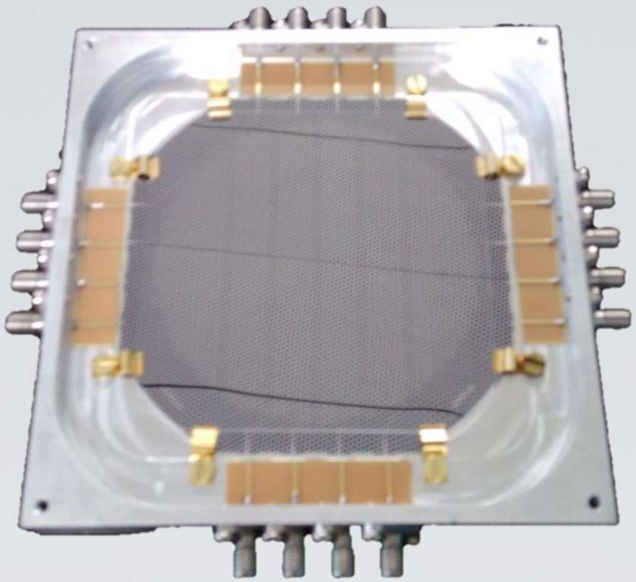
KIDs arrays for NIKA2

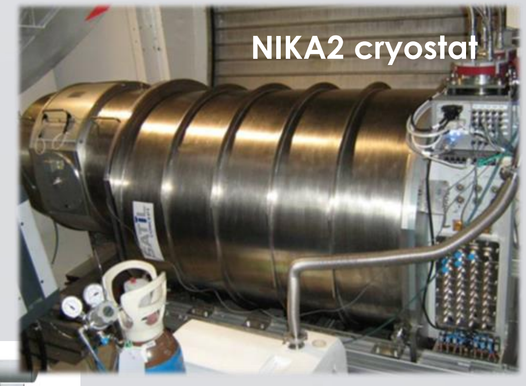


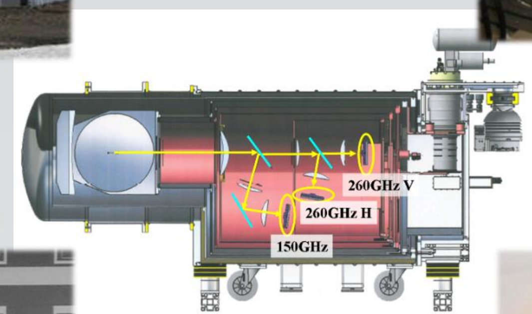
Grenoble –June 2019 – NIKA2 conference

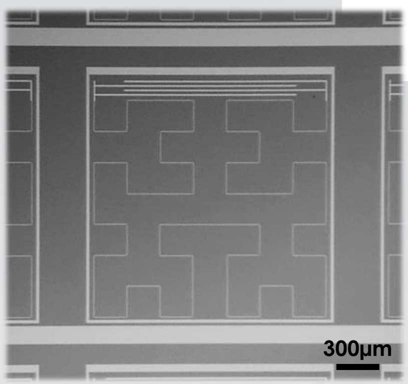
Context

Telescope at Pico Veleta (Spain)

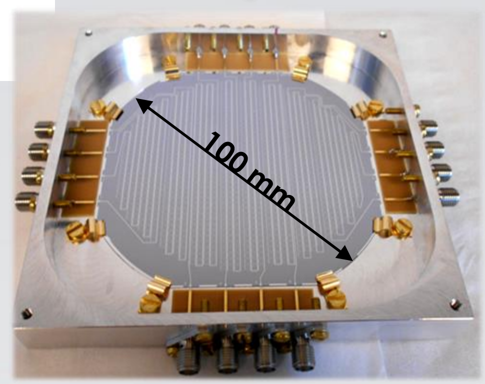
The NIKA2 instrument installed in the cabin







2mm array : 1 pixel



NIKA2 array (1200 pixels)

