KID for CMB

MONFARDINI Alessandro

Kinetic Inductance Detector working principle

DARK:

- $T << T_c \sim 1$ K
- deep & sharp resonance
- frequency → f_0

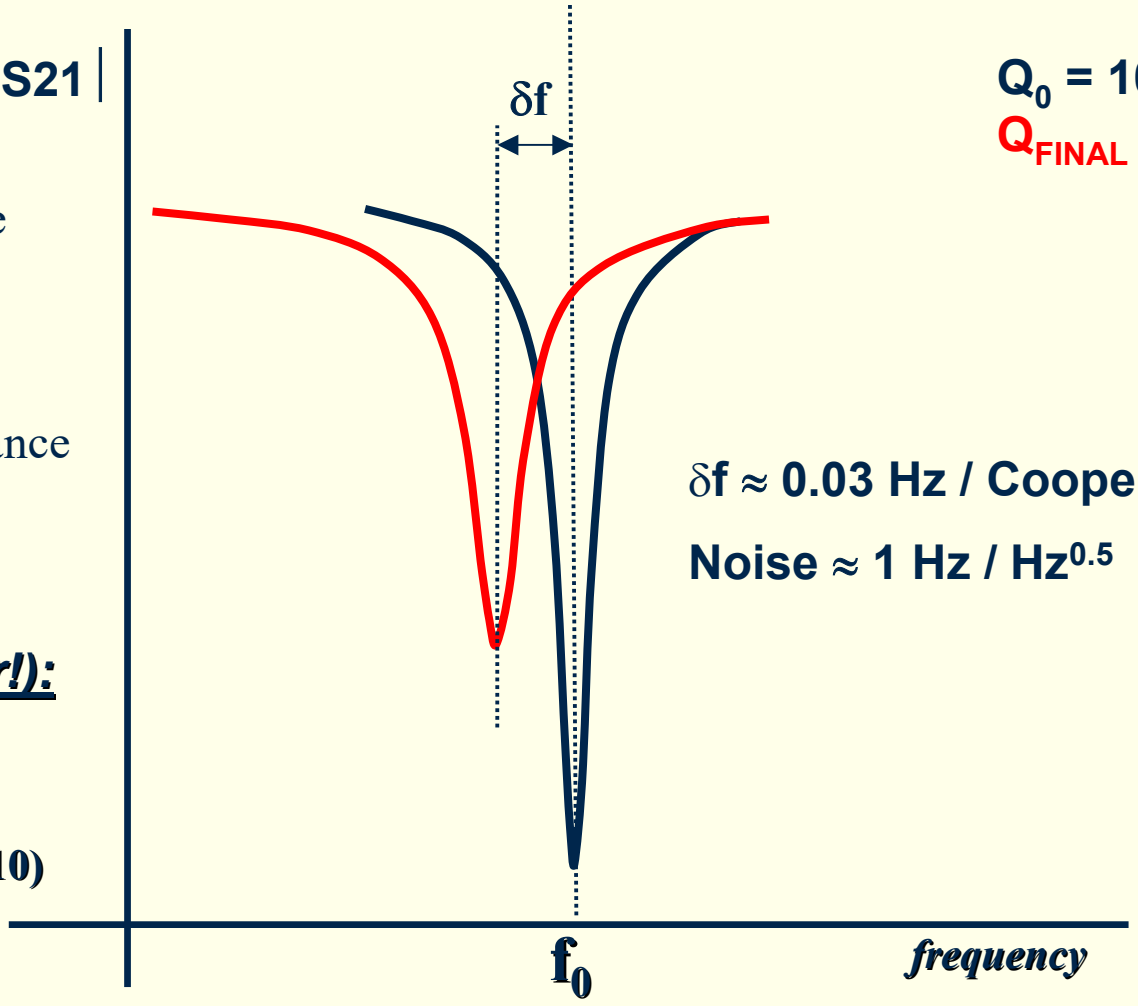
LIGHT:

- shallow & broad resonance
- frequency → $f_0 - \delta f$

Large dynamics (linear!):

$$\delta f \propto \delta L_K \propto \delta P$$

APL 96, Issue 26, 263511 (2010)



