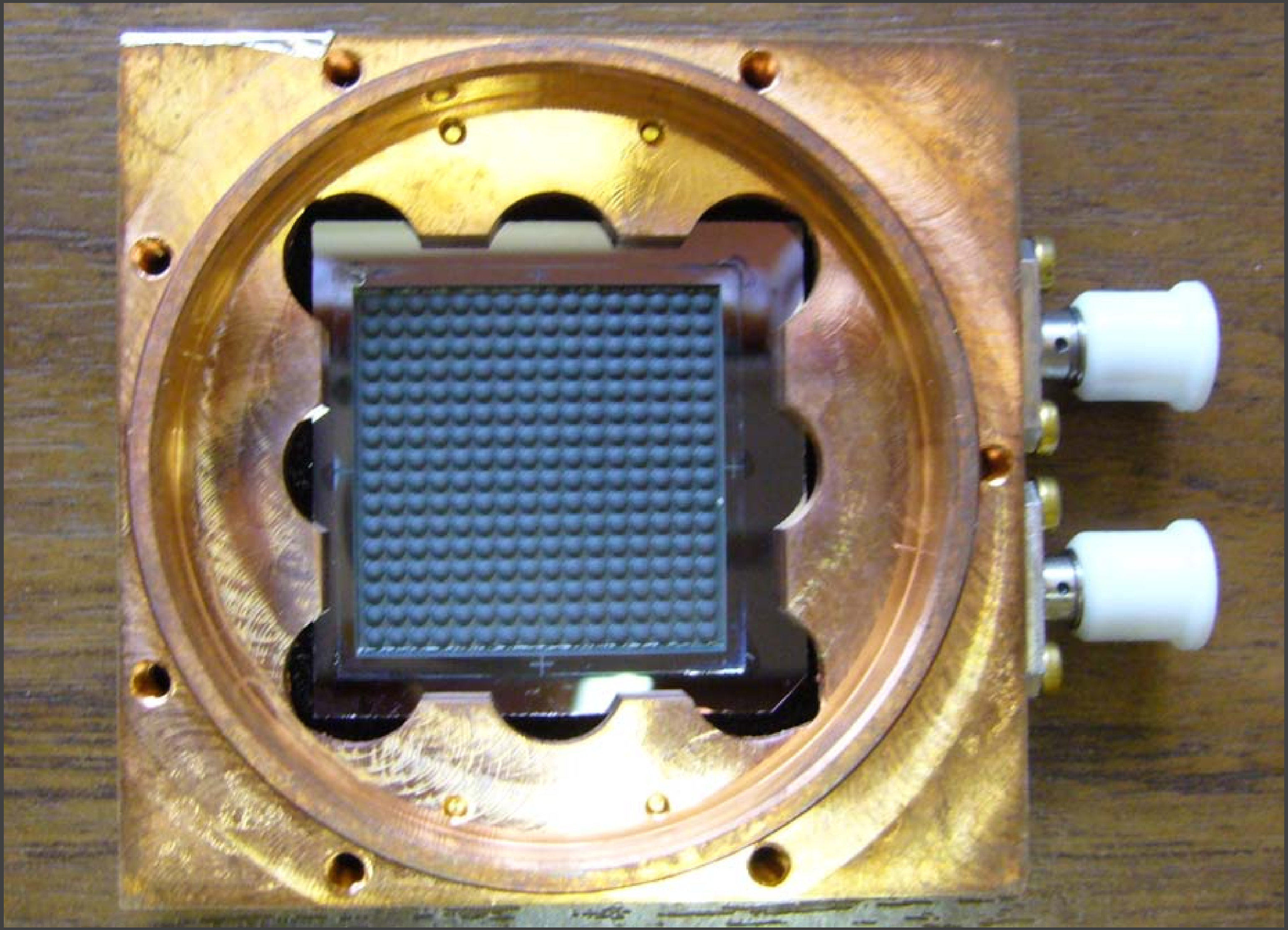