Plan

Context

I/ Microtechnology process
- standard
- Microstrip

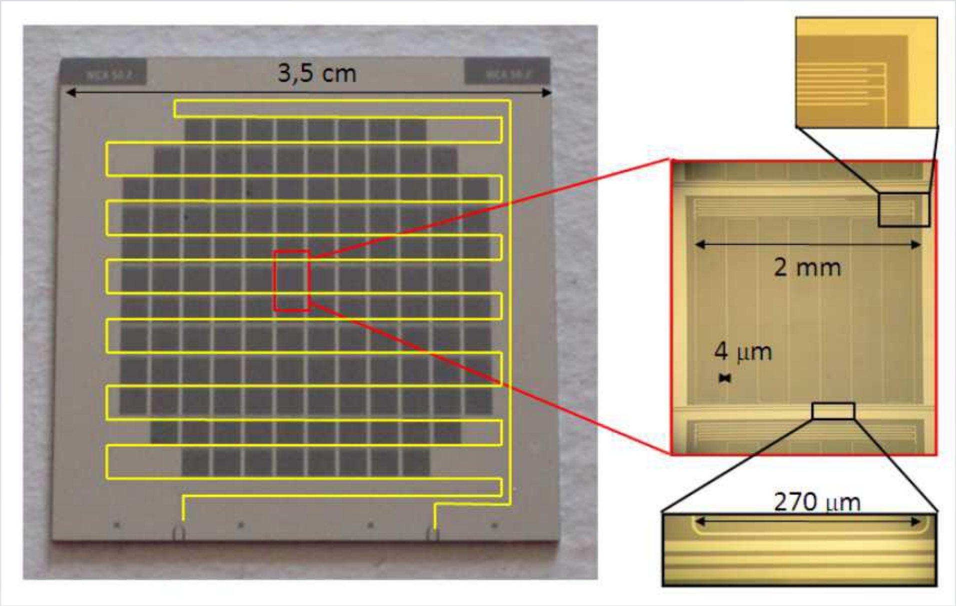
II/ “Generation 1” Arrays
- 1mm
- 2mm

III/ “Generation 2” Arrays
- 1mm
- 2mm

IV/ Last developments for NIKA’s arrays
- 1mm thin substrate
- perspectives

Microtechnology Process

NIKA1 technology roots



- CPW feedline

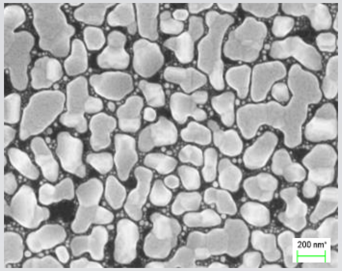
The ground plane is also the electromagnetic shield around each pixel.

The illumination is by the back side. A mirror is positioned on the top side to realize a λ/4 cavity.

- Aluminum thin layer

Superconducting gap: ~110 GHz

Lk ~ 2pH / □

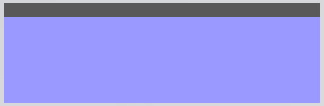


20 nm thickness

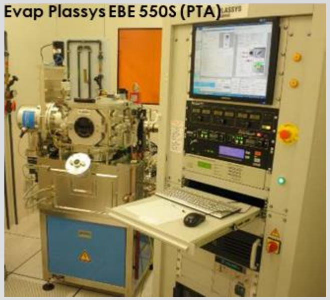
- 2 geometry patterns for 2 bands:
  1mm → 120 – 180 GHz
  2mm → 220 – 280 GHz

Microtechnology Process

Standard technological Process : Clean Room

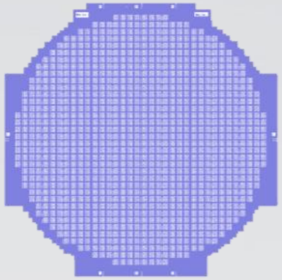


On a 4 inch silicon mono crystalline and high purity (> 1000Ω.cm) wafer, a thin layer (18nm) of aluminium is coated by electron beam evaporator (under a residual vacuum 5.10^{8} mbar)



Print patterns via optical lithography (λ = 365nm) through a dedicated mask

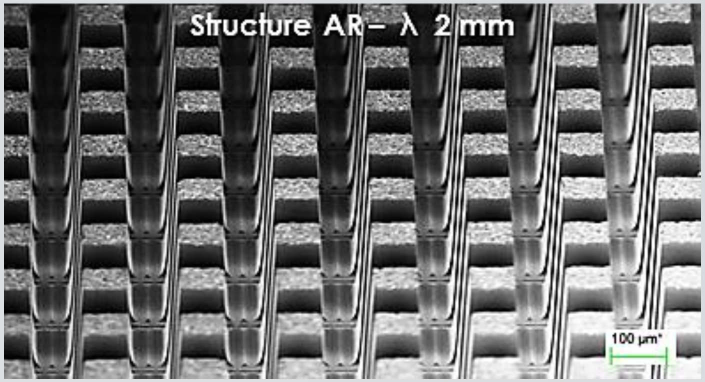
The metal is etched by a chemical (phosphoric acid) solution through resist apertures.



Hard points: The homogeneity of the aluminum layer, have a full 4 inch surface without major defects (dust, bubbles)

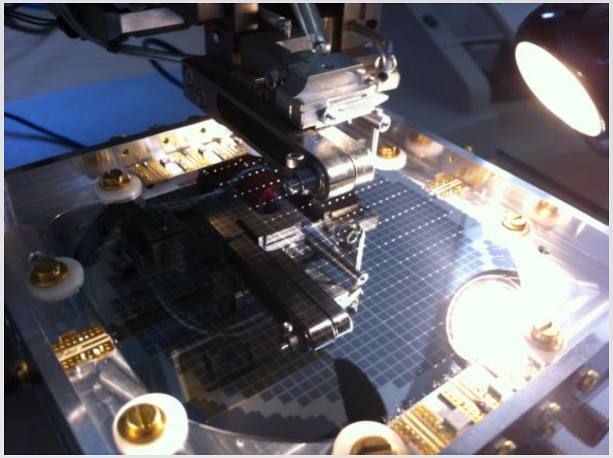
Microtechnology Process

Standard technological Process: Packaging



Dicing the edges of the array, and structure the backside of array to add a function of optical adaptation layer (AR).