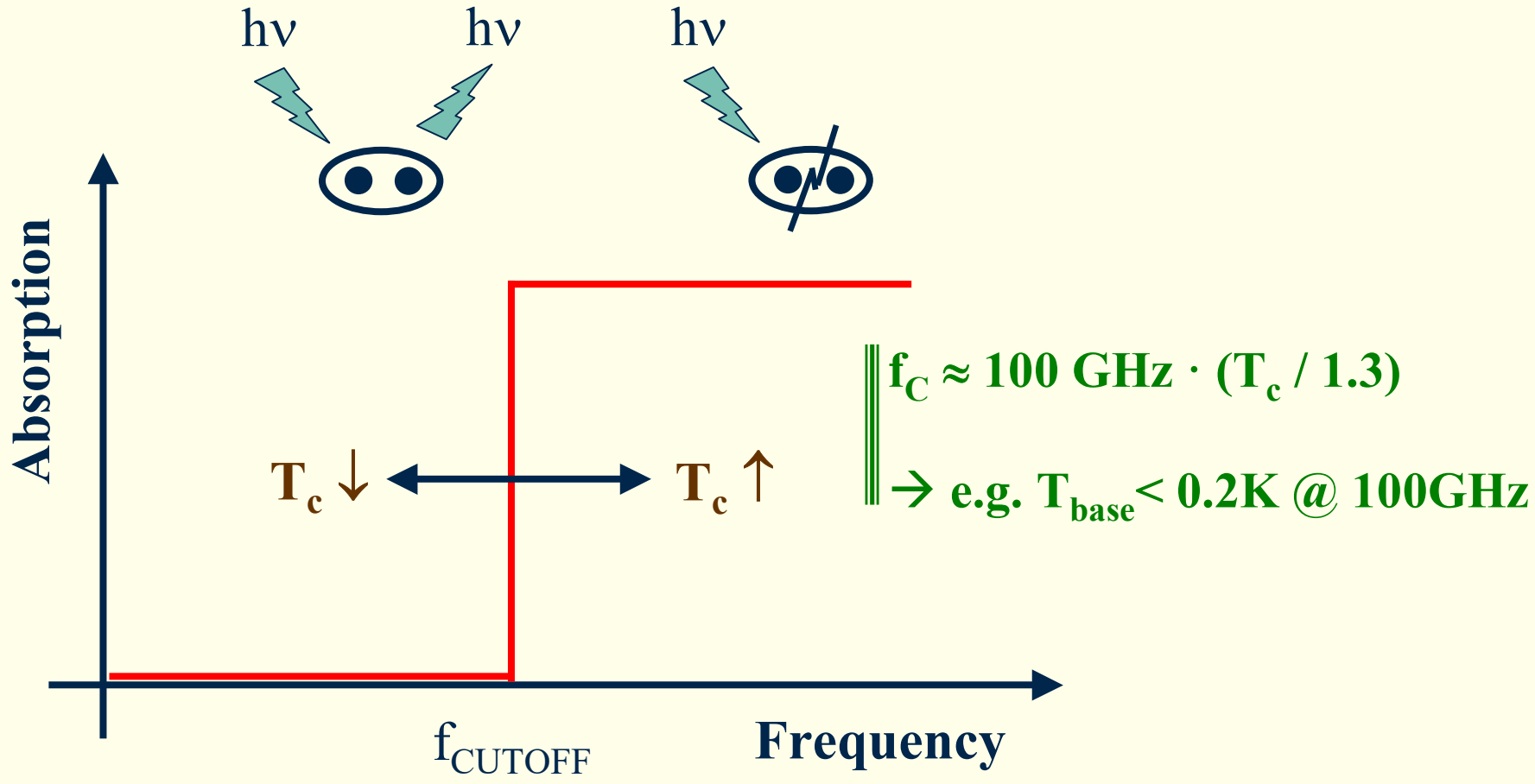
$Q_0 = 10^4 \div 10^6$

$Q_{FINAL} < Q_0$

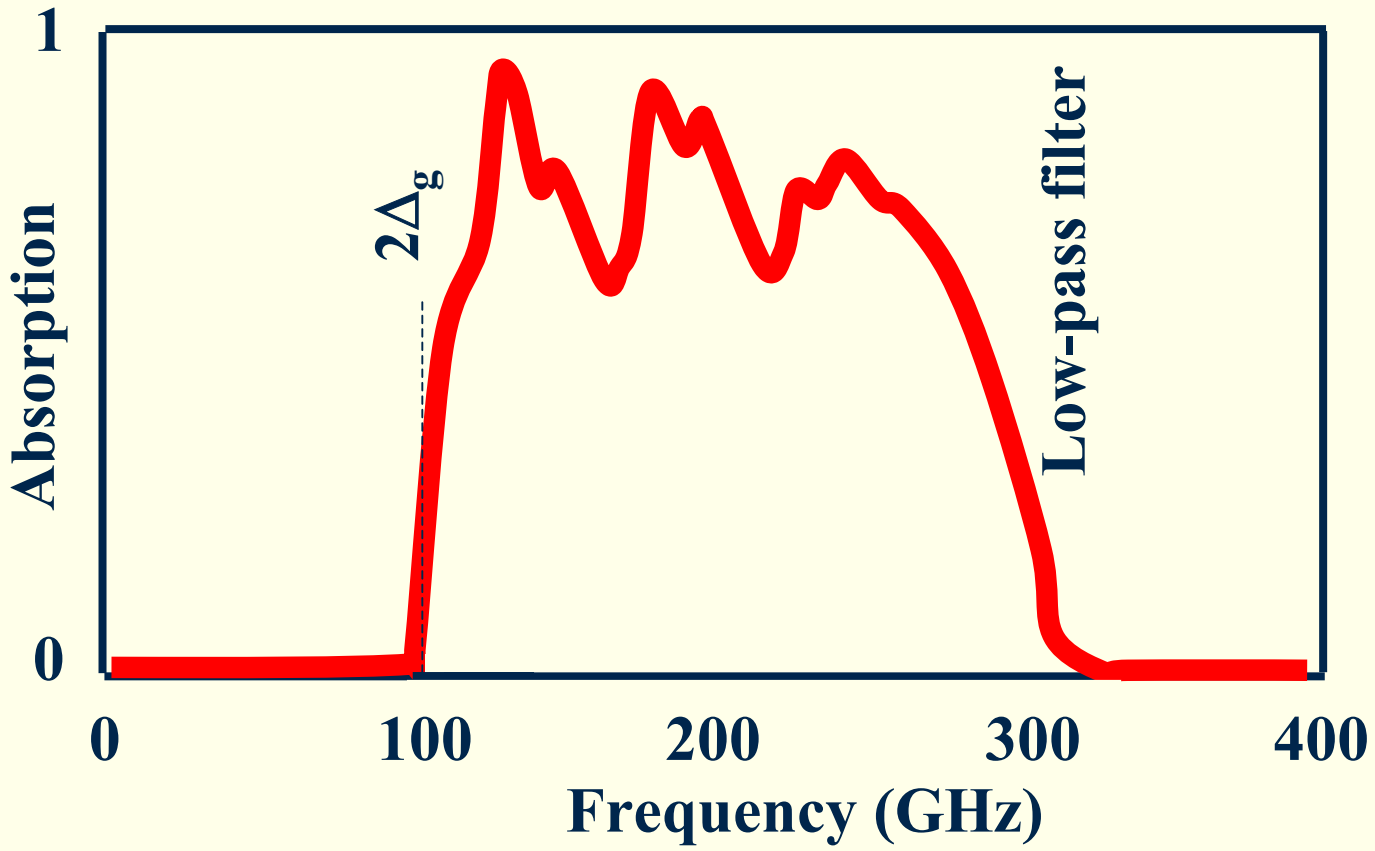
$\delta f \approx 0.03$ Hz / Cooper Pair

Noise ≈ 1 Hz / $Hz^{0.5}$

KID spectral response: expected



KID spectral response: Aluminium



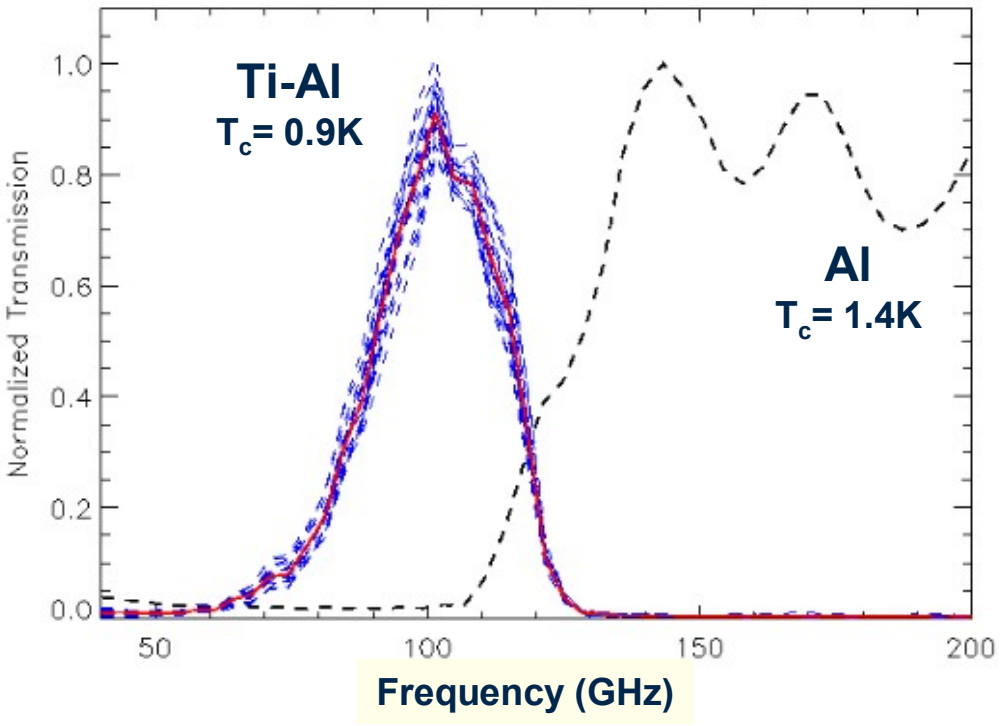
Lower frequencies: not a problem

NEW MATERIALS (gap engineering)