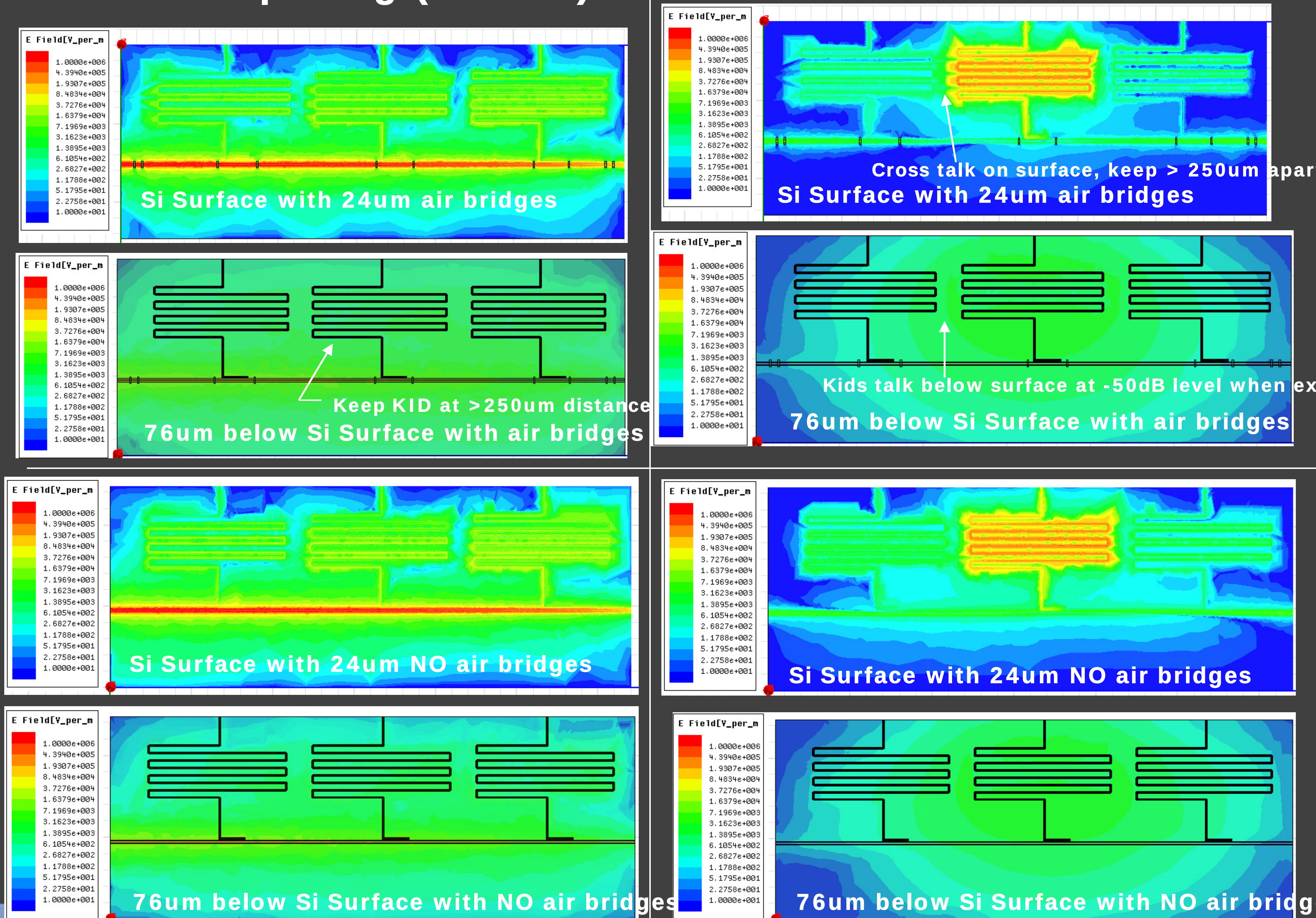
NIKA holder with Si-lens array



