KID activities in Grenoble

Martino CALVO
for the GIS KIDS

Overview

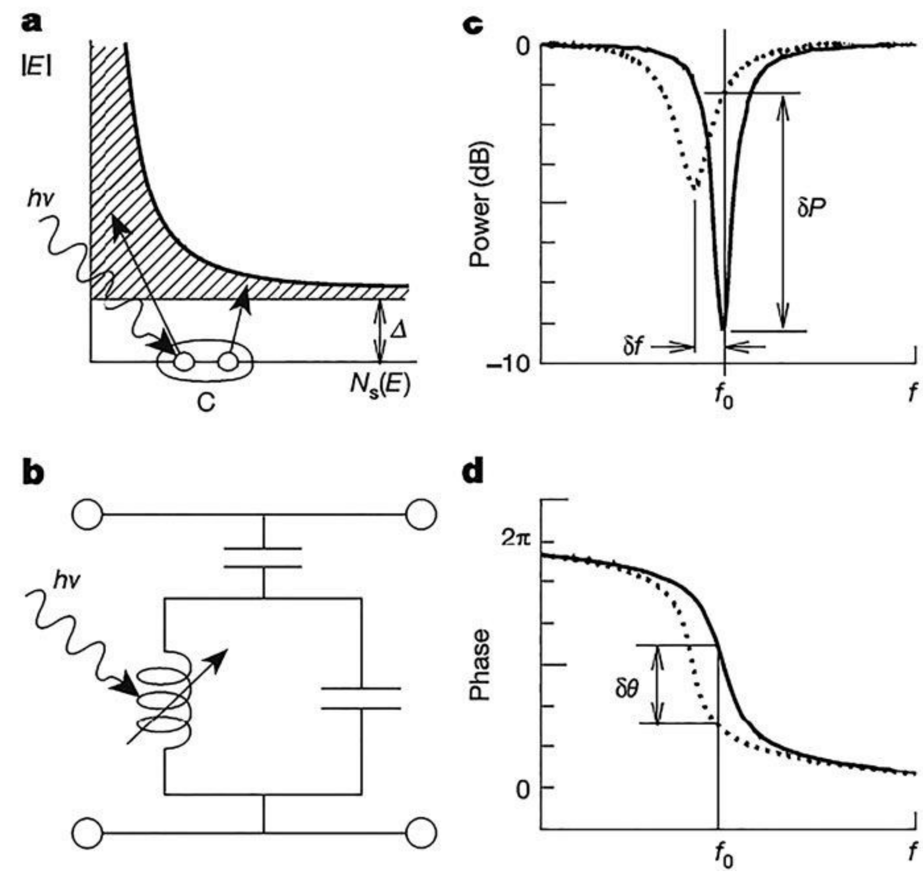
- KID developments: bigger and better!
- Main KID projects: ‘past’ (NIKA2/CONCERTO)
- Main KID projects: present/future (NIKA3/KAIROS)

KID working principle

Core of the device: a ***superconducting resonator***

- SC has *kinetic inductance* : $L_k(n_{cp})$
- Photons break Cooper pairs **(a)**
- Variation in n_{CP} variation in L_k **(b)**
- $f_0 = 1/\sqrt{(LC)}$

$\Delta L \rightarrow \Delta f_0, \Delta A, \Delta\theta$ **(c, d)**



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

Why KID?

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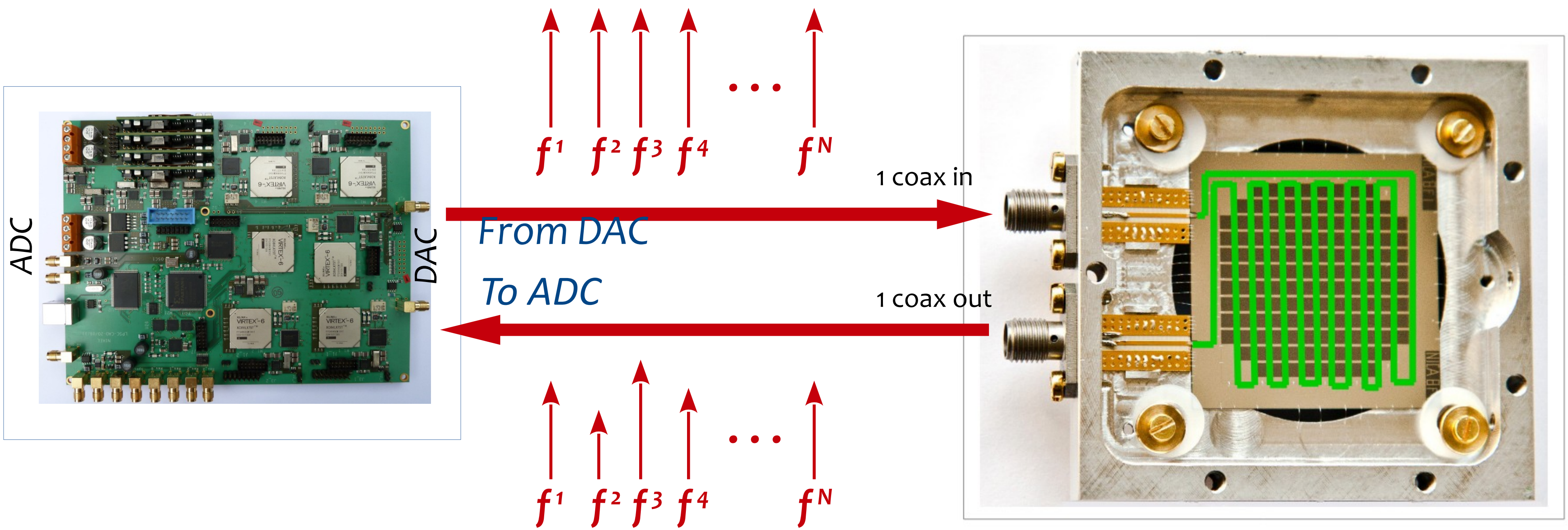
- Frequency Domain Multiplexing for free!



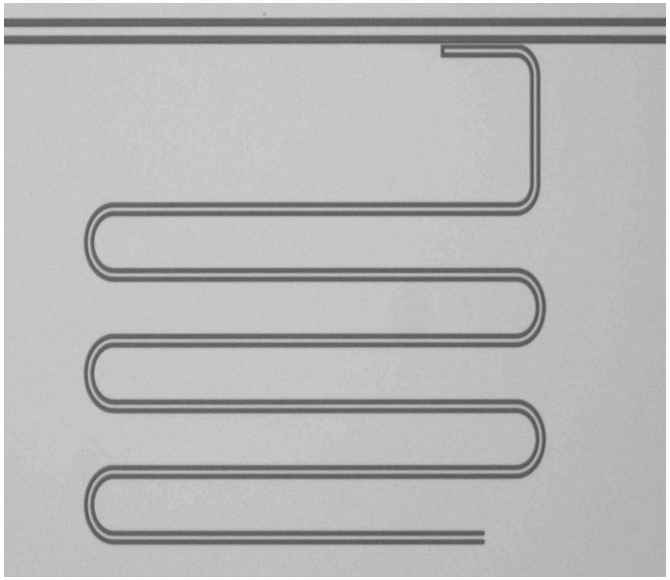
- Easy to fabricate (not always..)
- Non-thermal → fast, reduced T sensitivity..

KID implementations

Many different kind, but only 2 main 'families'

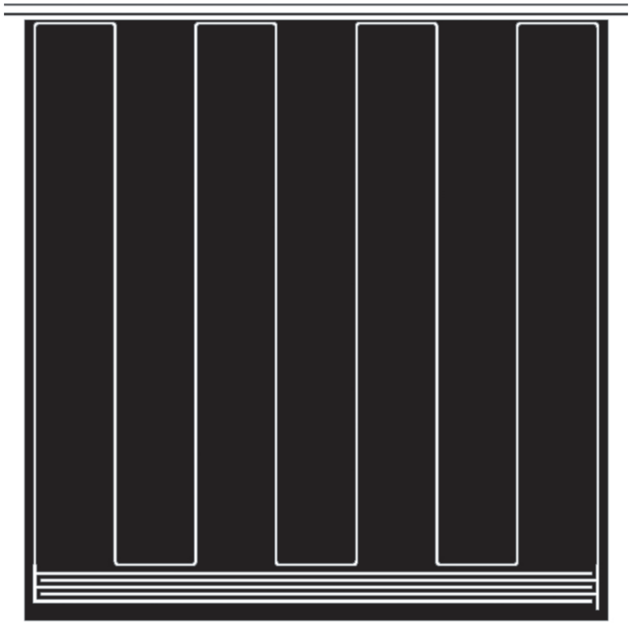
MKID (or 'distributed KID')

- f_0 determined by length
- EM field can be 'contained'
- Ideal for on-chip devices



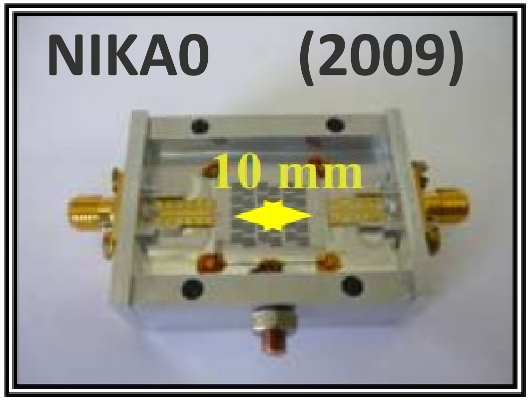
LEKID (Lumped Element KID)

- f_0 determined by L, C
- EM field more 'open'
- **Ideal for filled arrays**

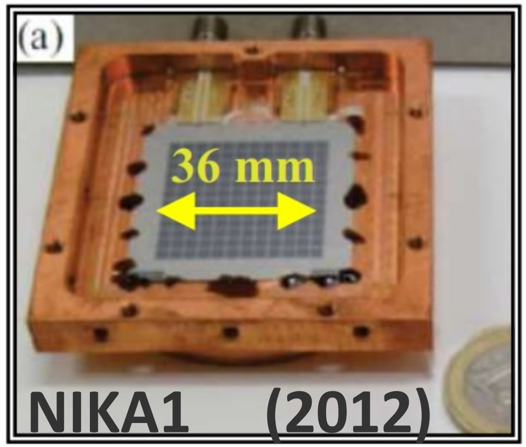


Bigger: KID large arrays

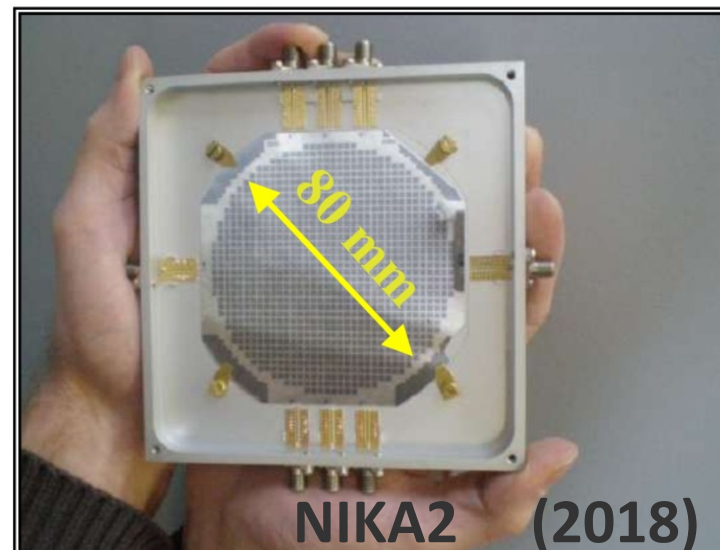
The proof that it works:



10s



100s



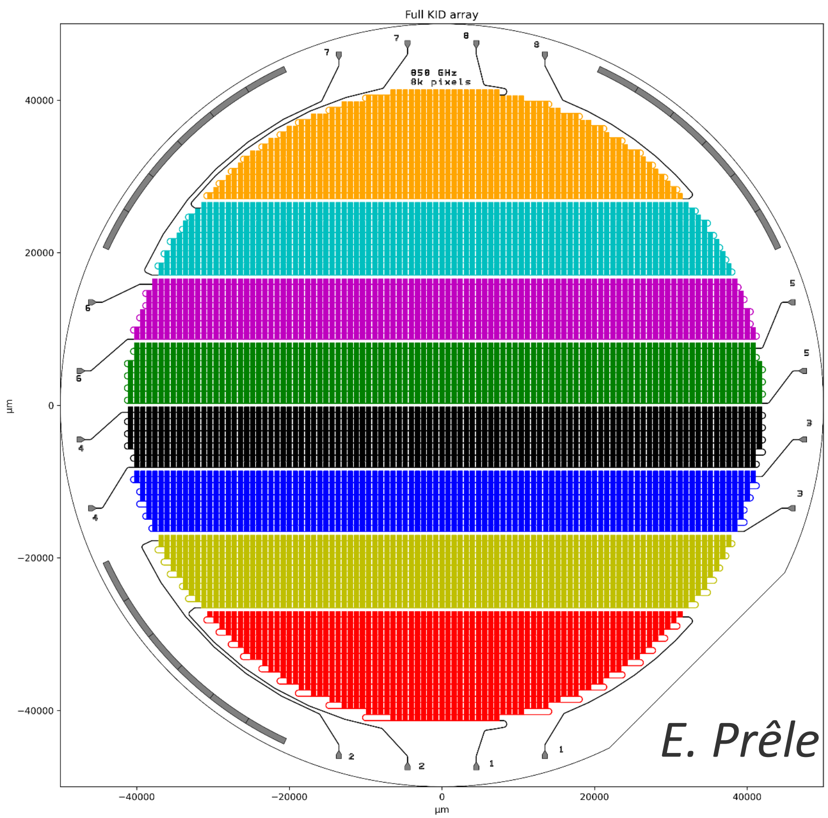
1000s

The next step: ***10000s****!* Is it doable?

Bigger: KID large arrays

- Easy solution: ‘just’ replicate (multiple feedlines)
- Main current limitation: readout electronics (improving!)
- Plus: film uniformity, control over design, cross-talk…
- No real stopping issue!

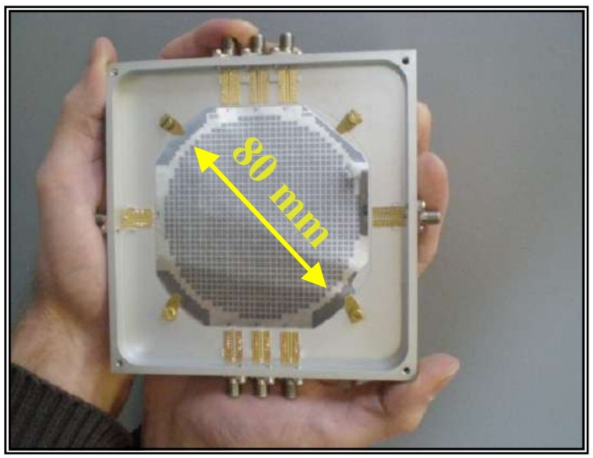
8 x 1100 → **9k KID mask**



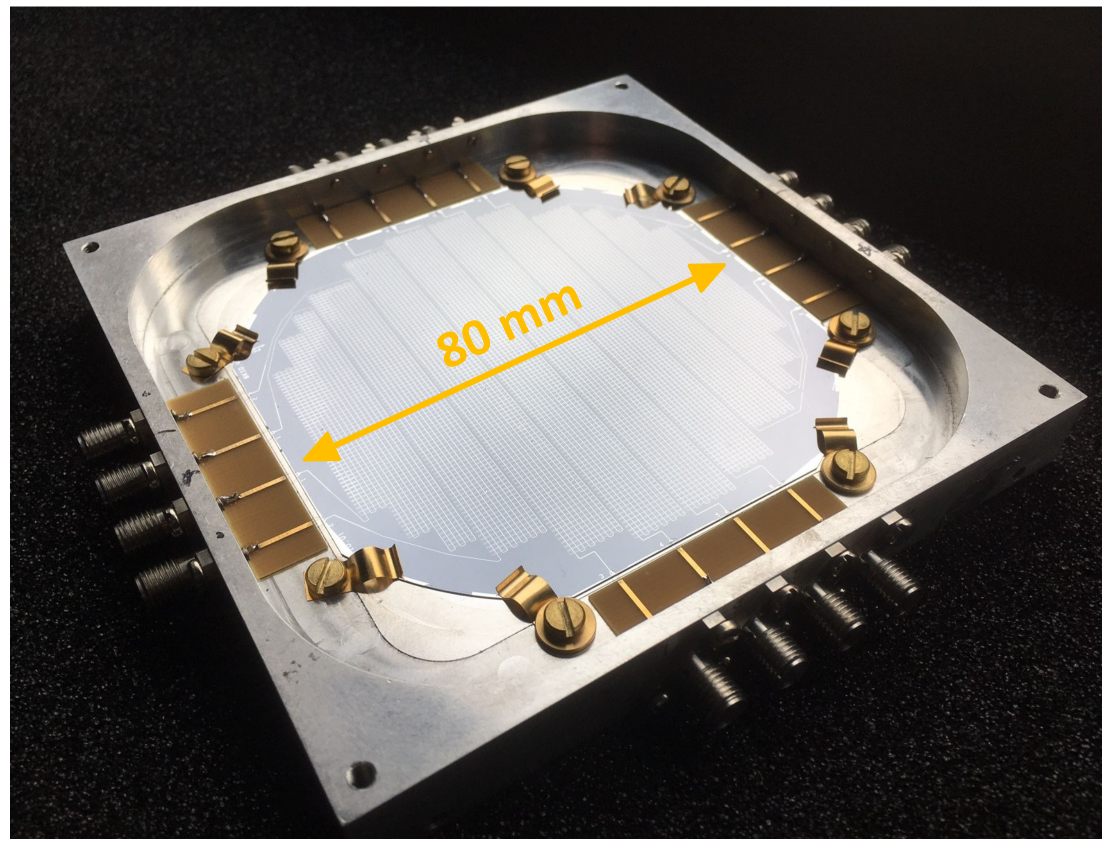
E. Prêle

Bigger: KID large arrays

- Focal planes with ~4k total detector already on sky
- First 8k array samples already tested



1000s



10000s

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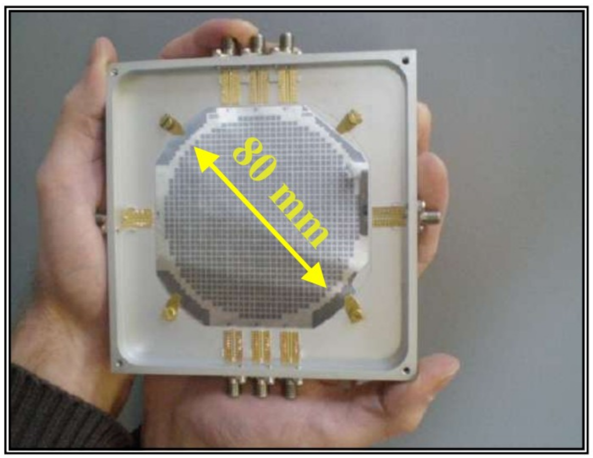
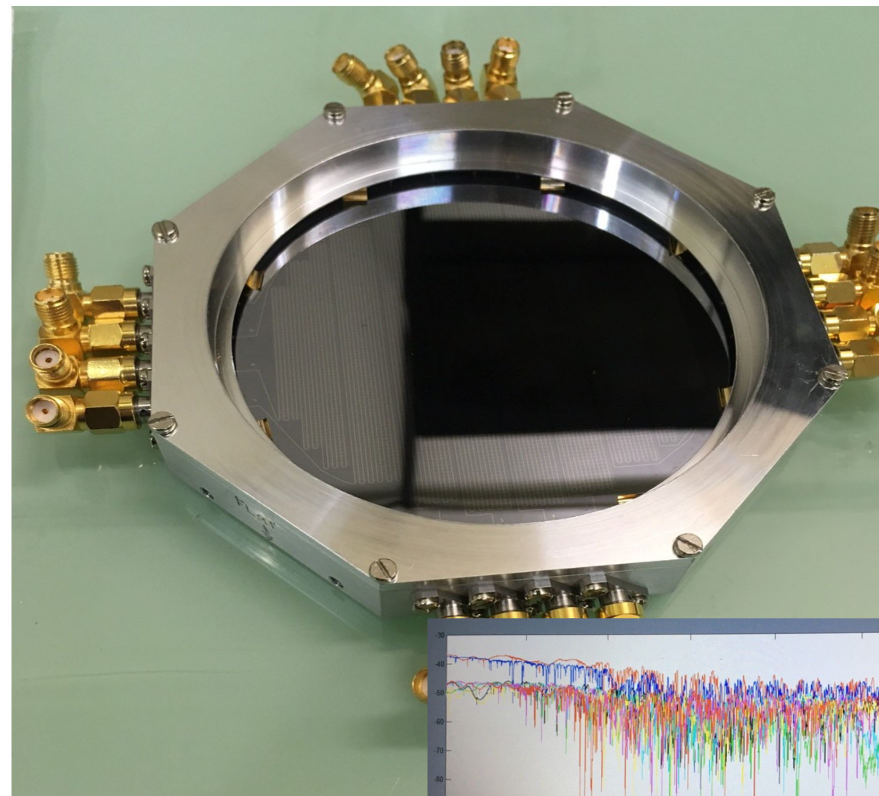
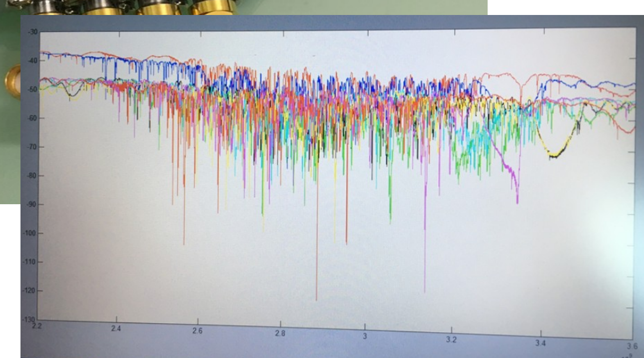


1000s





10000s

Need more room.. (@mm wavelengths!)