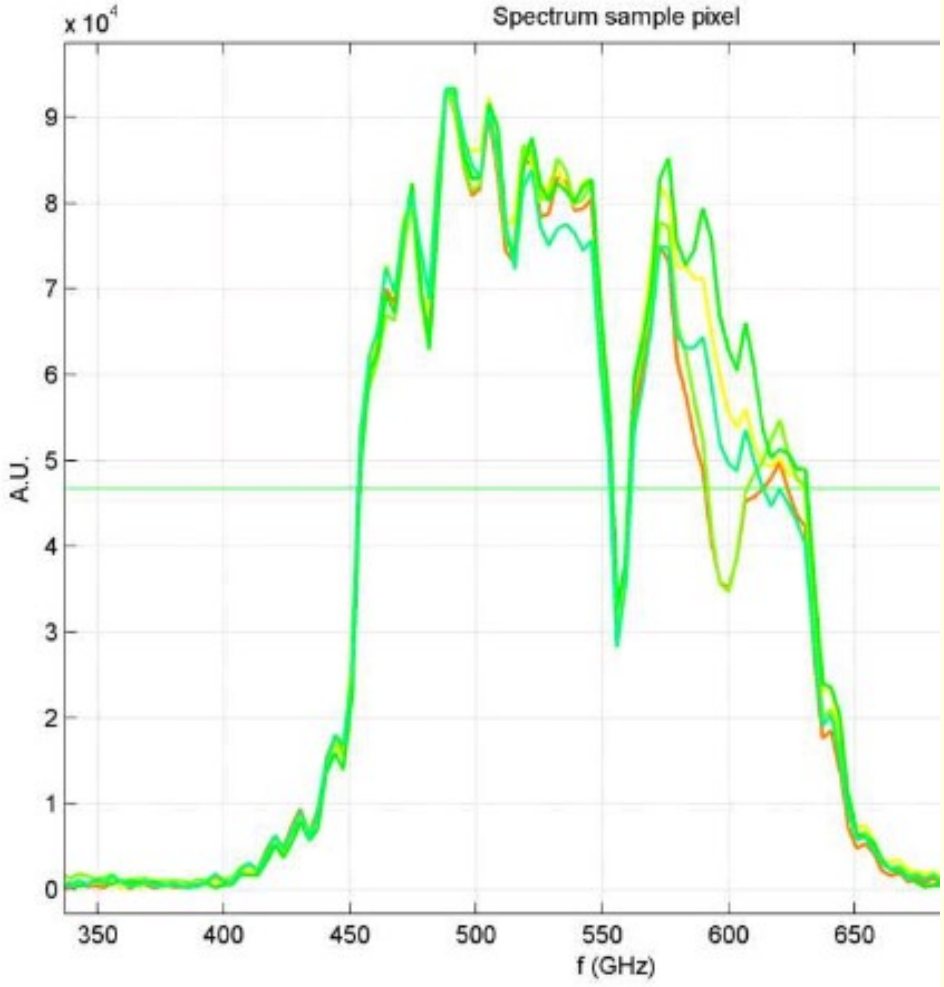
- Build our **preferred gap** to have access to lower frequencies

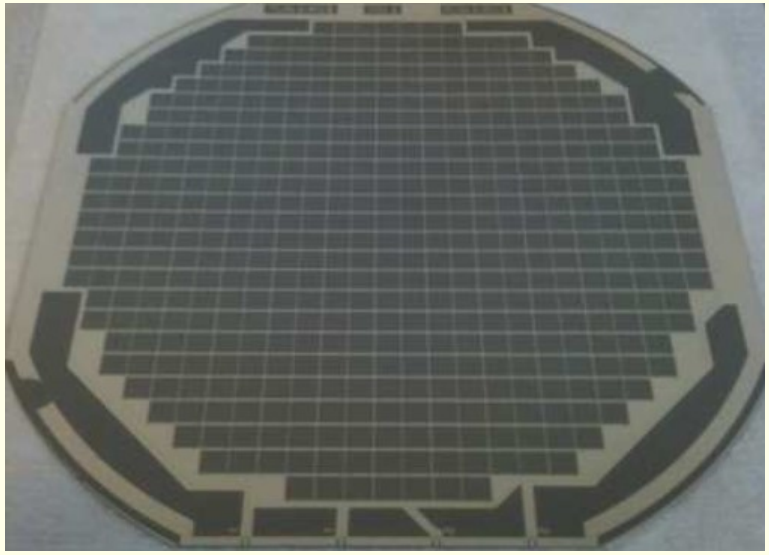
- **Maximize the Kinetic Inductance**

→ Exploring/synthesizing **new superconducting materials** (elements, alloys, multilayers)



Dusty (balloonable) frequencies: not a problem either

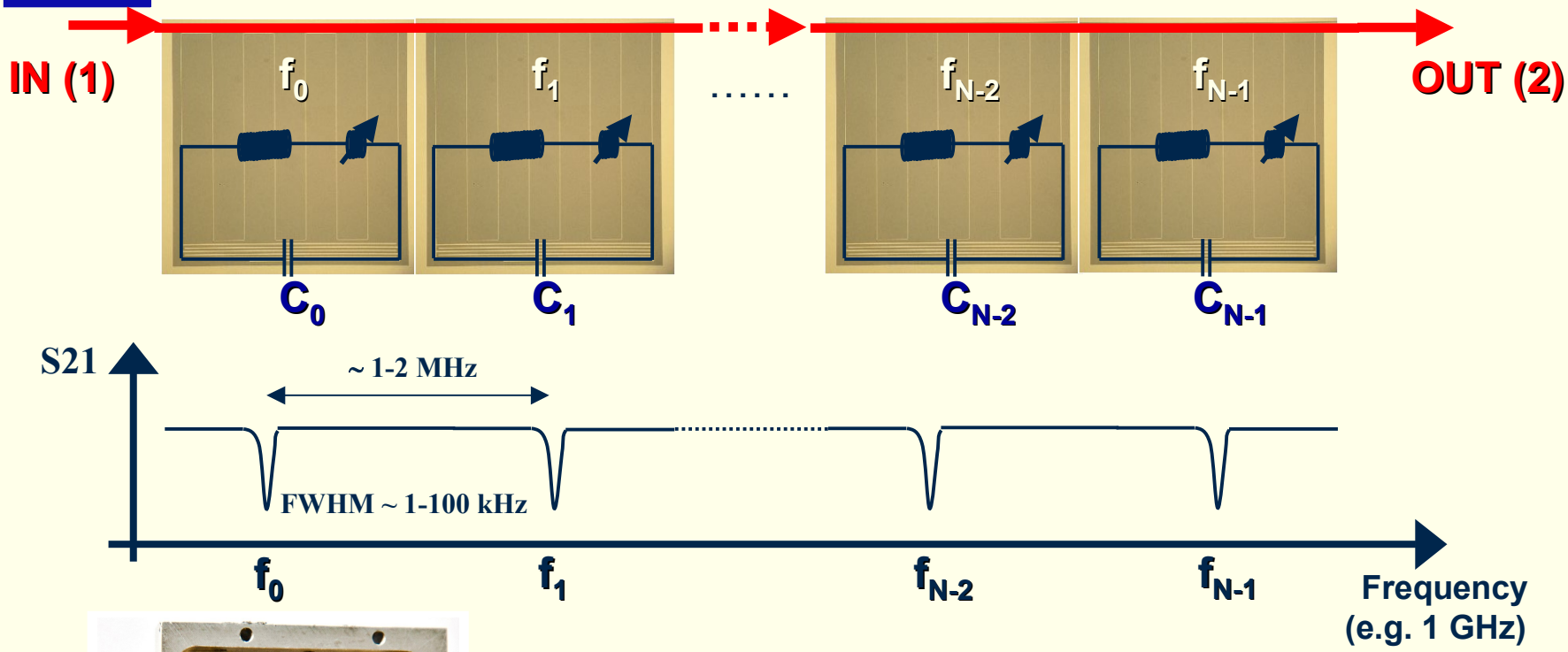


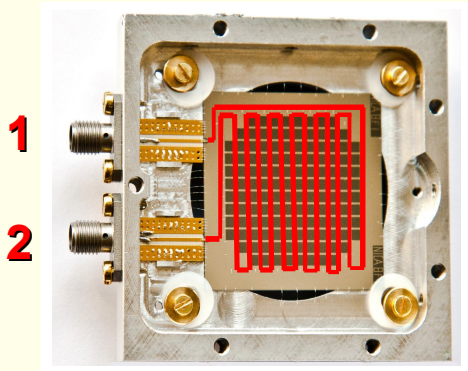


- 99.3% pixels identified !!
- background-limited sensitivity

Results from the « planB » balloon proposed to CNES in 2016 (rejected). Supposed to cover the band 450-650 GHz