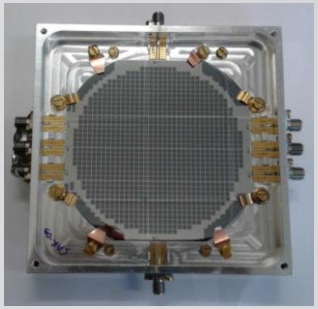
The AR strategy is to reduce the silicon density by grooves to obtain an effective index
$n_{void} = 1 < n_{adapt} \sim 2 < n_{Si} \sim 3.4$



After mounting in a dedicated holder, connect the feedlines and improve the equipotentiality of the ground plan by sticking small bridges above the signal line (25µm diameter wires).

"Generation 1" Arrays

2mm arrays, tested in NIKA2 @ Grenoble



CPW feedline, Al 18nm, Si 300µm,
1020 pixels, pitch 2,1mm

Spectral band ~ 130 – 170 GHz
Without AR

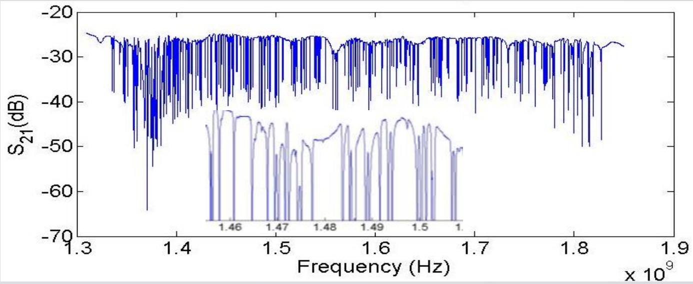
90% good pixels

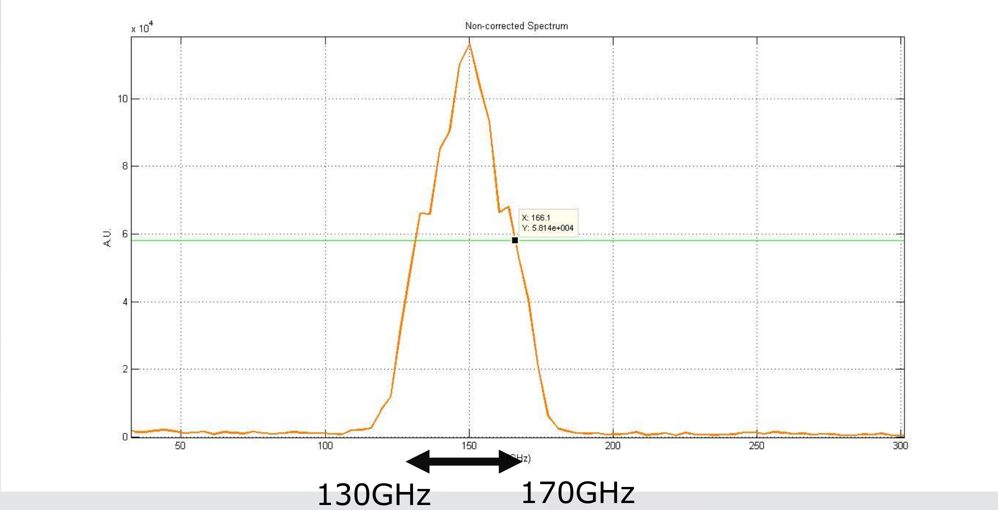
Qi ~ 30 k (sky 50 K)

Qc ~ 20 k

Optical resp (50 vs 300 K)
= 200 kHz

Noise ~2 $Hz/Hz^{0.5}$





“Generation 1” Arrays

2mm arrays, tested in NIKA2 @ Grenoble

CPW feedline, Al 18nm, Si 525µm, 1020 pixels, pitch 2,1mm

Spectral band ~ 125 – 175 GHz
With AR (250µm)