F Spacing (J. Kooi)



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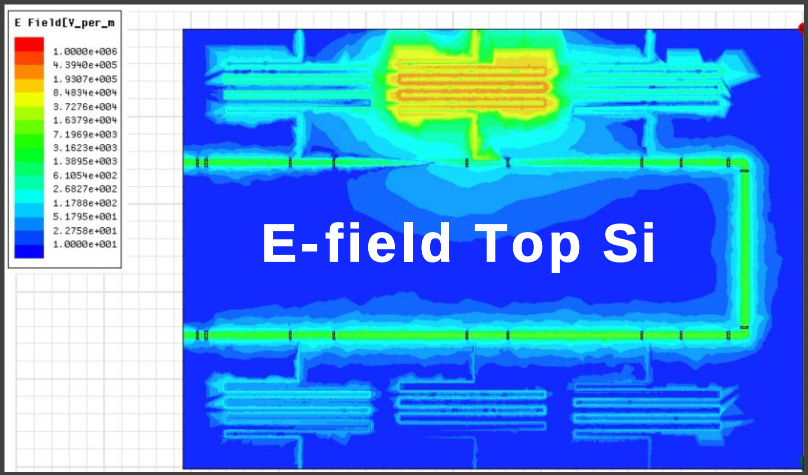
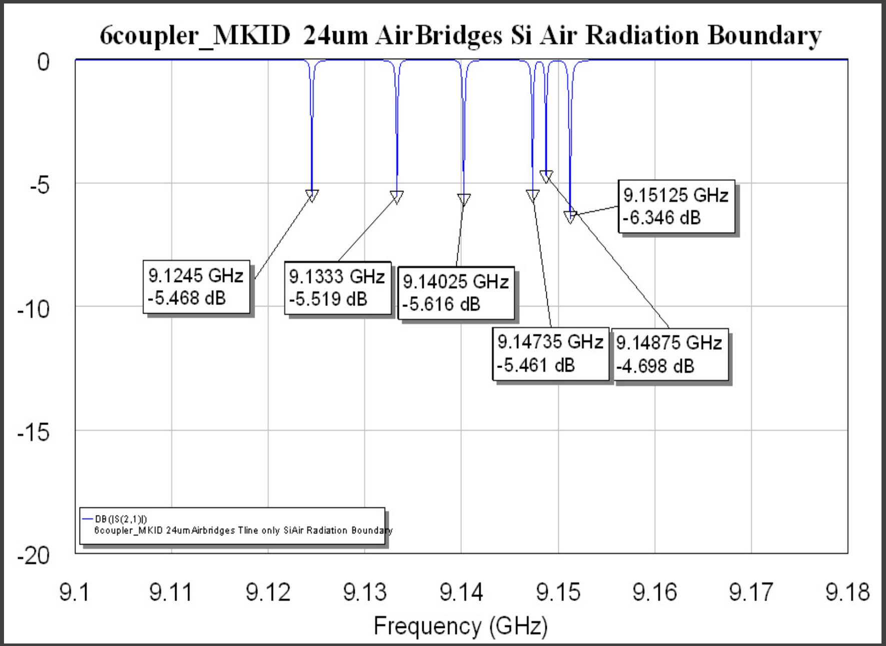
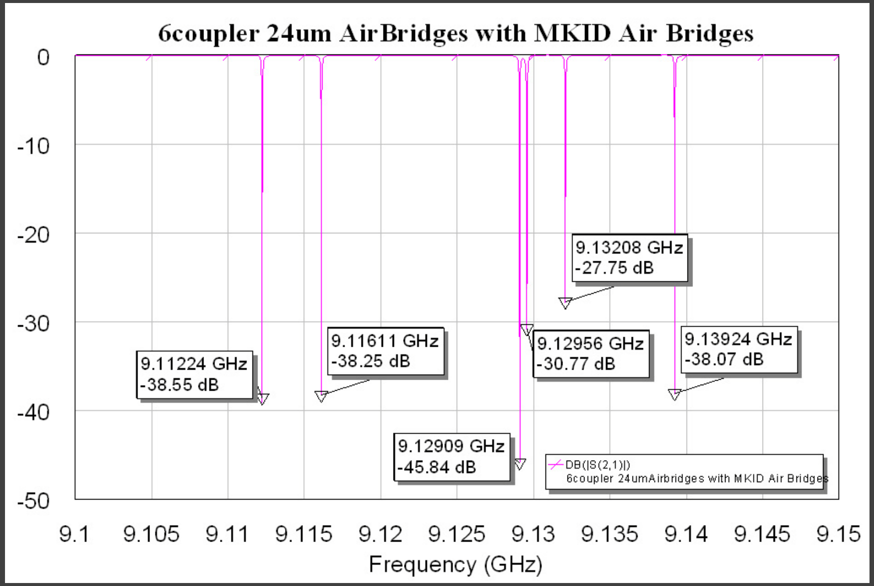
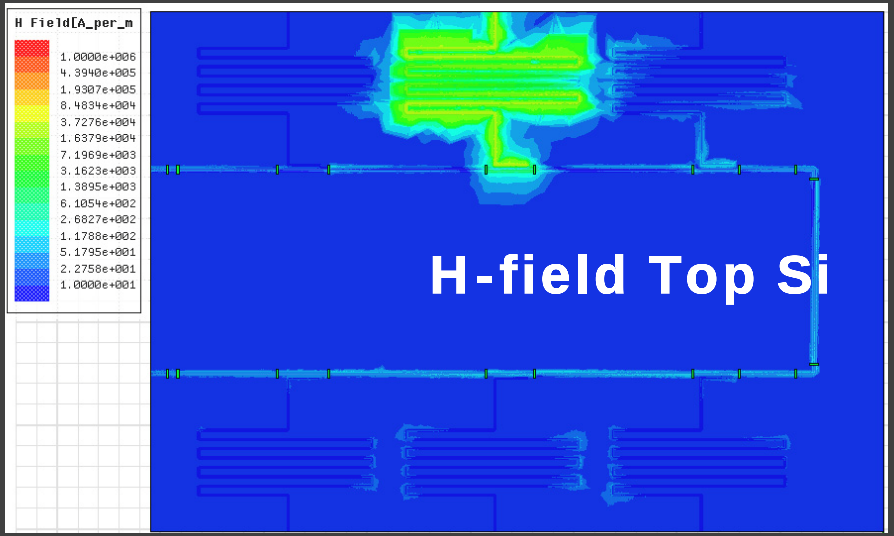