Multiplexing KID

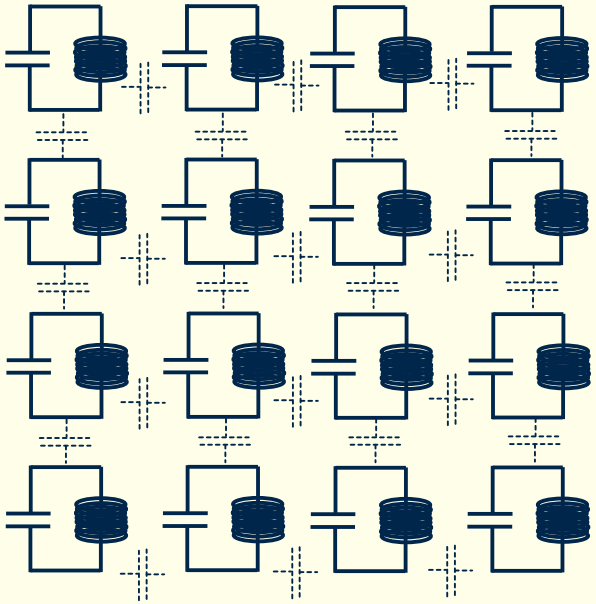


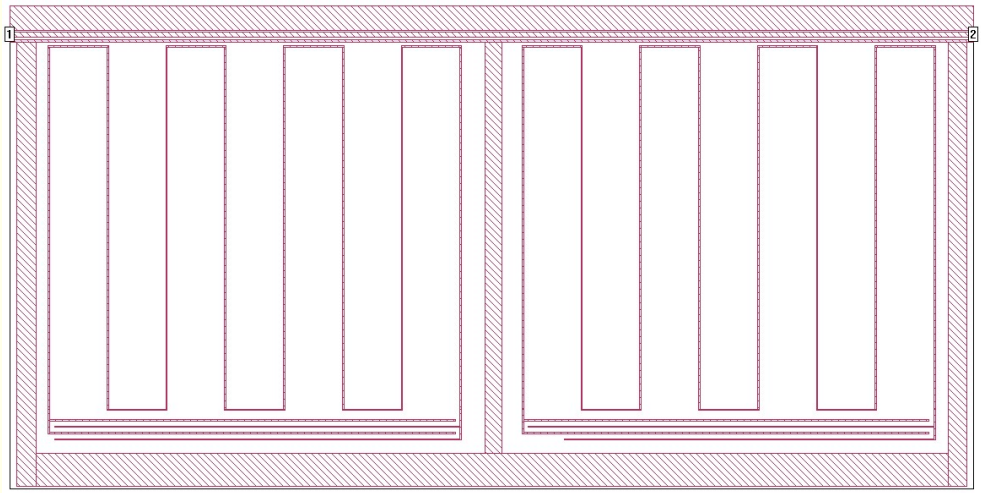


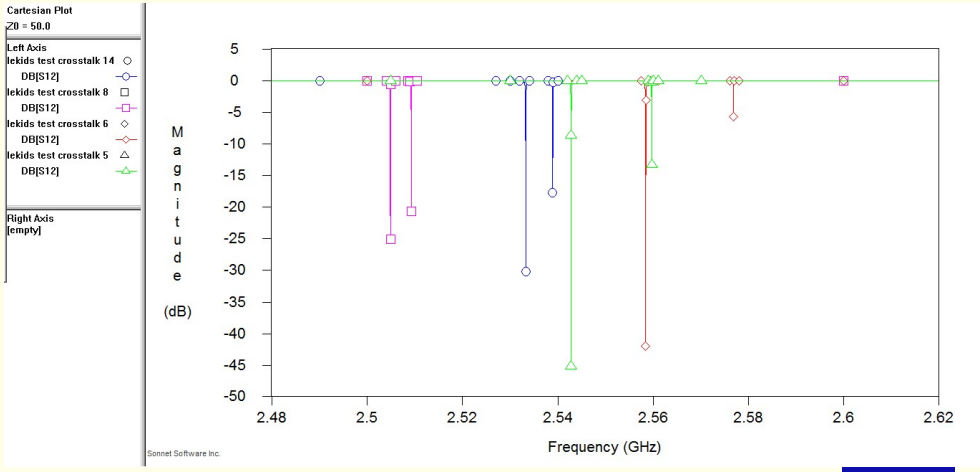
→ **Natural f-domain multiplexing**

→ **High MUX factor (hundreds-thousands)**

KID arrays: complex systems

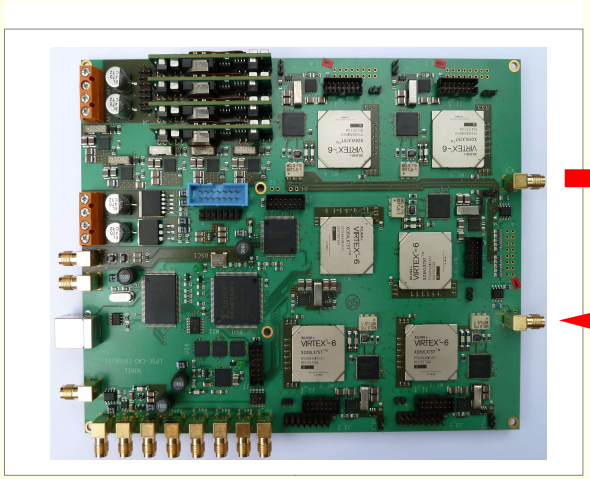




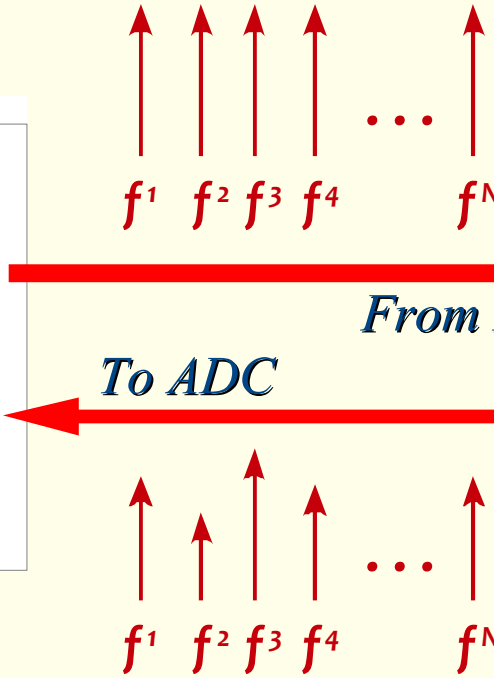


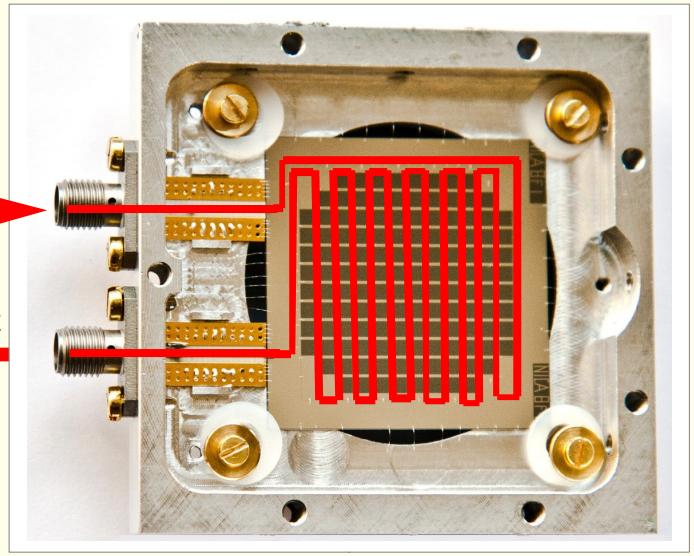
NOT A NUMBER OF ISOLATED SINGLE RESONATORS BUT A BIG N-MODES SYSTEM

FPGA readout electronics



400 channels/board
.. simultaneous 1KHz
..no dead readout time

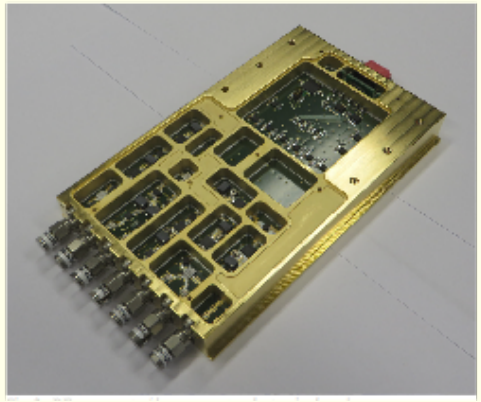




Single IN/OUT line for
hundreds pixels

Journal of Instrumentation 7, Issue 07, 7014 (2012)
Journal of Instrumentation 8, Issue 12, C12006 (2013)
Journal of Instrumentation, submitted, arXiv:1602.01288