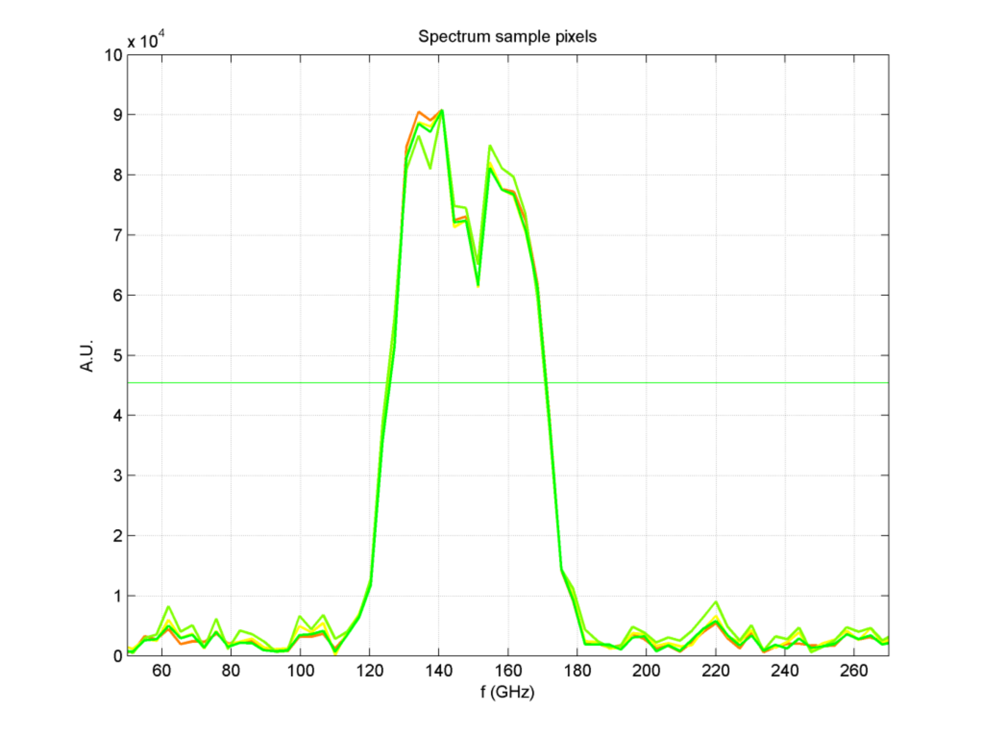
90% good pixels

Qi ~ 30 k (sky 50 K)

Qc ~ 12 k

Optical resp (50 vs 300 K) = 200 kHz

Noise ~2 Hz/$Hz^{0.5}$



The width and the area of the effective spectral band is increased by AR

“Generation 1” Arrays

1mm arrays, tested in NIKA2 @ Grenoble

CPW feedline, Al 20nm,
Si 180μm, 1200pix, pitch 1,6mm

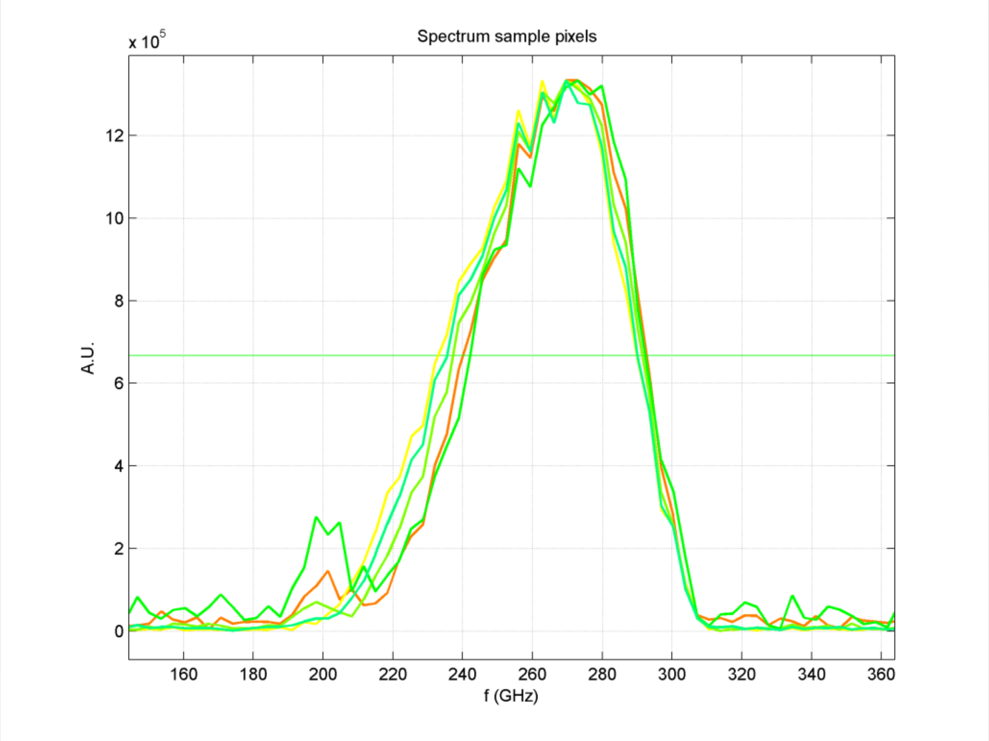
Spectral band ~ 240 – 290 GHz
Without AR

Qi ~ 14 k (sky 50 K)