Bigger: KID large arrays

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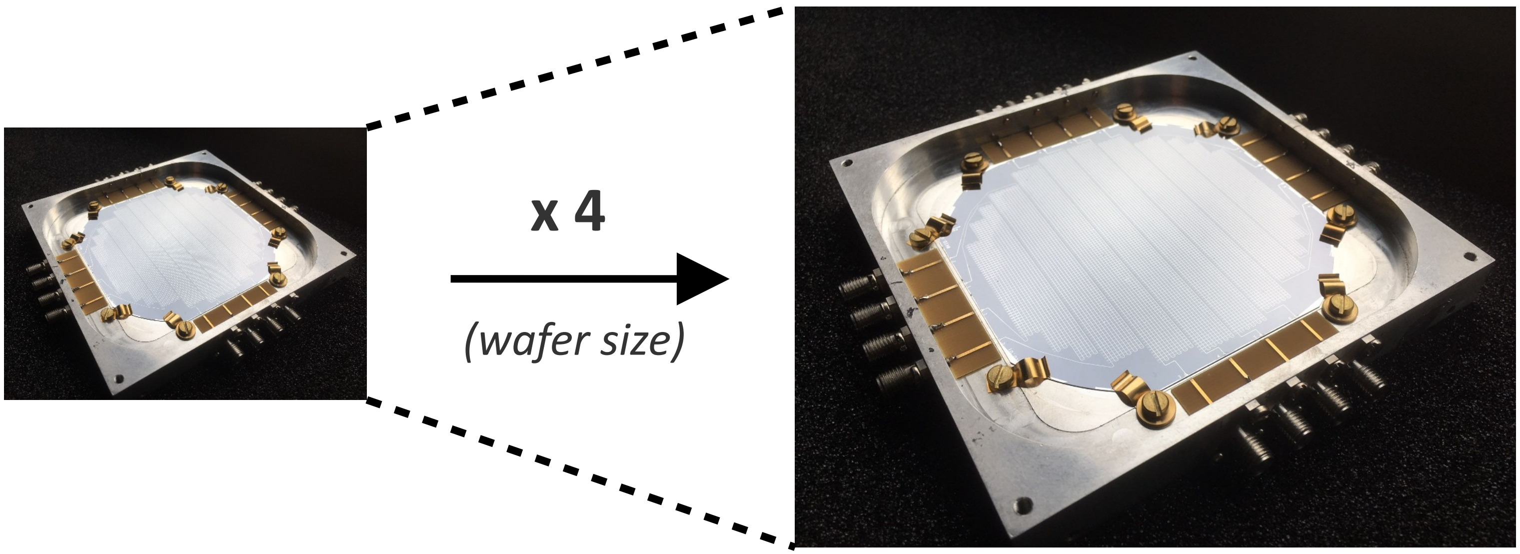
Further increasing pixel count

- Longer term: 8” technology!



- Bigger wafer → more pixels
- Improved thickness uniformity
- New dedicated machine hosted at new IRAM cleanrooms
- Funding confirmed (this week!)

Better: on-chip spectrometers

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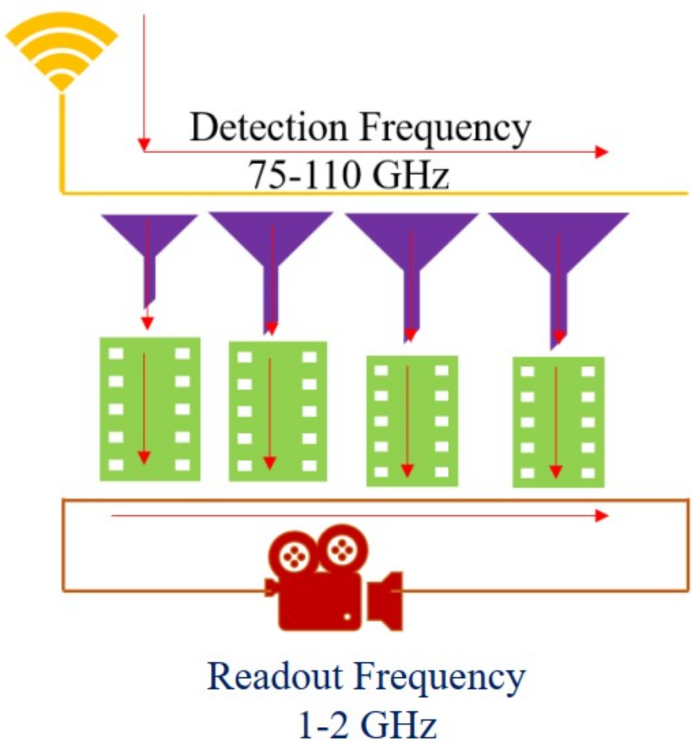
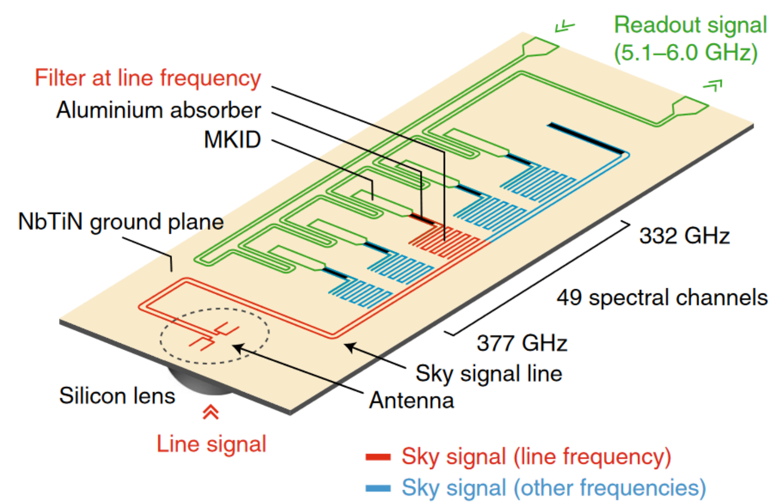
- 'Better': it depends..
- But plenty of potential!
- The goal: adding extra functionalities, such as *colour*!



Eg: DESHIMA

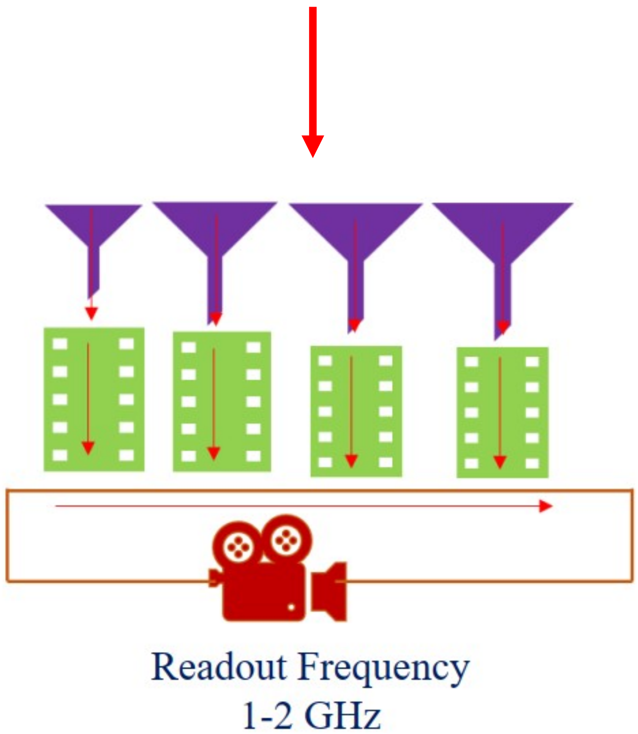


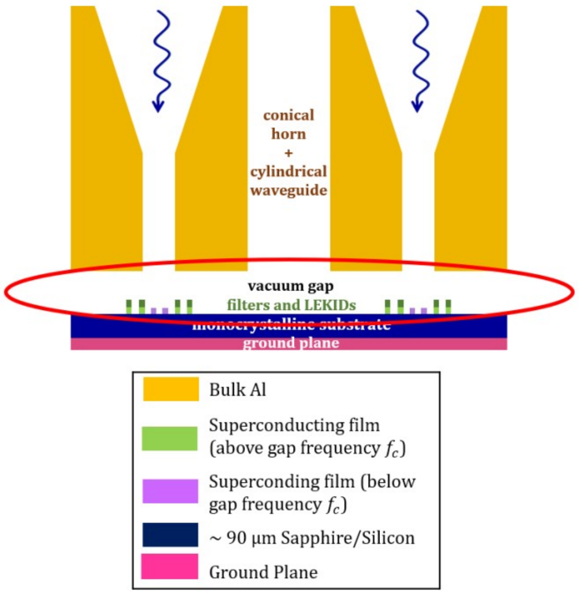
Endo et al., **2018**

- Very challenging.. efficiency, lithographic precision...

Better: on-chip spectrometers

- An alternative: **HYPKID**

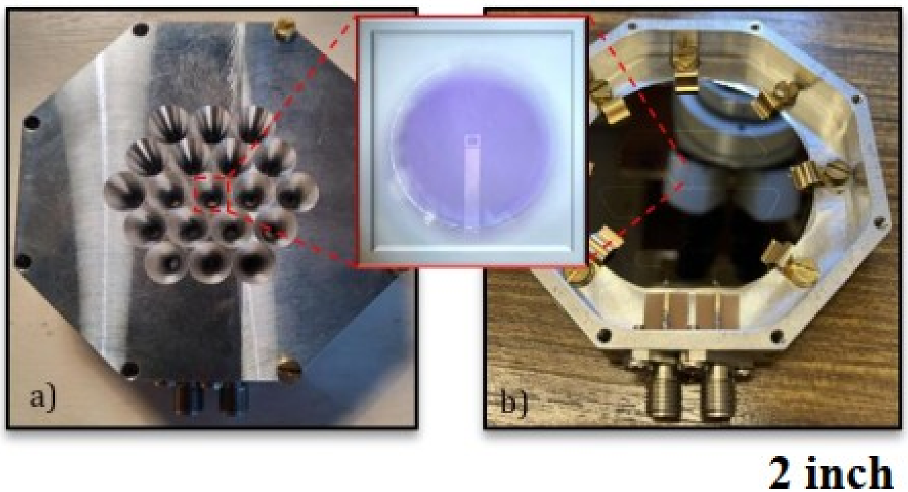




- Simpler approach → easier fabrication, less losses (hopefully..)