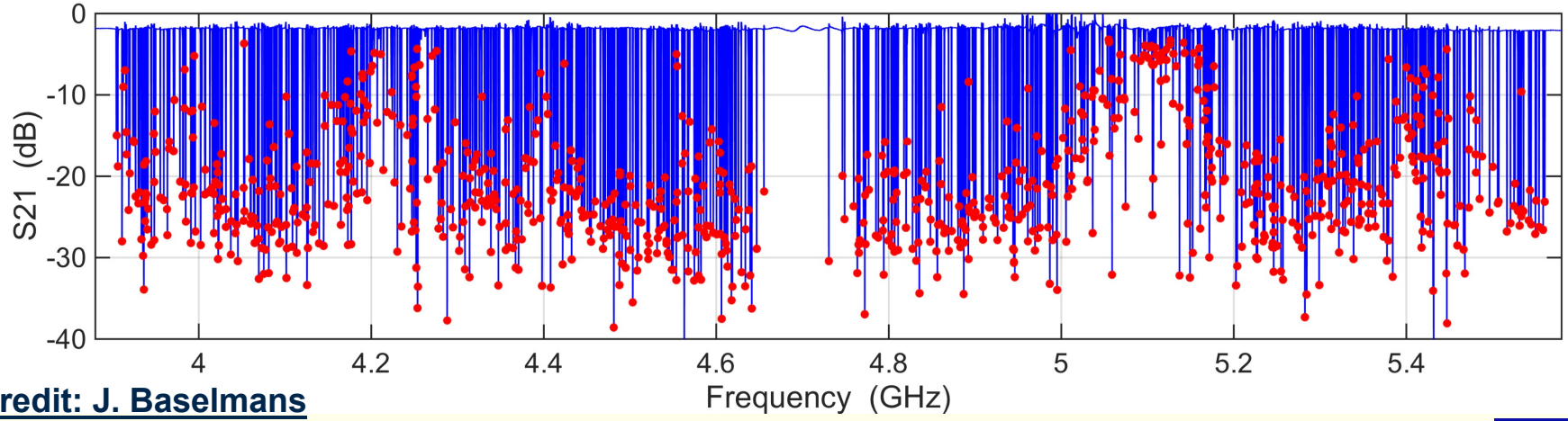
Higher-MUX fastest electronics



« SPACEKIDS » electronics
→ **2 GHz band**
→ **1000 channels** MUX demonstrated

spaceKIDS
Kinetic Inductance Detectors for Space

UK
NL
France
Spain



Credit: J. Baselmans

Why KID for CMB here ?

1) **They have demonstrated the performance** (sensitivity, stability, calibration, spectral range etc.) for both ground-based (see next) and possible (not foreseen for now) space CMB applications (see next)

2) Several **thousands pixels** cameras have been demonstrated

3) They are **fast (<< 1 ms) and immune from thermal time constants**
→ fast spinning (polarisation modulation at > 10 Hz) half-plates are possible

4) **The technology is mature in Europe**

5) **The cost of a KID camera is compatible with standard (despite very competitive) EU calls**

KID instruments (mostly focusing on EU)

Operating, science grade:

- NIKA/NIKA2 → 100-300 GHz, 3,000 pixels
- ARCHONS/DARKNESS → VIS/NIR, 10,000 kpixels **-- USA –**

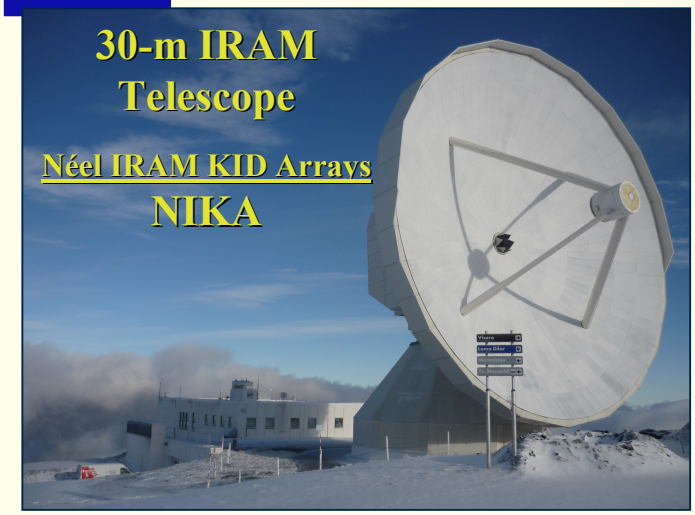
In commissioning (Summer 2017):

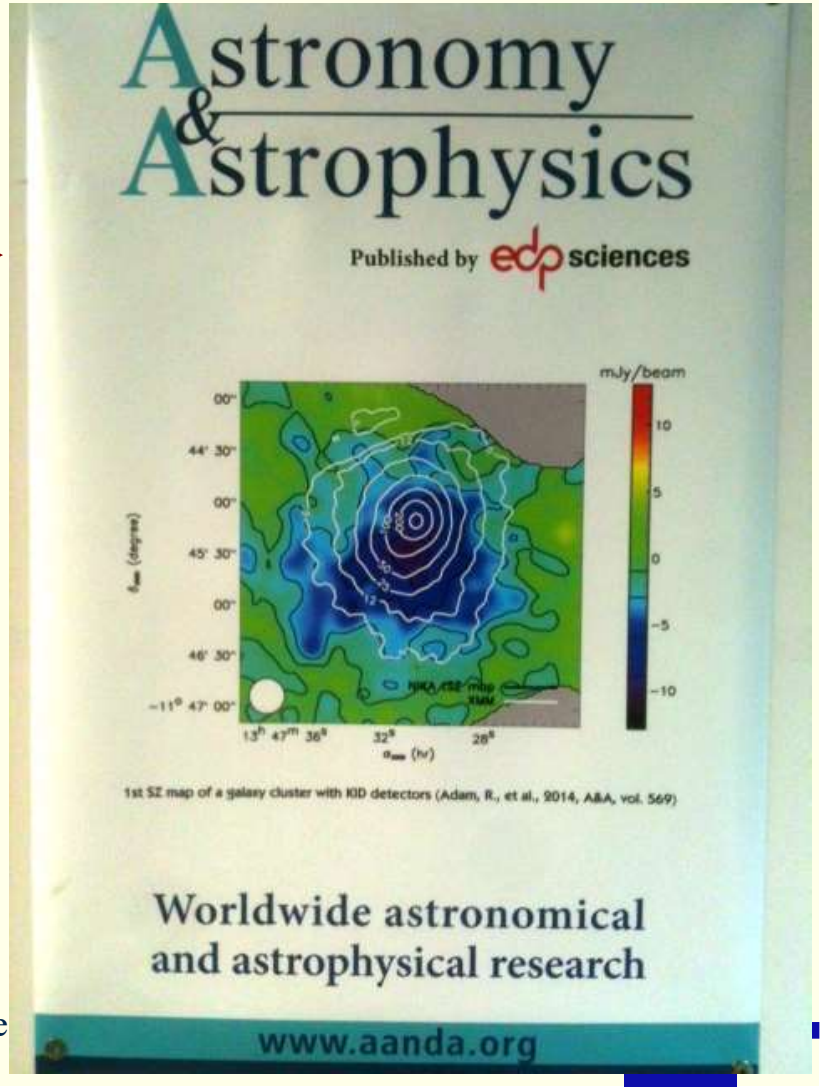
- AMKID → 360GHz, 3 kpixels (+ 20kpix planned at 850GHz)
- Others that I don't know ? Surely BLAST-TNG in the USA