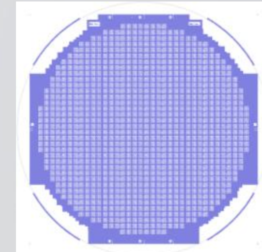
Qc ~ 20 k

Optical resp (50 vs 300 K)
= 600 kHz

Noise ~4 $Hz/Hz^{0.5}$



“Generation 1” Arrays



1mm arrays, tested in NIKA2 @ Grenoble

CPW feedline, Al 25nm,
Si 350µm, 1200pix, pitch 1,6mm

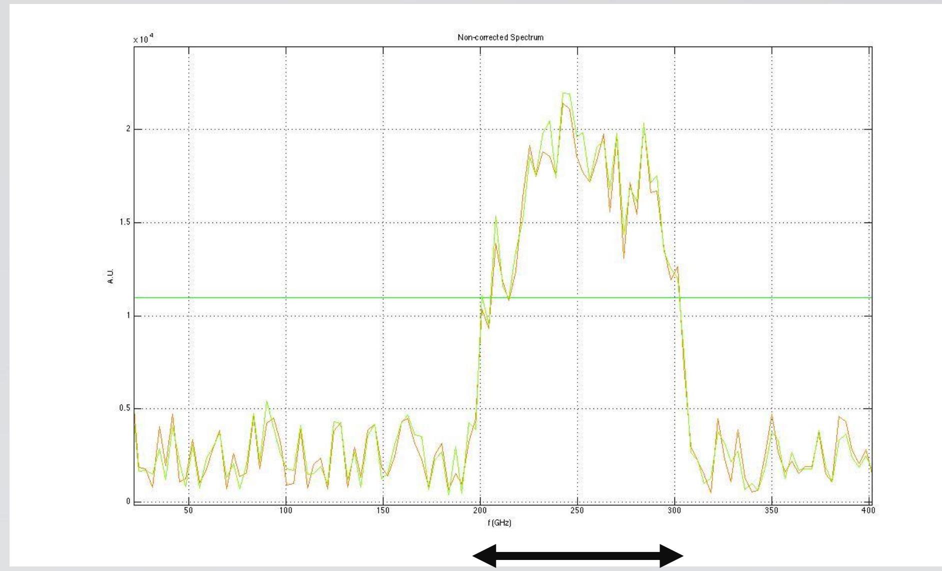
Spectral band ~ 200 – 300 GHz
With AR (150µm)

Qi ~ 16 k (sky 50 K)

Qc ~ 25 k

Optical resp (50 vs 300 K)
= 500 kHz

Noise ~5 Hz/$Hz^{0.5}$



200GHz 300GHz

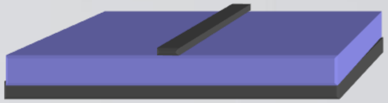
The width and the area of the effective spectral band is increased by AR

In this first period (12 months) around 40 arrays has been fabricated by Grégoire Coiffard (IRAM), Alessandro Monfardini and Johannes Goupy (Neel Institute).

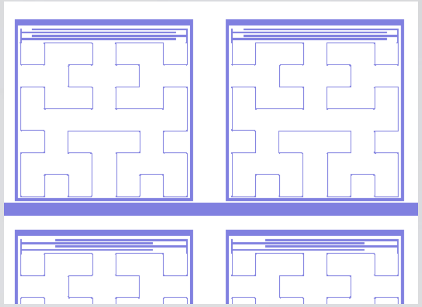
“Generation 2” Arrays

Improve the technology

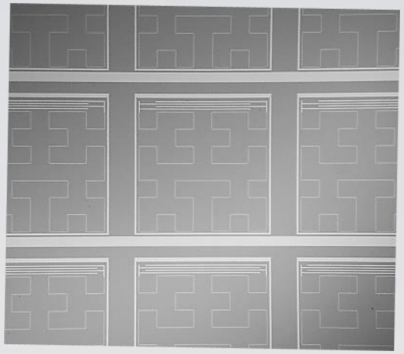
Change the feedline strategy. Using Microstrip :
Thanks to the backside ground plane, no need for bridges.



We have modified the design to adjust the coupling by adding a “loop” (electromagnetic shield effect) around the pixel.



In this configuration, the illumination is by the top side. The thickness of the silicon wafer determines the λ/4 cavity above the mirror of aluminum (200nm) layer on the backside.



We have initiated a study to understand the source of resonance shuffling.

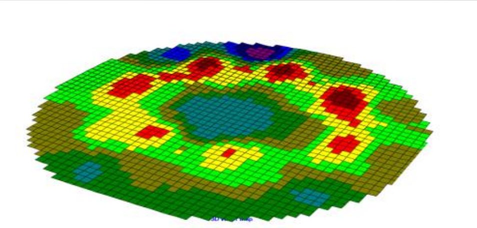
“Generation 2” Arrays

Improve the technology

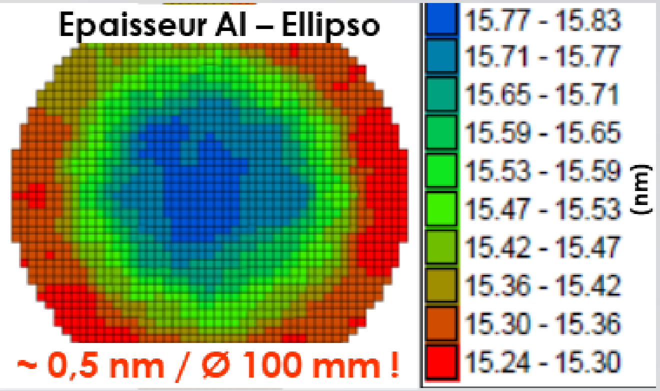
We have initiated a study to understand the source of the resonance shuffling in order to reduce double pixels