Better: on-chip spectrometers

- An alternative: **HYPKID**



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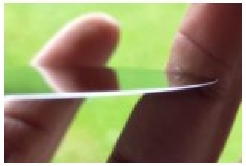
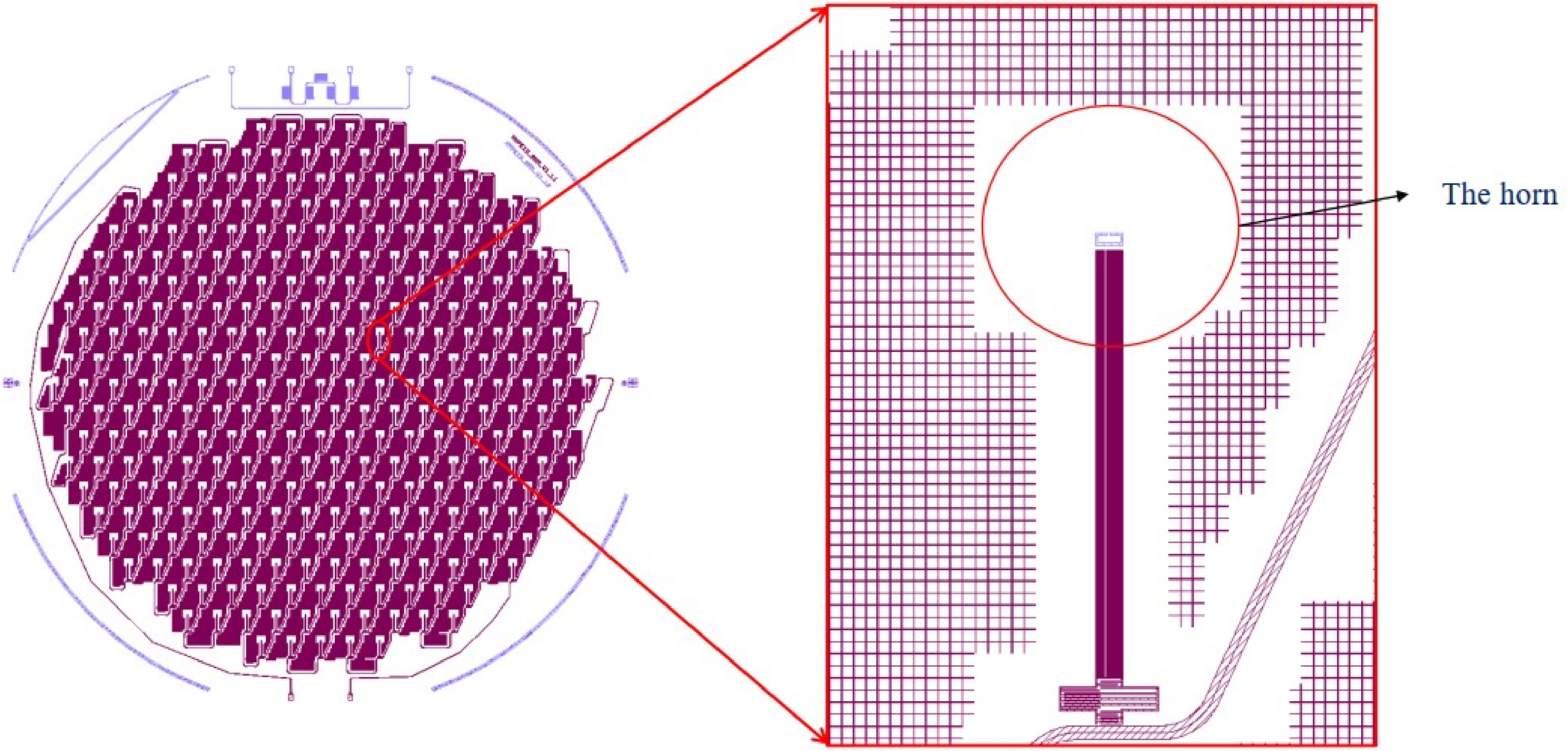


Plaquette: 90 µm



Better: on-chip spectrometers

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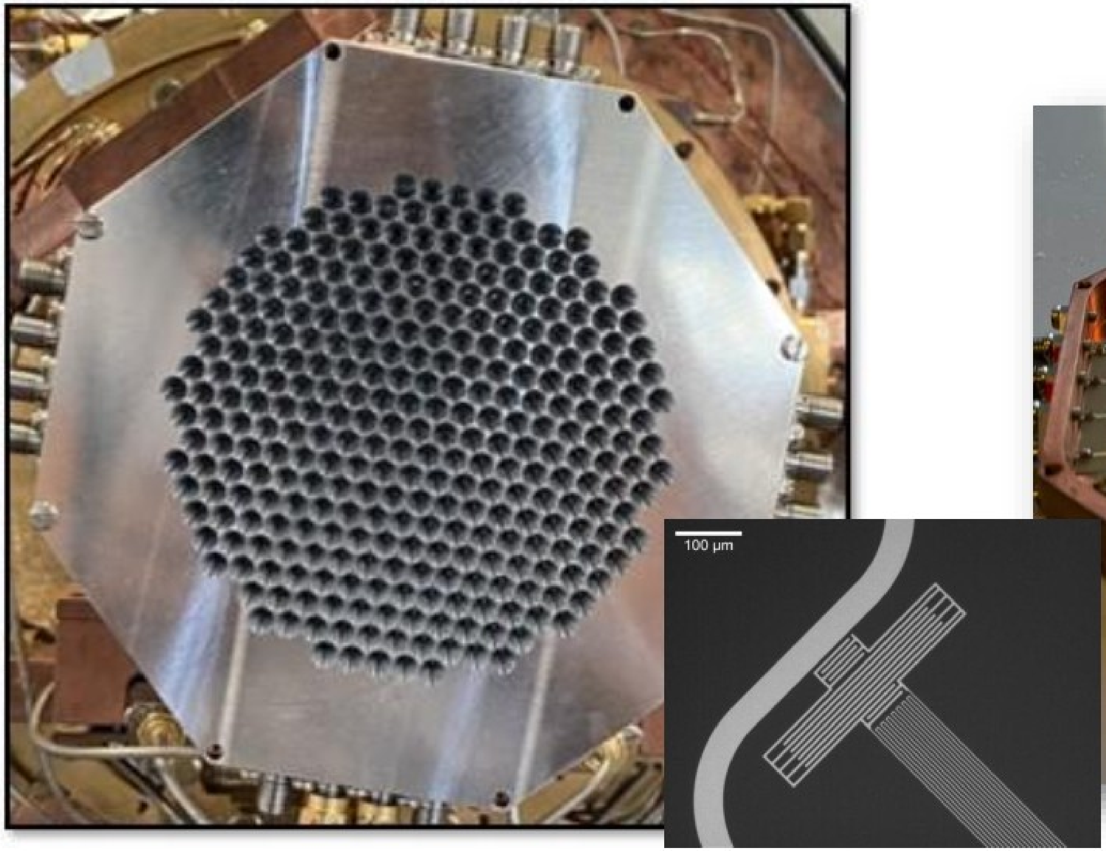
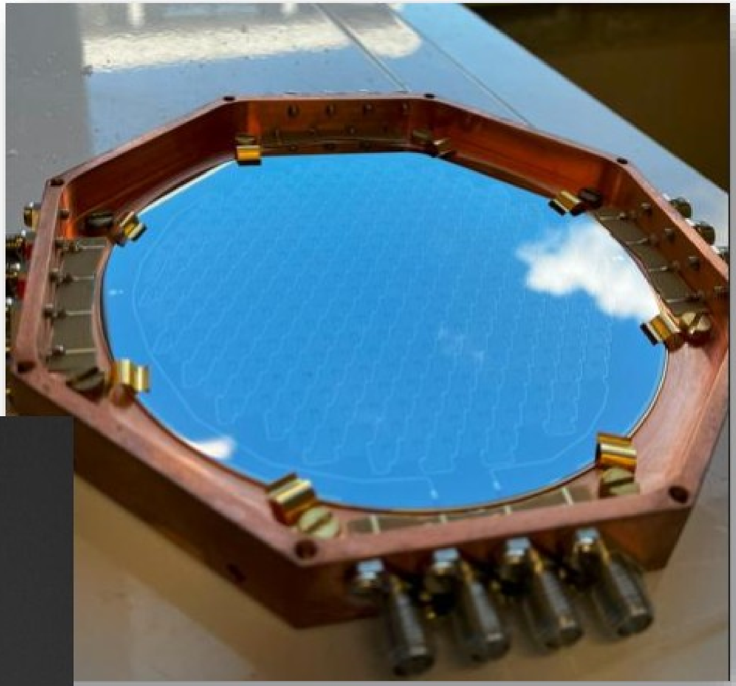
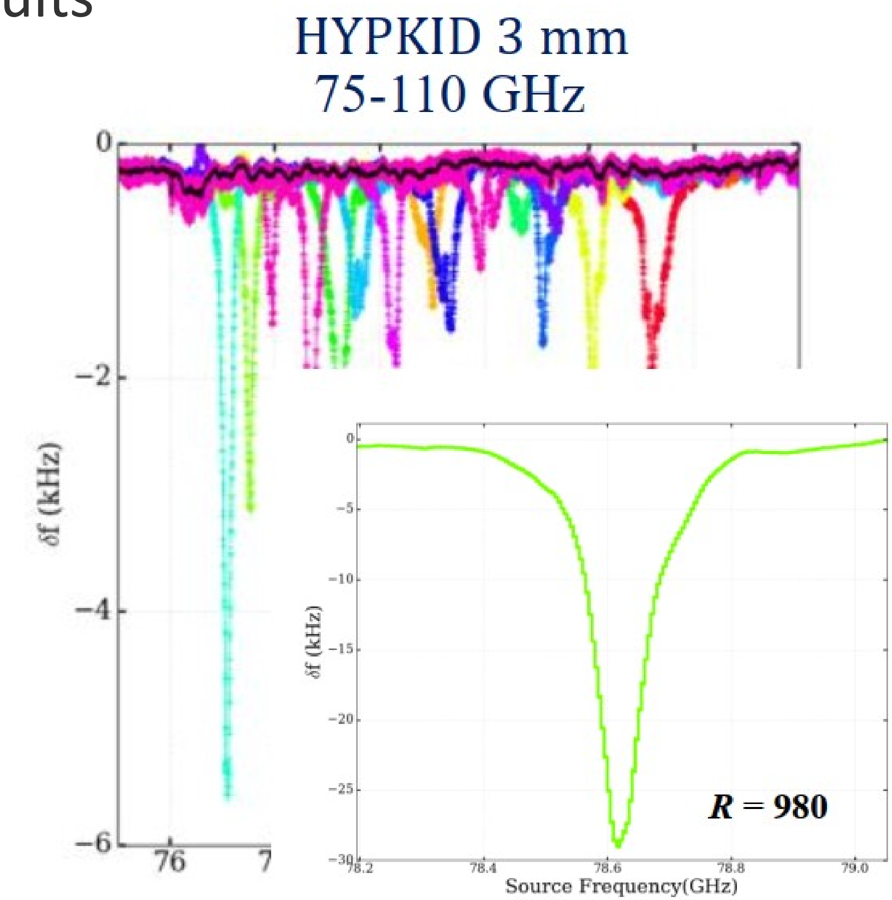




Better: on-chip spectrometers

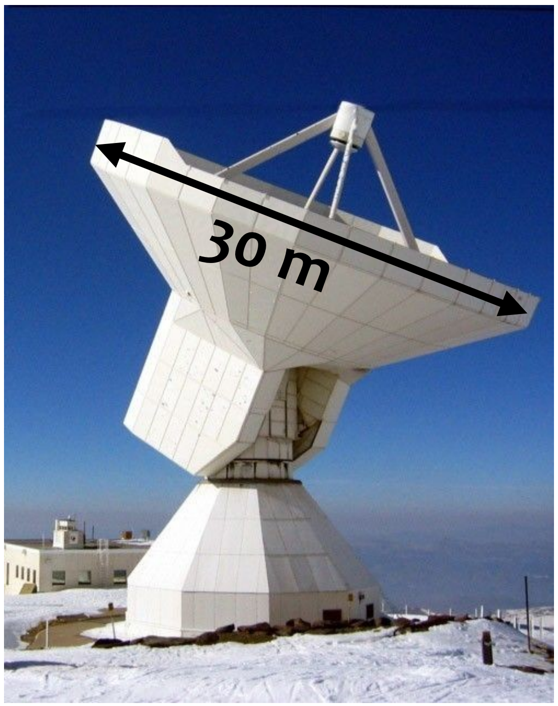
- **HYPKID** sample results

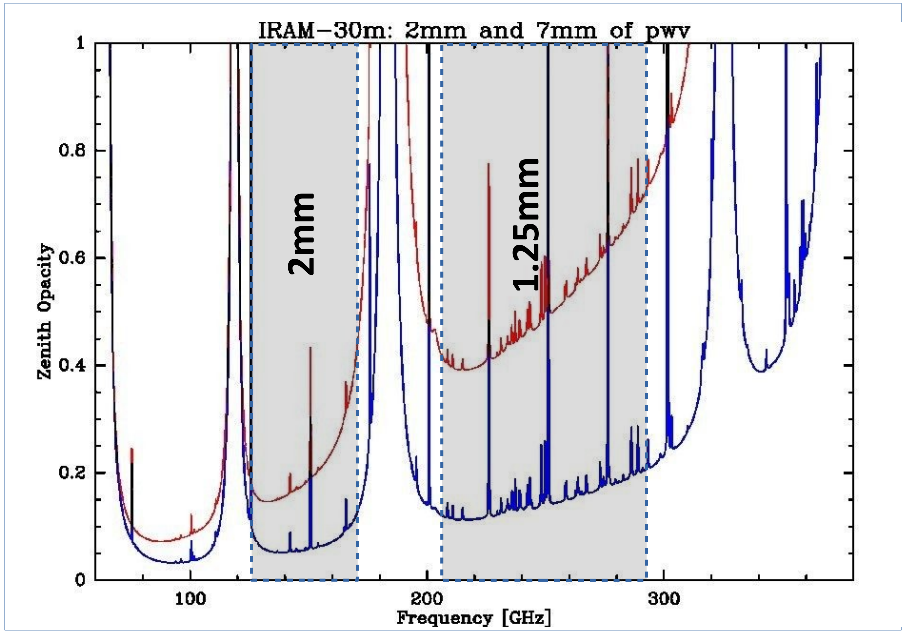


- Different channels properly distinguished, noise seems OK
- Still work to do! (uniformity, larger arrays for 1mm, 'common mode'..)