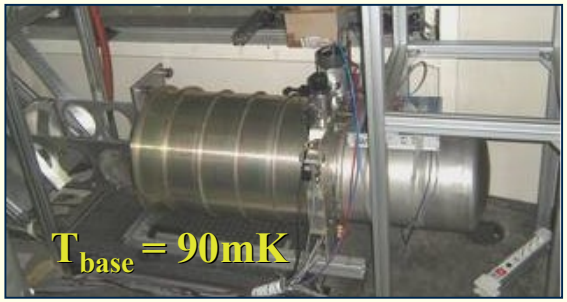
In preparation (for 2018-19):

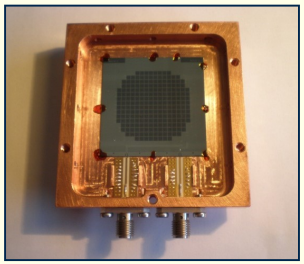
- OLIMPO → 150 – 480 GHz
- KISS → 80 – 250 GHz, 600 spectro-imaging pixels with R ≈ 100
- DESHIMA (on-chip spectrometer) → hundreds spectral pixels
- GroundBird
- And surely many others …

NIKA: the pathfinder for KID technology (2010 - 2015)



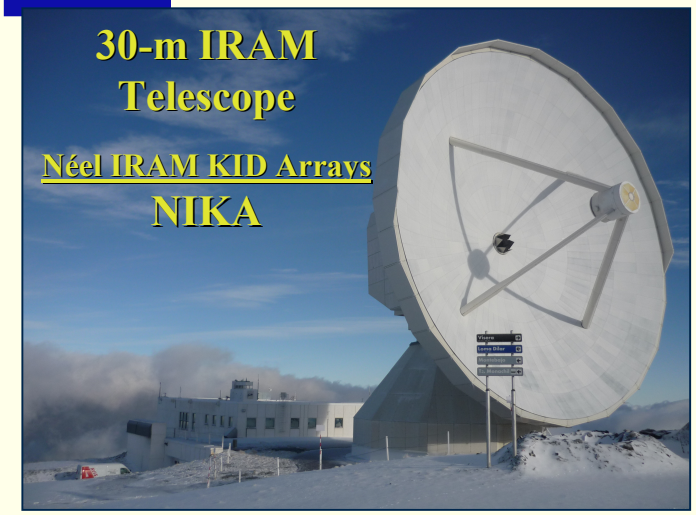


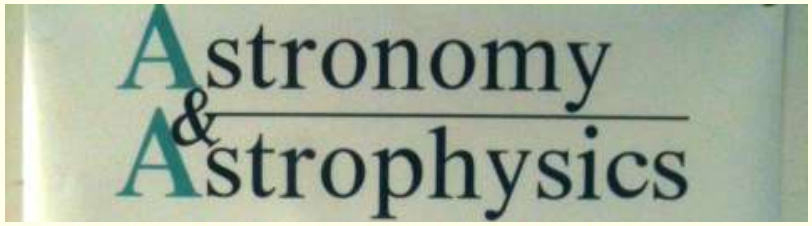




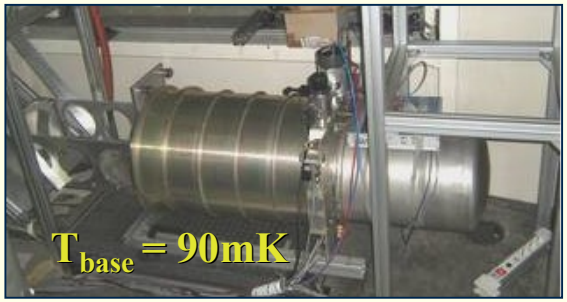
120 - 300 GHz

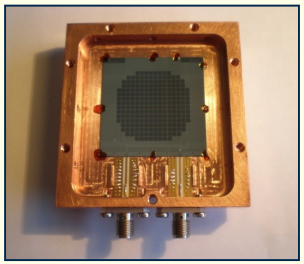
NIKA: the pathfinder for KID technology (2010 - 2015)



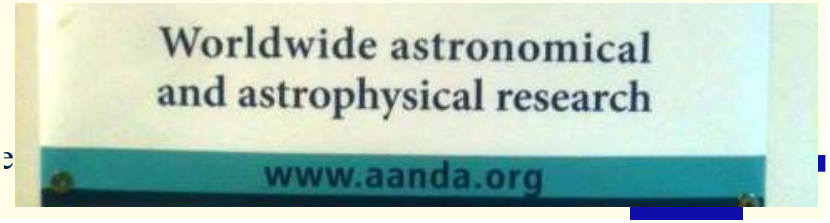


1) A. Rigby et al., « A NIKA view of two star-forming infrared dark clouds:β variations and mass concentration », submitted
2) A. Bracco et al., « Probing changes of dust properties along a chain of solar-type prestellar and protostellar cores in Taurus with NIKA », 2017A&A...604A..52B
3) C. Romero et al., « A multi-instrument non-parametric reconstruction of the electron pressure profile in the galaxy cluster CLJ1226.9+3332 », arXiv:1707.06113
4) R. Adam et al., « The NIKA2 large field-of-view millimetre continuum camera for the 30-m IRAM telescope », A&A, in press, arXiv:1707.00908
5) R. Adam et al., « Mapping the hot gas temperature in galaxy clusters using X-ray and Sunyaev-Zel'dovich imaging », in press, arXiv:1706.10230
6) A. Ritacco et al., « Polarimetry at millimetre wavelengths with the NIKA camera: calibration and performance », 2017A&A...599A..34R
7) R. Adam et al., « Mapping the kinetic Sunyaev-Zel'dovich effect toward MACS J0717.5+3745 with NIKA », 2017A&A...598A.115A
8) F. Ruppin et al., « Non-parametric deprojection of NIKA SZ observations: Pressure distribution in the Planck-discovered cluster PSZ1 G045.85+57.71 », 2017A&A...597A.110R