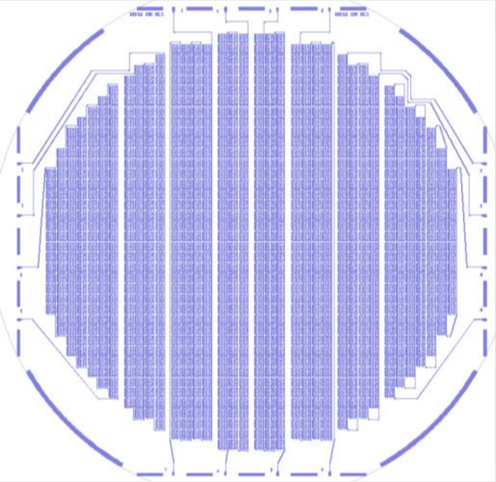
The main source of shuffling is mainly due to the aluminum thickness variation across the wafer (center to edge)

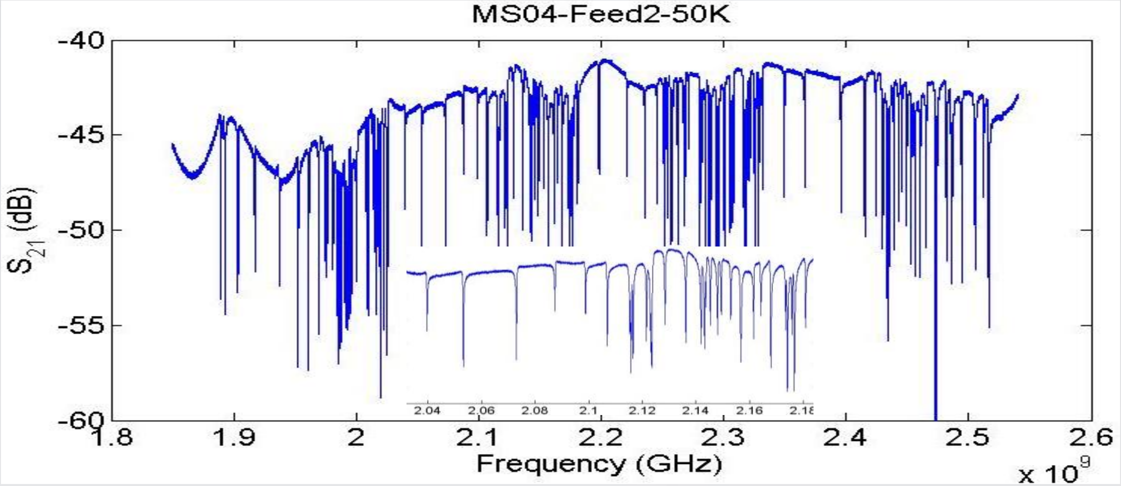
The variation is tiny, but it has a huge impact on the kinetic inductance (0,5nm → ~5%)