'Past' instruments: NIKA2

Goal: a KID camera for the IRAM 30m telescope



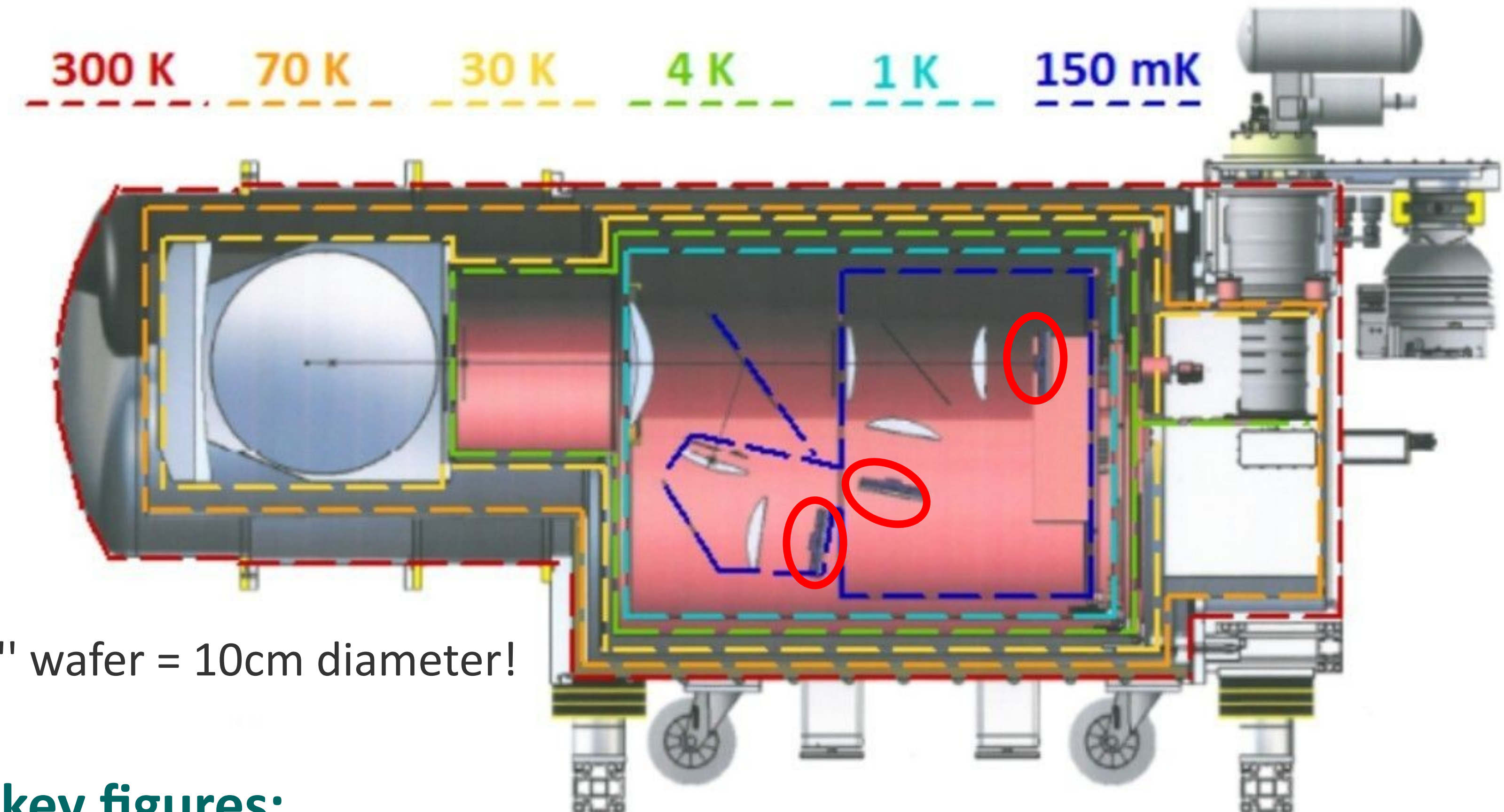


Main contributions from: I. Néel, LPSC, IPAG + IRAM

Planck heritage, + **KIDs**!

'Past' instruments: NIKA2

First 'real' KID instrument!



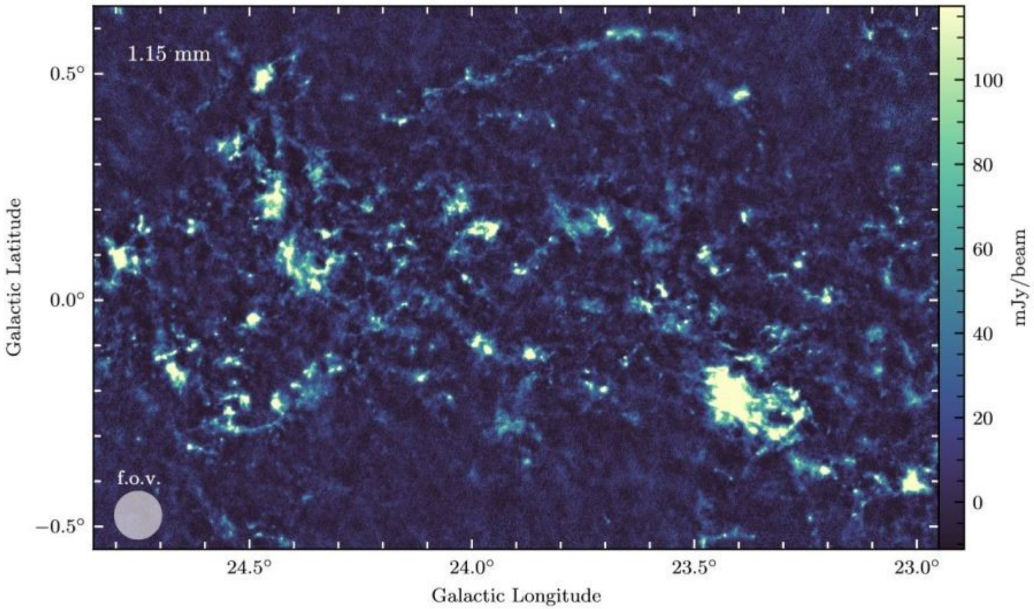
3x **array**, 4'' wafer = 10cm diameter!

NIKA2 key figures:

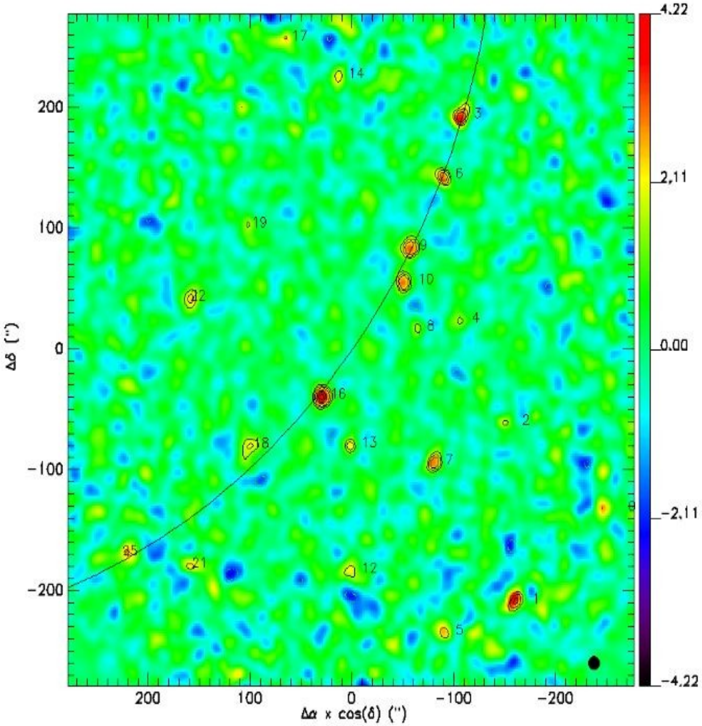
- 1.2 tons, 2.5m long, >3000 pieces
- Double PT
- Full remote operation
- Completely cryogen free

NIKA2 science

NIKA2 observing regularly since 2018



Rigby et al., MNRAS 502-3, 4576 (2021)



Lestrade et al., A&A 667, A23 (2022)

- 100s of cold massive sources discovered
- Insight in early stages of star formation

- Candidate distant SMG in GJ526 field
- A cosmic filament?

NIKA2 arrays

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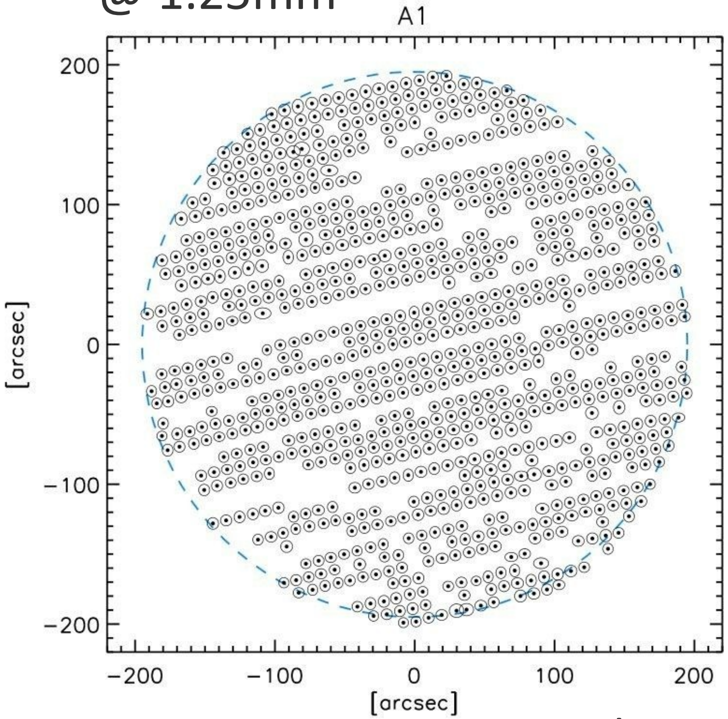
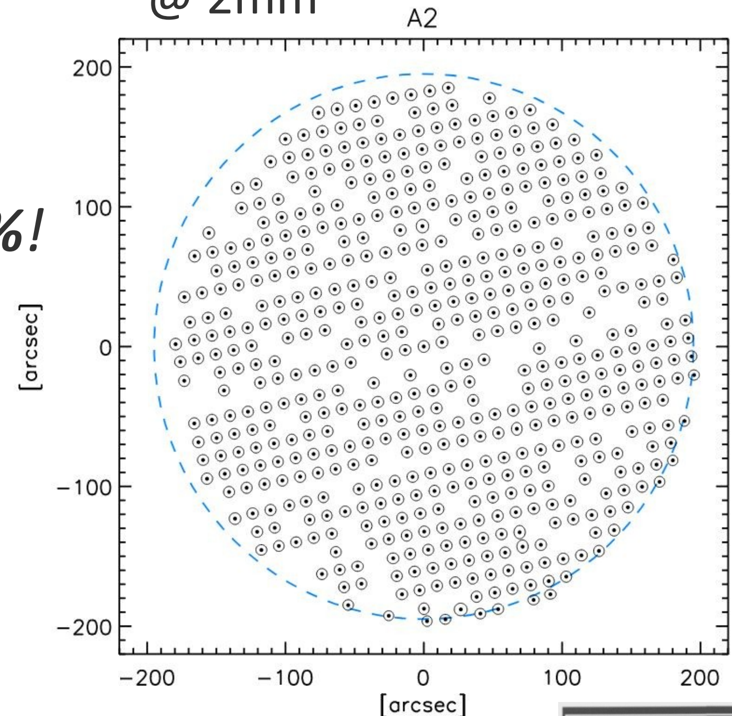
Sample footprint of a NIKA2 arrays