120 - 300 GHz

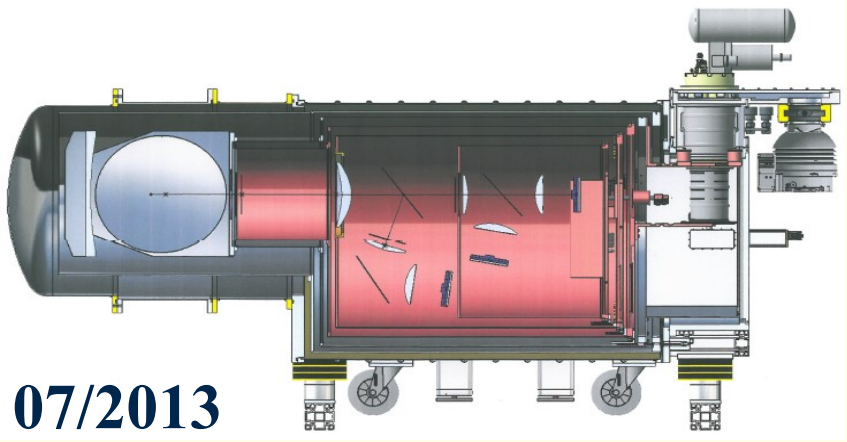


Next step … NIKA2

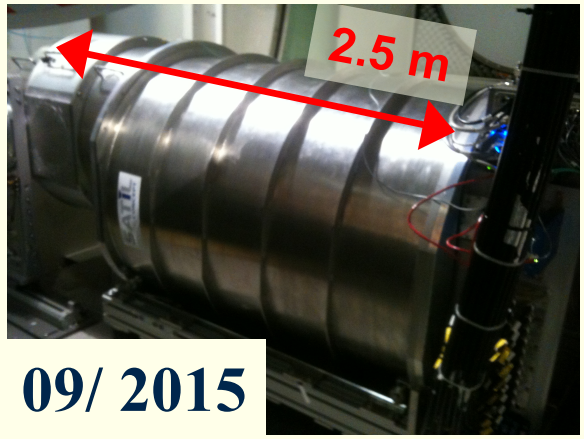
→ **10 times bigger** (and efficient) than NIKA
→ 3,000 pixels, **three arrays**
→ Imaging + **Polarisation** (120 - 300 GHz)

The **NIKA2 team** includes ≈ 100 collaborators, mostly astronomers

Cryostat 1.3 tons, fully remote control, ≈ m^3 at 100mK



07/2013



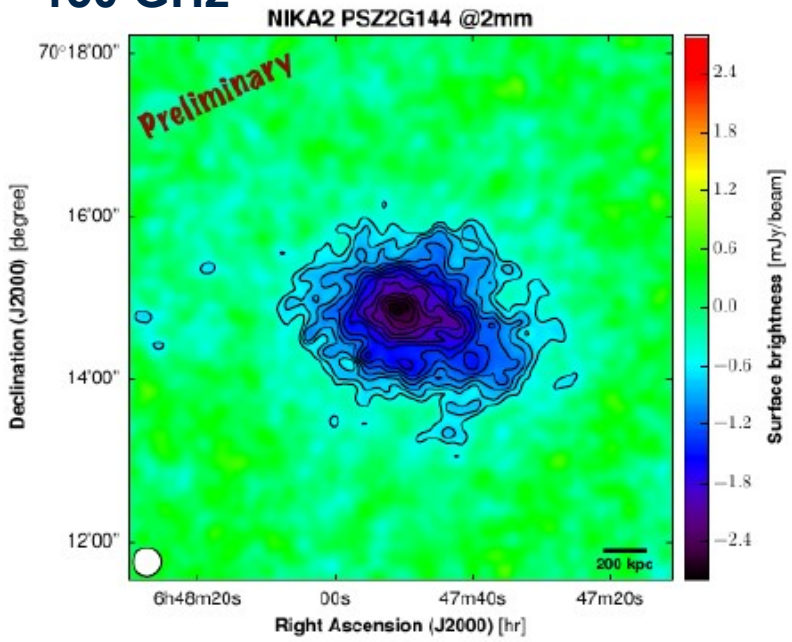
09/ 2015

NIKA2 first science results (2017)

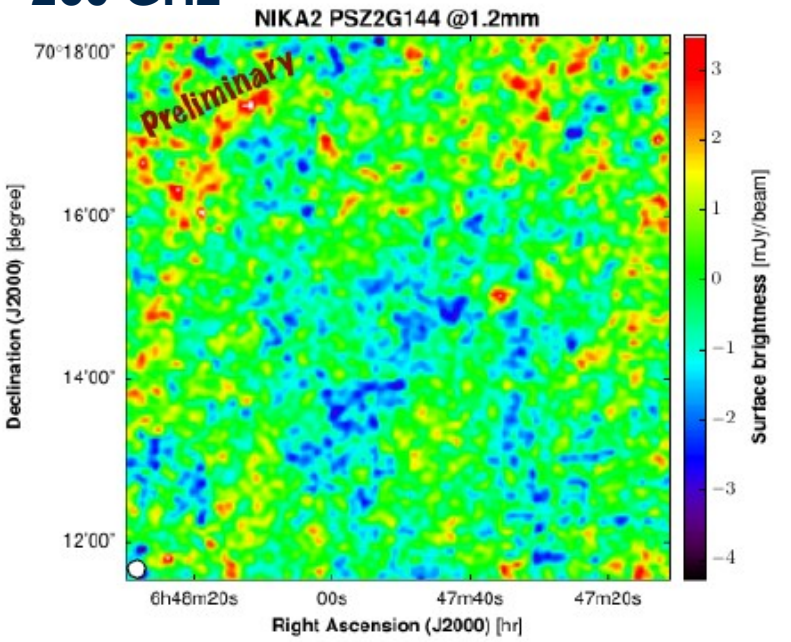
- Planck tSZ detected cluster at redshift, z = 0.58, high mass M_{500} = 7.8 x 10^{14} M
- 11h observations with NIKA1 in poor weather conditions (atmospheric opacity 0.3@225 GHz)
- Already observed: SZ – Mustang & Bolocam, X-rays - XMM

[Ruppin et al, 2018]

150 GHz

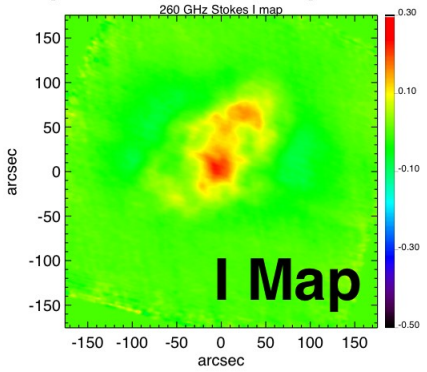


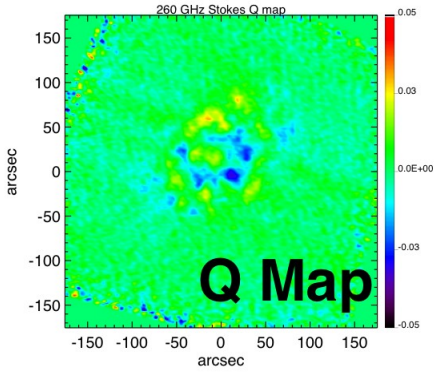
260 GHz

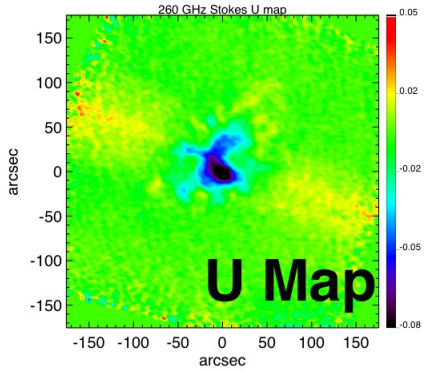


NIKA and NIKA2: the polarisation

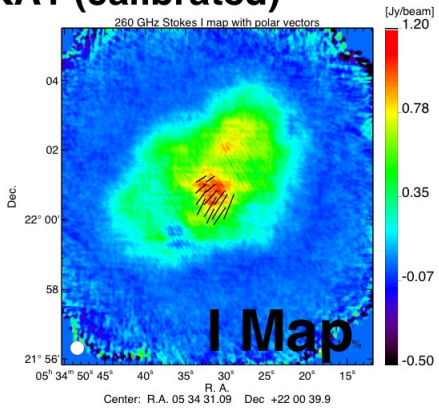
NIKA2 (not calibrated)