Al evap PTA 18 nm ± 0,5 nm

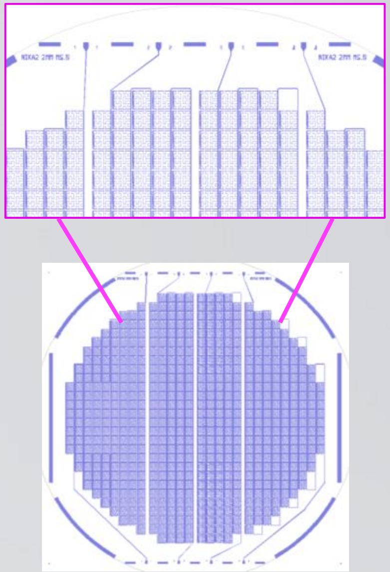






“Generation 2” Arrays

2mm arrays, tested in NIKA1.5 @ Grenoble



MS feedline, Al 18nm,
Si 156µm, 616pix, pitch 2.8mm

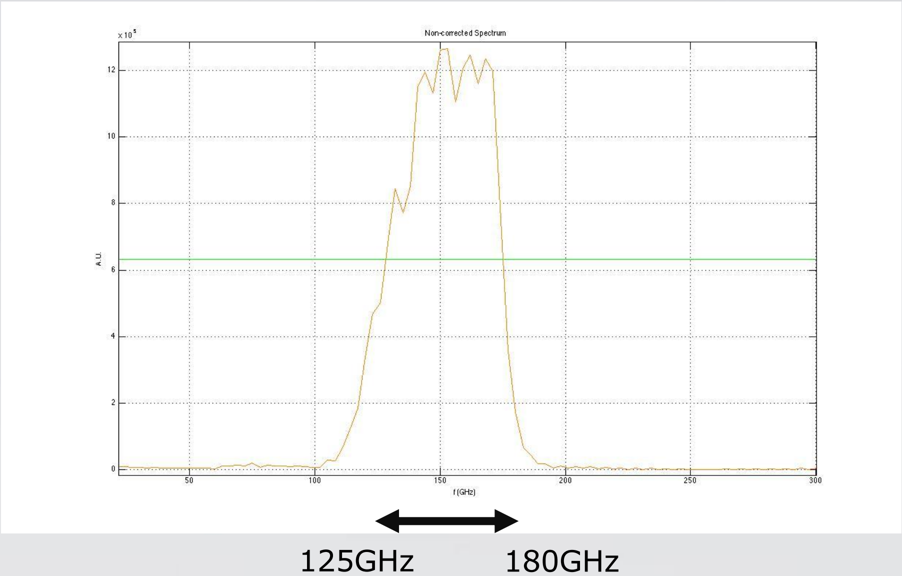
Spectral band ~ 125 – 180 GHz

Qi ~ 50 k (sky 50 K)

Qc ~ 12 k

Optical resp (50 vs 300 K)
= 120 kHz

Noise ~1 $Hz/Hz^{0.5}$



Preserve the good spectral band by a λ/4 cavity, and decrease the noise
→ Final array !

“Generation 2” Arrays

1mm arrays, tested in NIKA1.5 @ Grenoble

MS feedline, Al 20nm,
Si 240µm, 1140pix, pitch 2.0mm

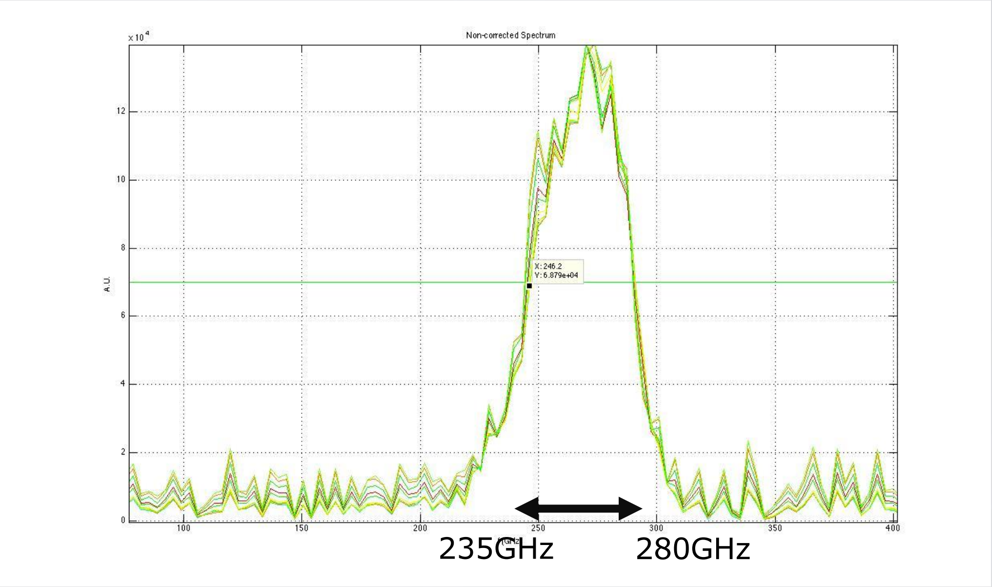
Spectral band ~ 235 – 280 GHz

Qi ~ 18 k (sky 50 K)

Qc ~ 12 k

Optical resp (50 vs 300 K)
= 500 kHz

Noise ~4 Hz/Hz$^{0.5}$



Not the full spectral band due to the 3λ/4 cavity.
→ Change technology

Last developments

1mm arrays with λ/4 (90µm) thickness silicon wafer

The main difficulty is the manipulation of very thin crystalline wafers.
With a lot of care, we still break 30% of them..