@ 1.25mm



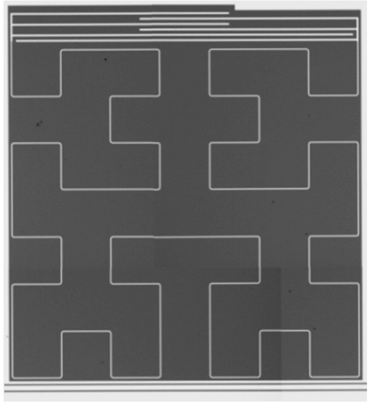
Yield:
70% to 90%!

@ 2mm



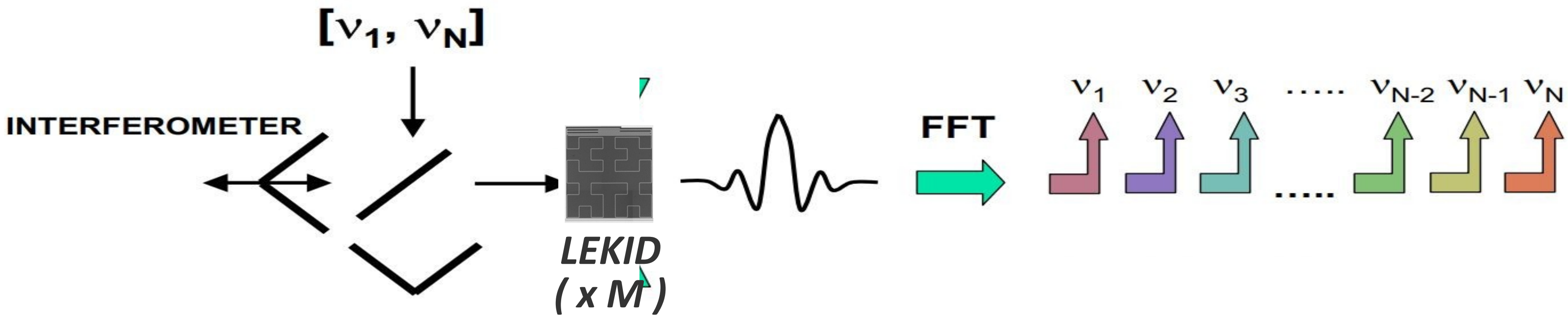
Adam et al, A&A 609, A115 (2018)

- Possible thanks to **LEKID** approach *(1-step process)*



CONCERTO: off-chip spectrometer

- LIM → moderate resolution but large focal plane
- One possible option: MP interferometer
- Take advantage of temporal domain (KID are fast)



Pros:

- Adapted to large focal planes
- No strong R&D needed for the detectors

Cons:

- Size (optics)
- Risk of systematics

CONCERTO

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- MPI + LEKID array @ **APEX**
- On-sky: 2021-2023

CONCERTO specifications:

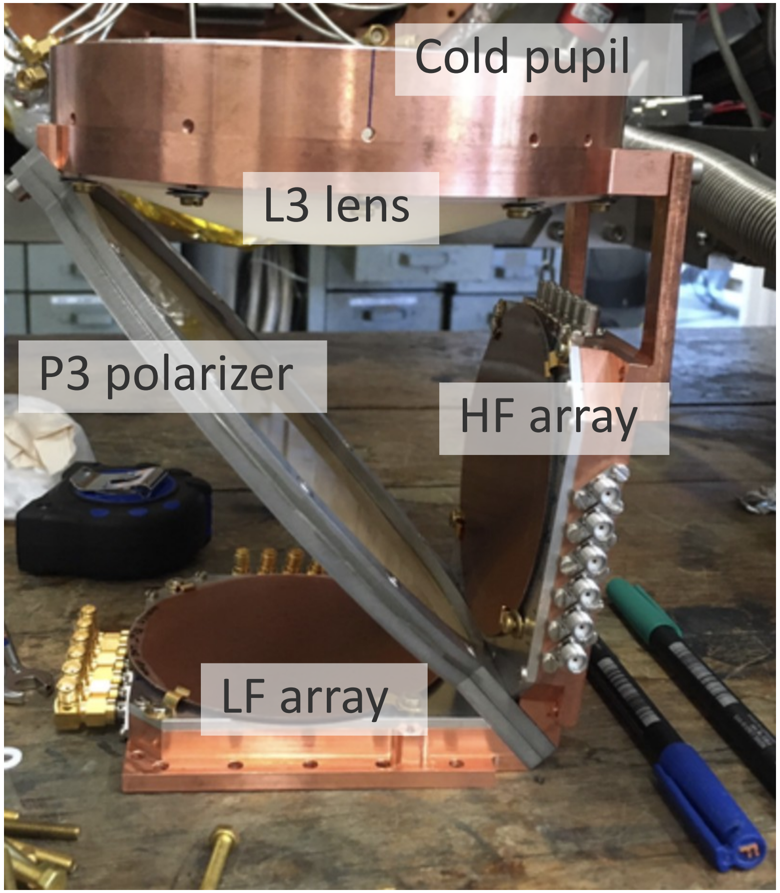
Telescope primary mirror diameter [m]	12
Field-of-view diameter [arcmin]	20
Absolute spectral resolution [GHz]	≥ 1
Relative spectral resolution R [#]	1-300
Frequency range HF | LF [GHz]	195-310 | 130-270
Pixels on Sky HF | LF [#]	2152 | 2152
Angular resolution HF | LF [arcsec]	20-32 | 23-45
Average angular resolution HF | LF [arcsec]	26 | 34
Instrument geometrical throughput [sr m^2]	2.5×10^{-3}
Single Pixel geometrical throughput [sr m^2]	1.16×10^{-6}
Data rate [MBytes/sec]	128

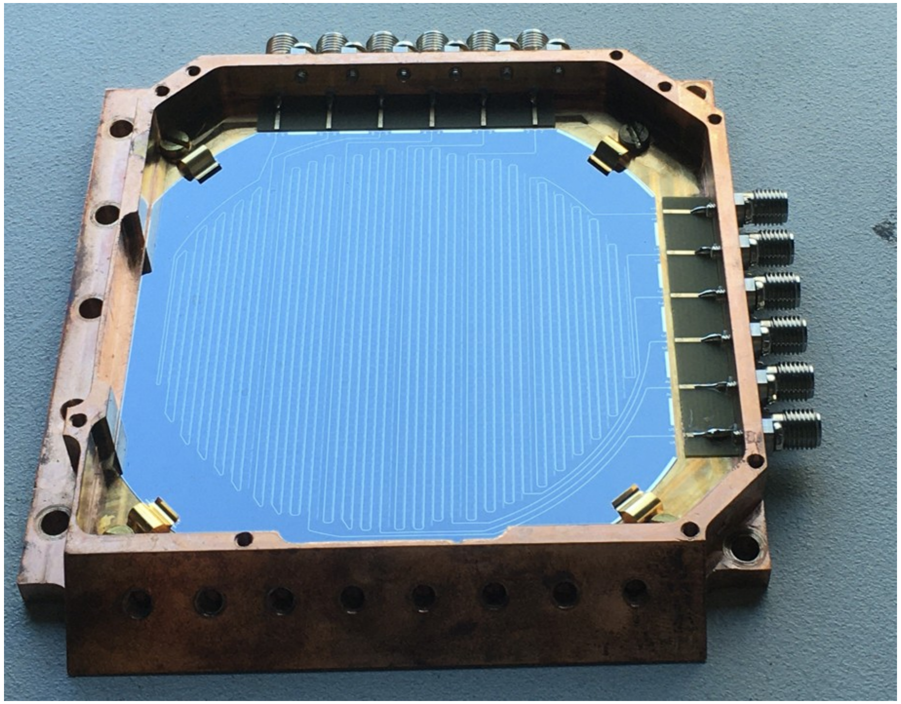
Monfardini et al, JLTP 209, 751-757 (2022)

CONCERTO

- MPI + LEKID array @ **APEX**
- A total of ~4000 “spaxels” each with R~100!

*(the equivalent of **400kpixels** !)*





2x 2152 LEKID arrays

CONCERTO

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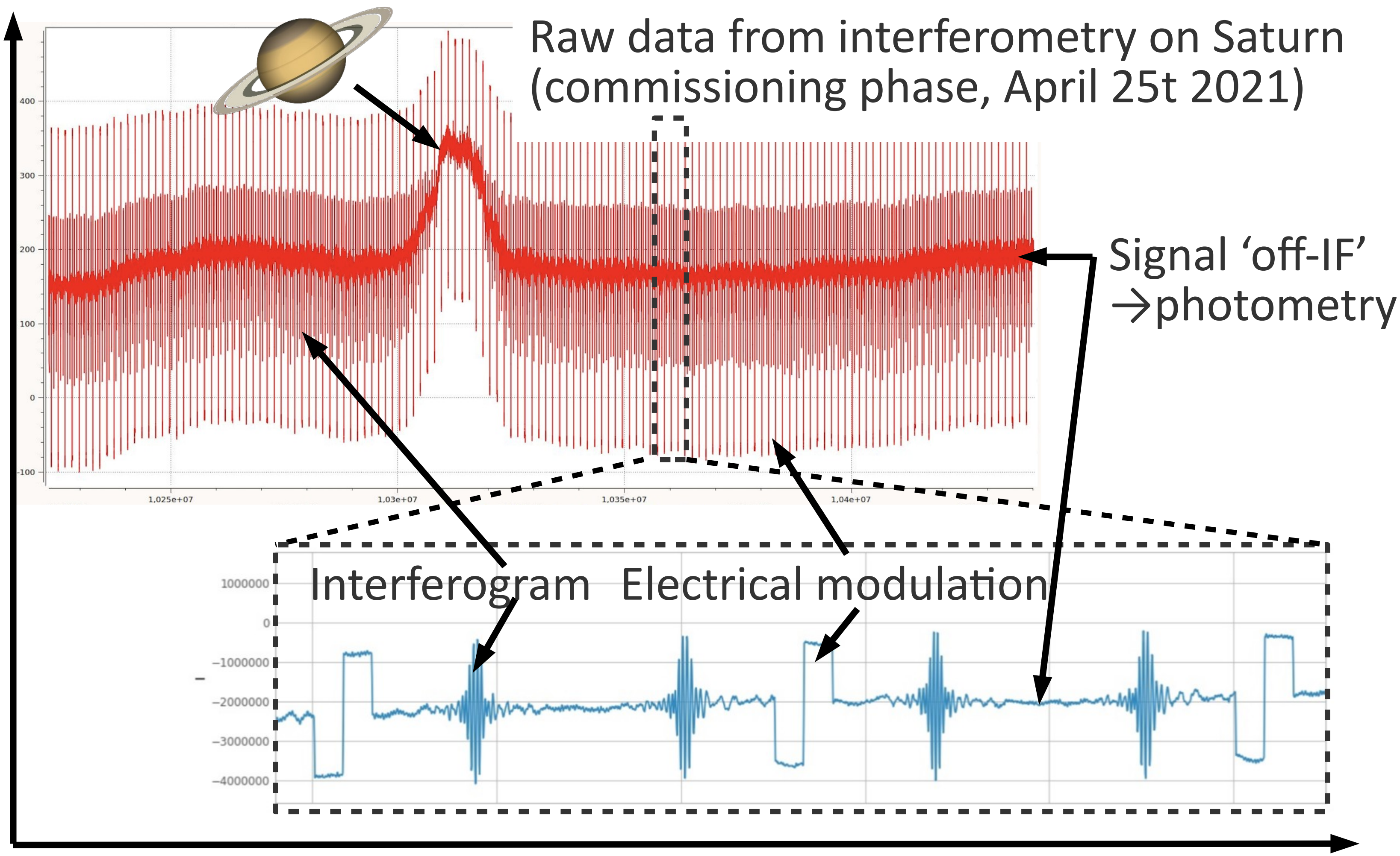
- The price to pay..