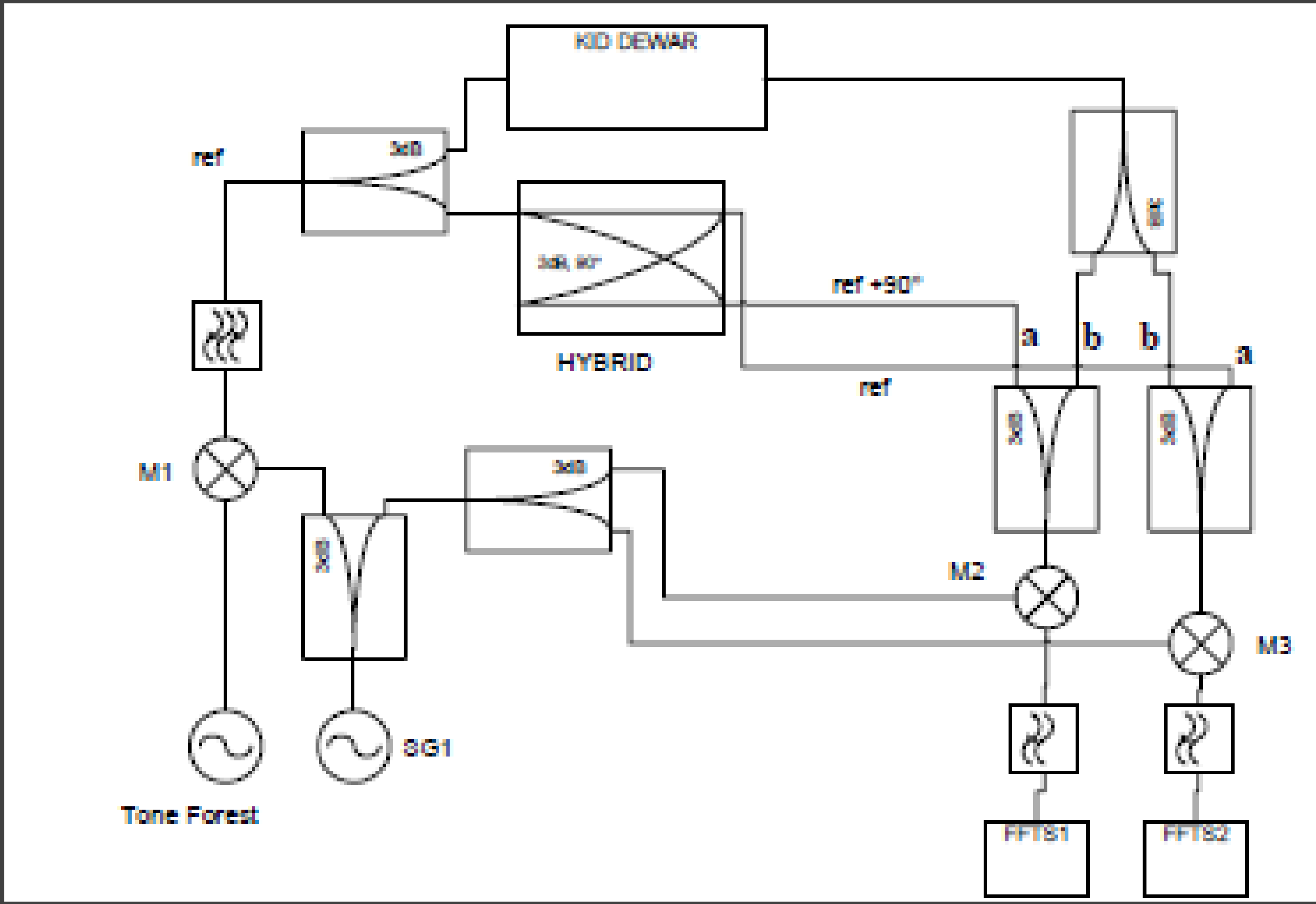


Readout

Euvis generator
2 GHz BW I-Q

50dB SSB upconvertor

Dual channel FFTS, 8k channels 1.5 GHz bw



Next steps

- Several batches with bridges, optimizing coupling, KID volume, Qs, etc (this run)
- AR-coat lens array (this run)
- F-spacing, M-strip central line and symmetrical M-strip-CPW coupling
- Alternative optics coupling schemes (in progress)
- TiN (in progress)
- Readout

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