MS feedline, Al 20nm,
Si 90µm, 1124pix, pitch 2mm

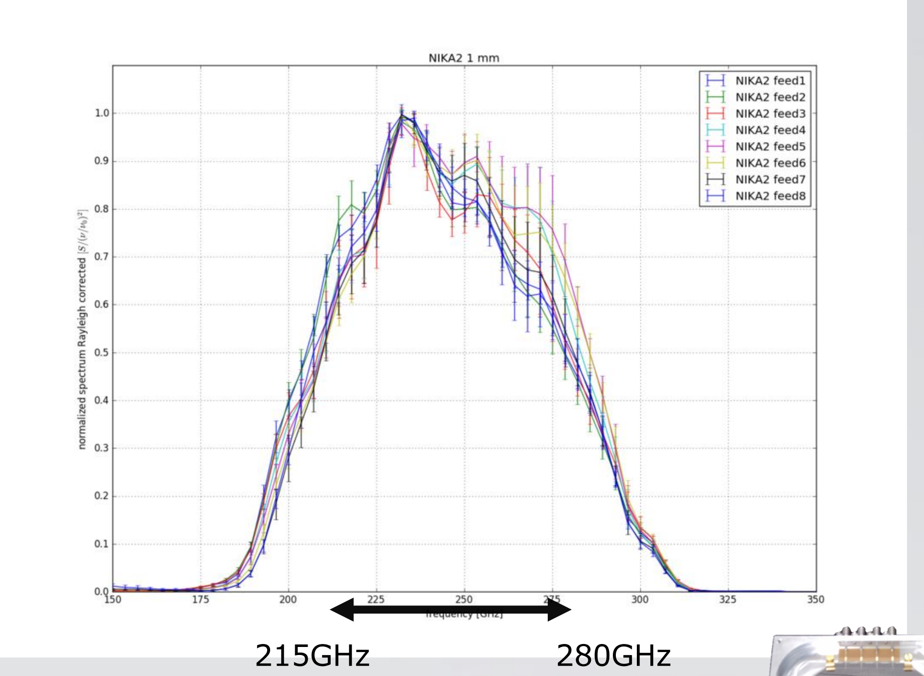
Spectral band ~ 215 – 280 GHz

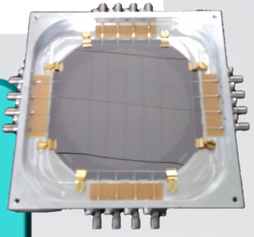
Qi ~ 18 k (sky 50 K)

Qc ~ 15 k

Optical resp (50 vs 300 K)
= 350 kHz

Noise ~3 Hz/Hz$^{0.5}$





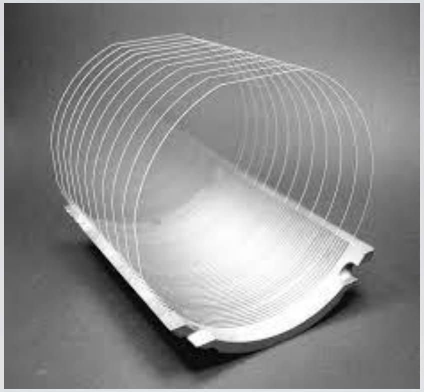
Full spectral band thanks to the λ/4 cavity.
→ We have already 3 spare arrays fully tested for 1mm band waiting to be mounted in the instrument at Pico Veleta.

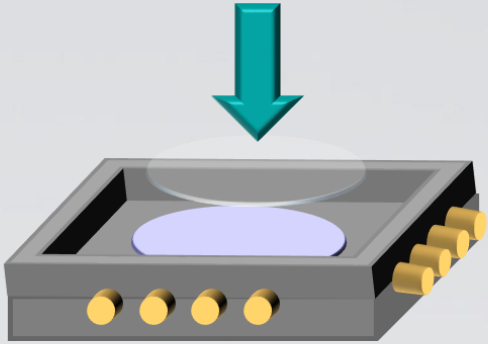
Last developments

Perspectives

Another option to increase the absorption of the arrays will be to add an AR layer on top of the MS arrays.

For CONCERTO, we have demonstrated that by covering the top face of arrays with a quartz wafer (ad-hoc thickness), it is possible to make a AR layer without increasing the noise of the detectors.



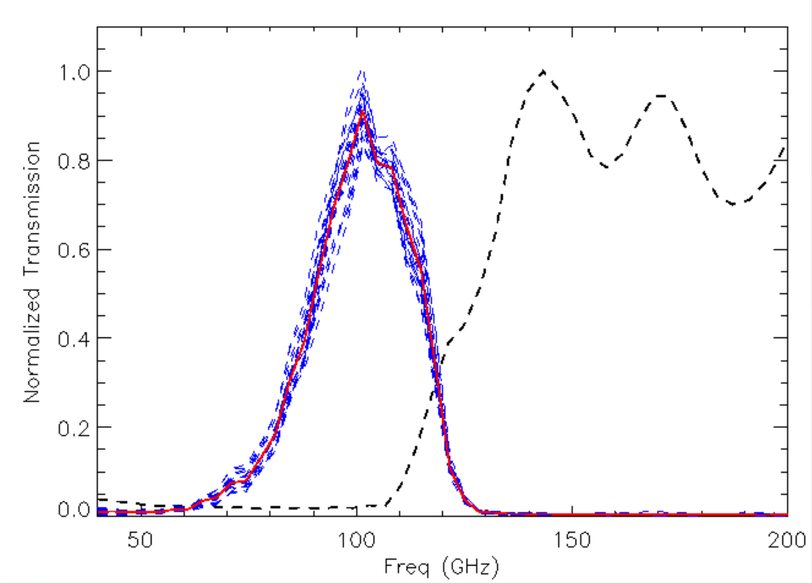


Another way has been developed by **Shibo (IRAM)** to reduce drastically the shuffling of the position of the resonances and recovering the 10% of resonators lost.

Last developments

Perspectives

Lower frequency absorption:
If we replace the aluminum layer of the KID by a Titanium (10nm) / Aluminum (25nm) bilayer, the superconducting gap decreased thanks to the superconductors proximity effect. This opens the way to the “3mm” (90GHz) band.



Thank you !