CONCERTO: spectroscopy!

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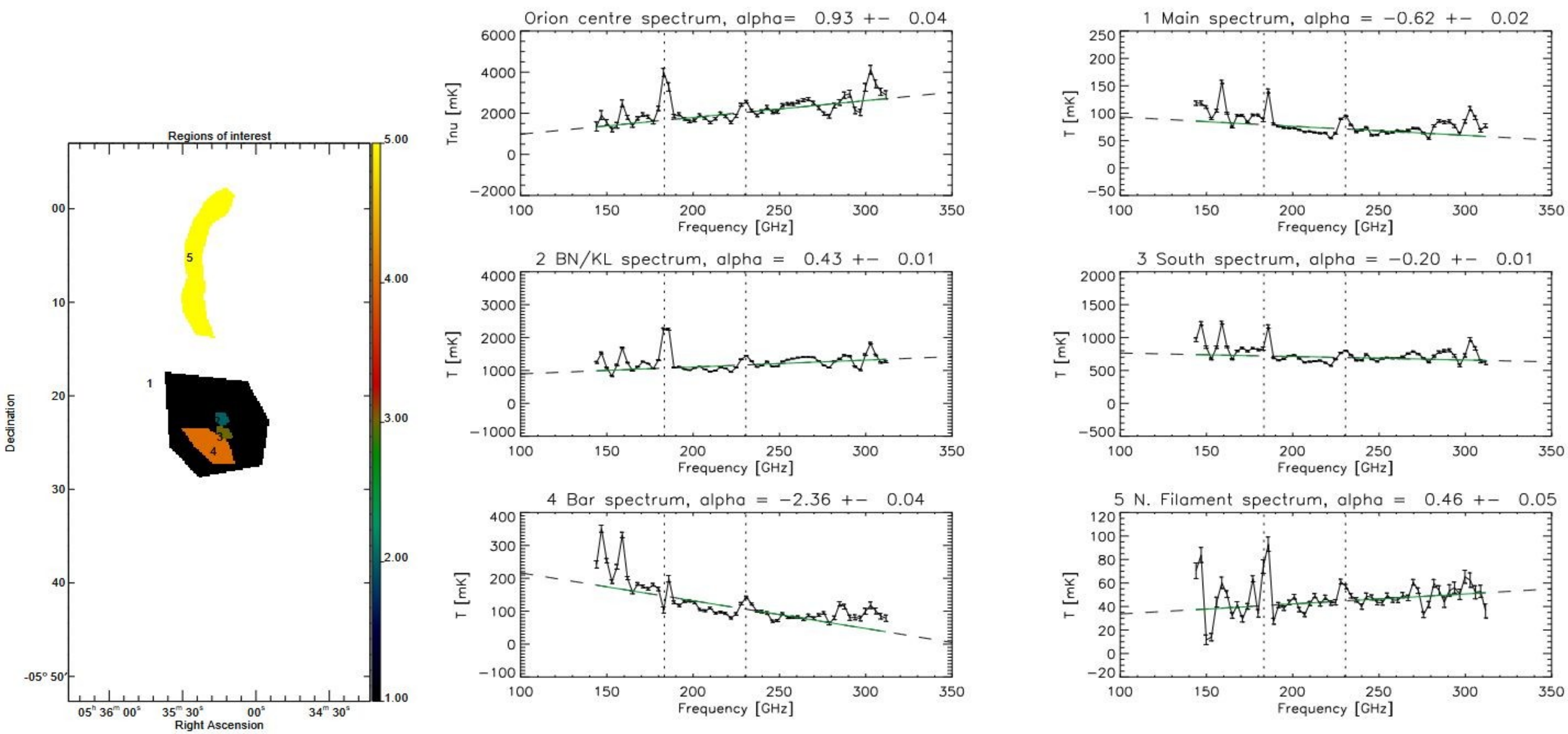
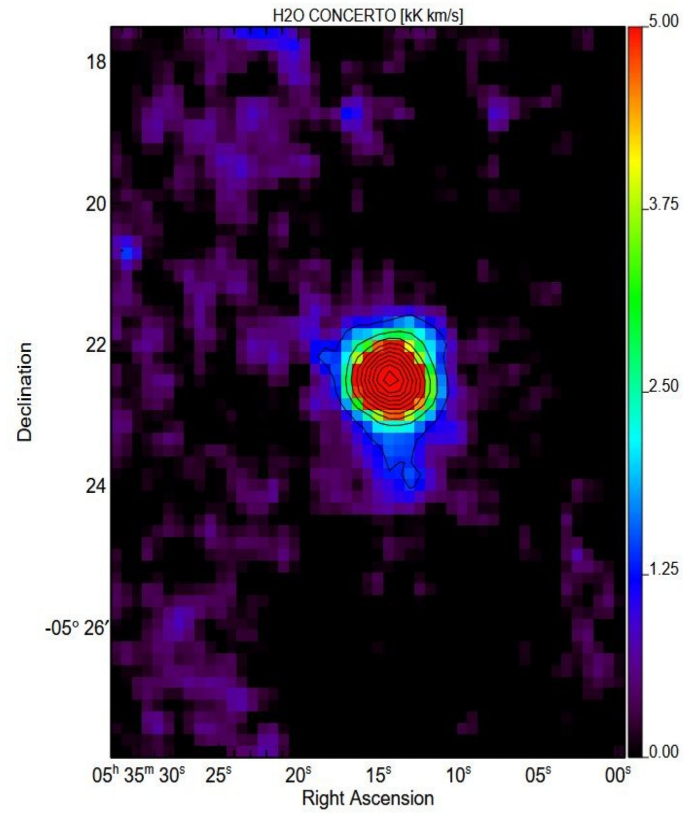


Désert et al, submitted to A&A (04/25, arXiv:2504.20487)

- Studying dust emission in Orion nebula

CONCERTO: spectroscopy!



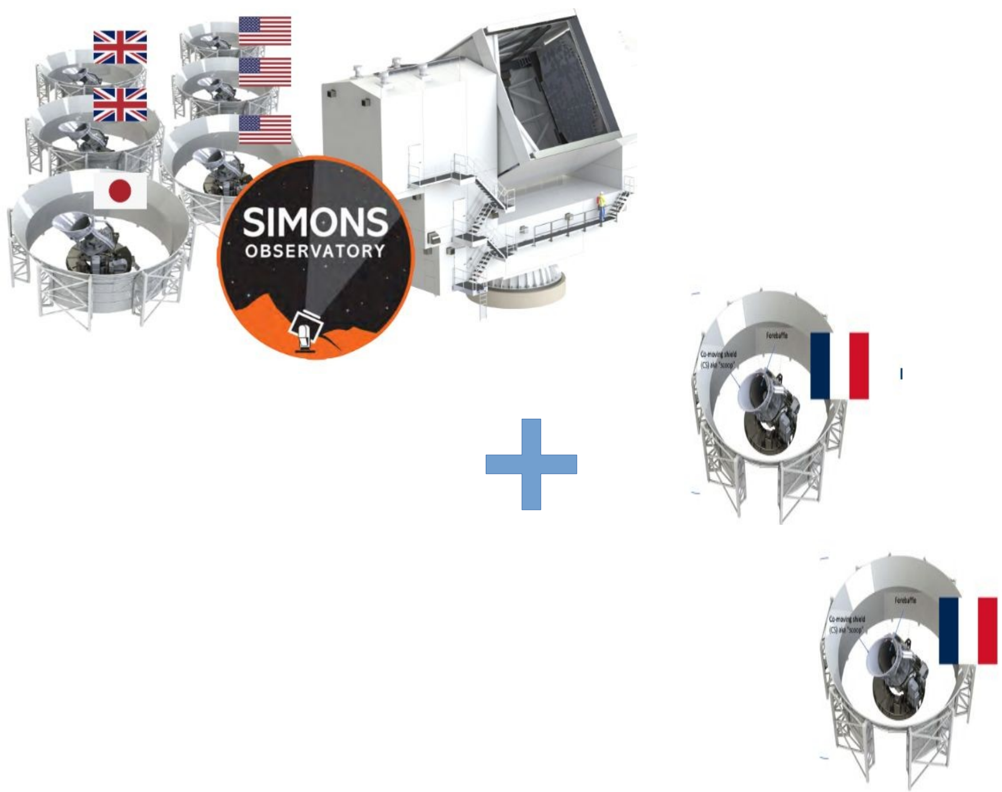
Désert et al, submitted to A&A (04/25, arXiv:2504.20487)

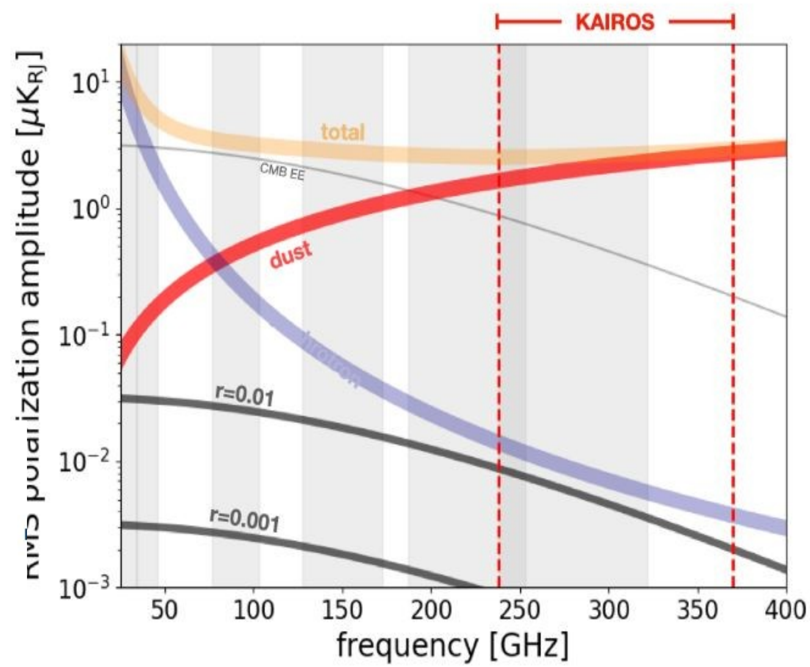
- Studying dust emission in Orion nebula
- And: mapping water!

Future instruments: KAIROS

KAIROS, a new SAT for SO?

- High frequency SAT for SO
- Looking for funds..



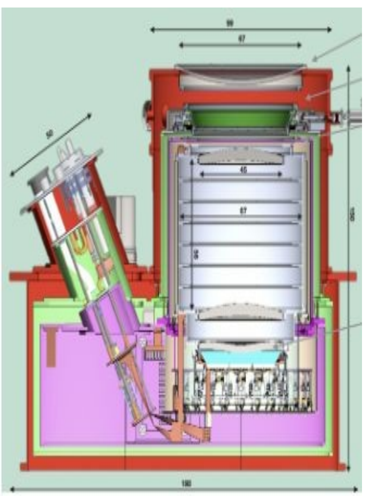


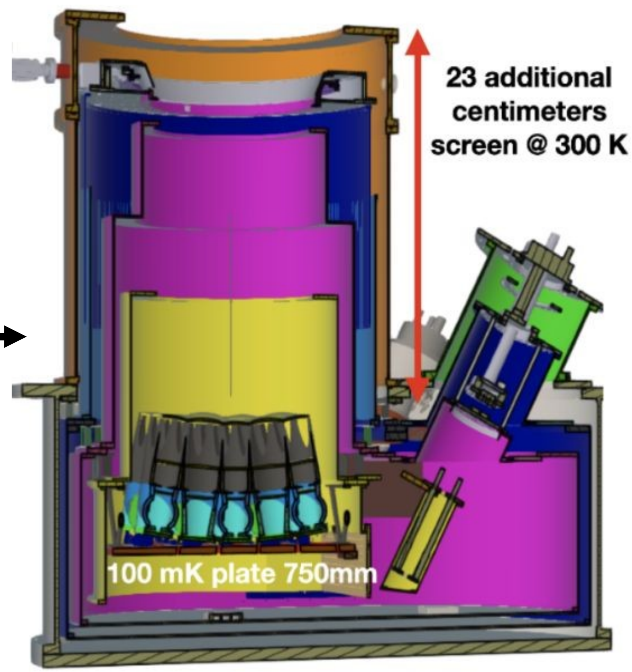
Future instruments: KAIROS

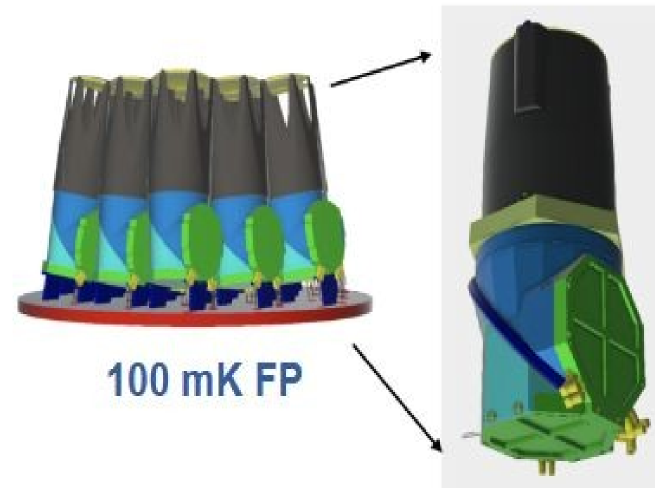
GDR-DI2I Groupement De Recherche
Détecteurs et Instrumentation pour les 2 Infinis

KAIROS, a new SAT for SO?

- High frequency SAT for SO
- Will host a total of **~30000** LEKID





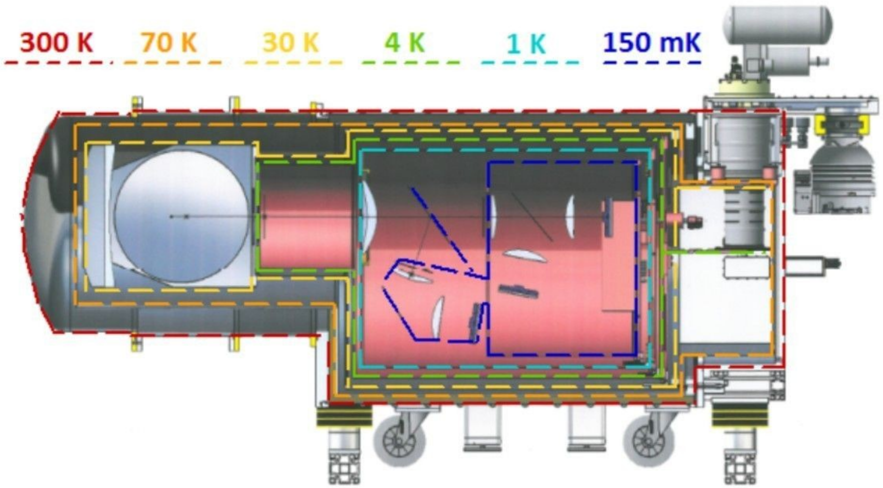


19 x 2 x 800
LEKID!

- Pushing towards the 100kpixel level!

Future instruments: NIKA3

- NIKA2 is great.. But can be even better!
- Take full advantage of 30m FoV (+ cryostat space?)



NIKA3 goals:

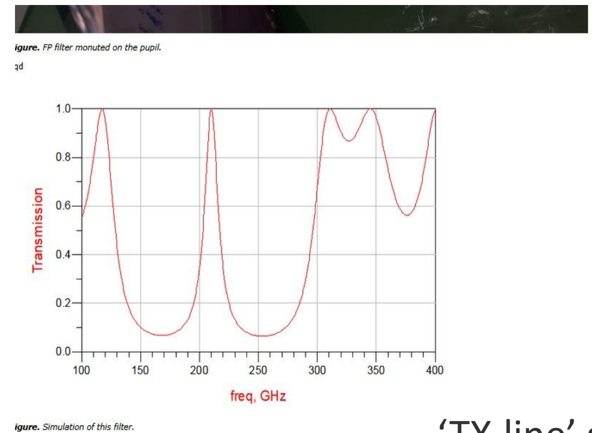
- >= 10arcmin FoV (from 6)
- 4 arrays, polarization sensitive (from 2+1)
- Possibly, 1 of them spectrometric? (HYPKID)
- In a short timeframe..

Thank you!

First tests on FP approach

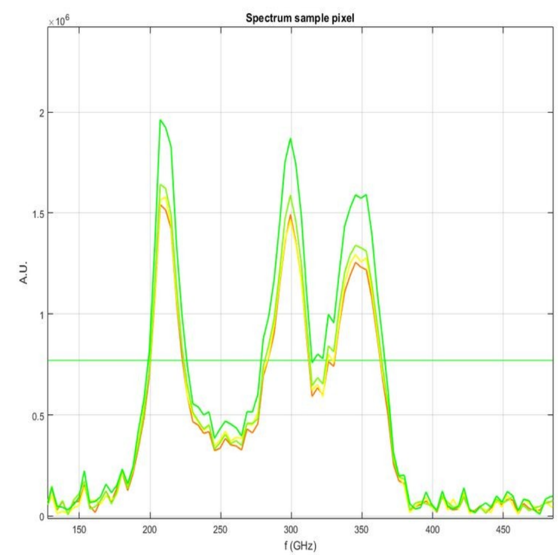
Filt_FP-120Si-140Q-230Si-140Q-120Si

FWHM = 18GHz, f_0 = 210GHz ➞ **R~12**



‘TX-line’ simulation

. Simulation of this filter.



Observed spectra

Photon noise limits on KID

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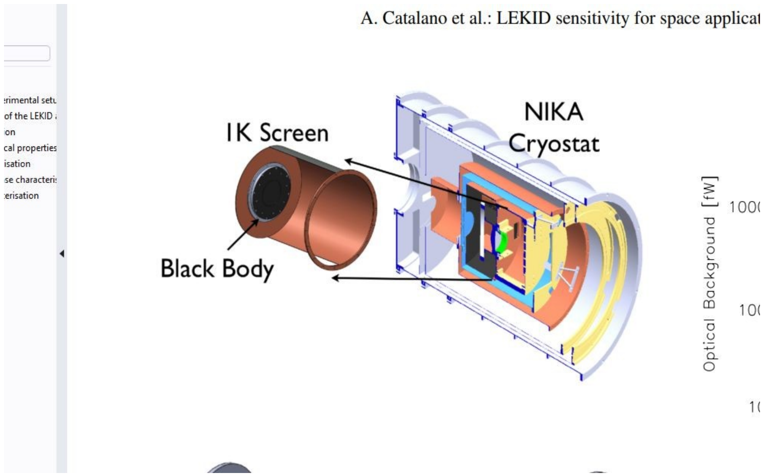

- Detectors tested under controlled optical load
- Detector noise is at photon noise limit in for wide range of frequencies

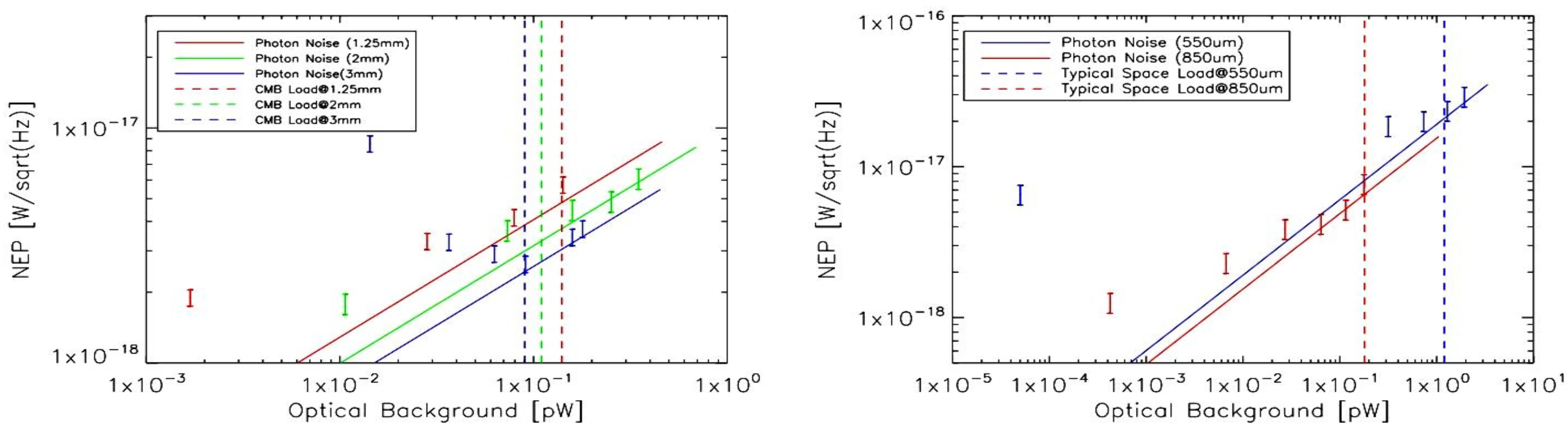

Fig. 9. Noise Equivalent Power (NEP) measured for the 1 mm, 2 mm and 3 mm arrays. Each point is derived from responsivity and noise measurements for different temperatures of the cold black-body. The corresponding optical load per pixel for each temperature