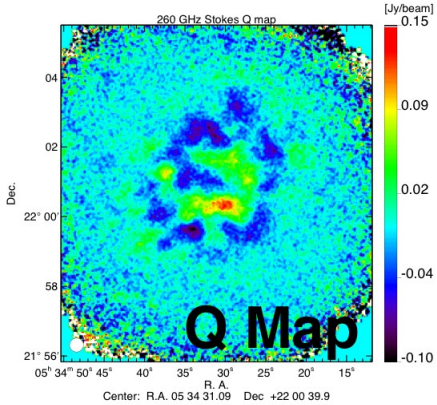


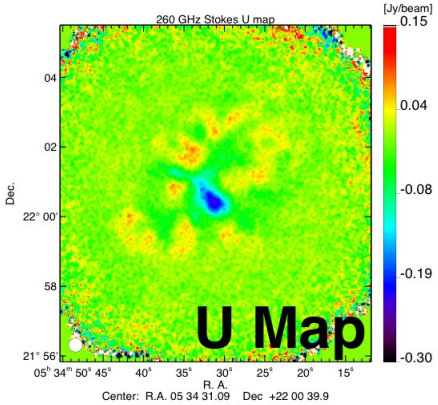




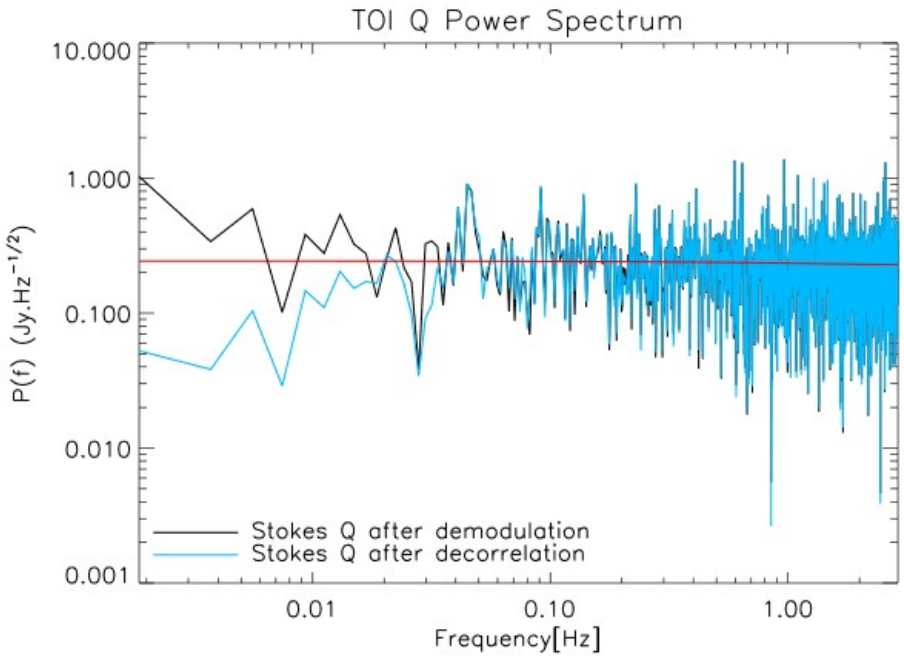
NIKA1 (calibrated)

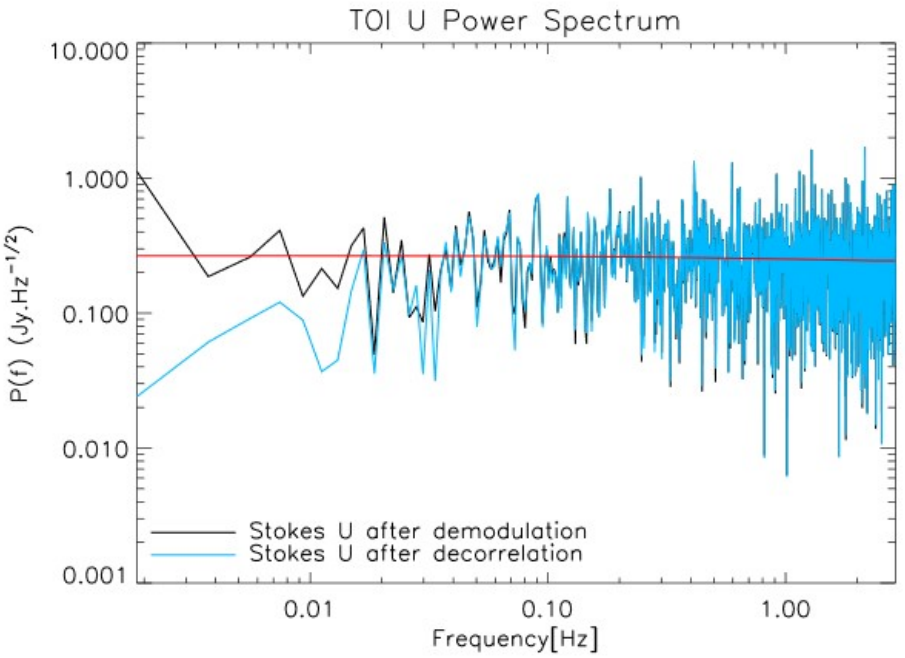






NIKA and NIKA2: the polarisation



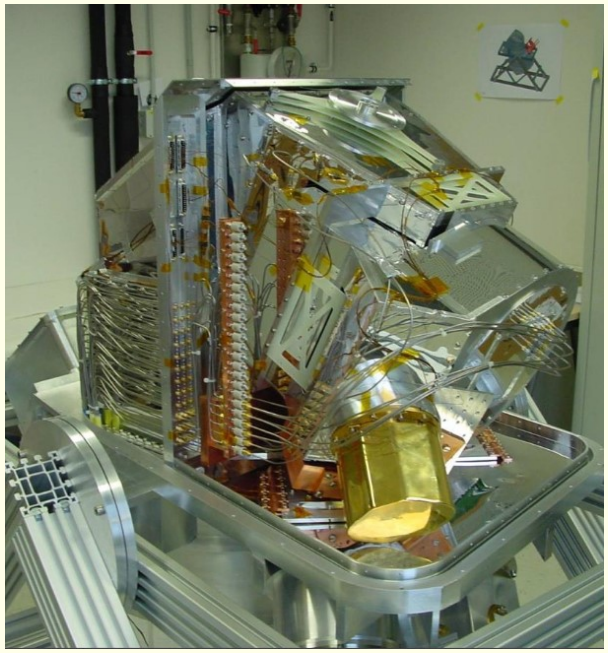


Flat noise spectrum thanks to the fast rotating half-plate
(polarisation modulated at 12 Hz)

A. Ritacco et al., Astronomy & Astrophysics 599, A34, 17 (2017)

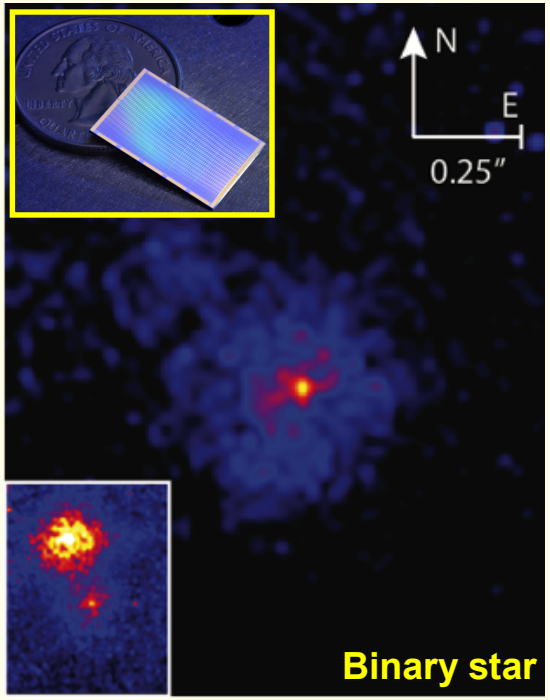
Other cameras using KID

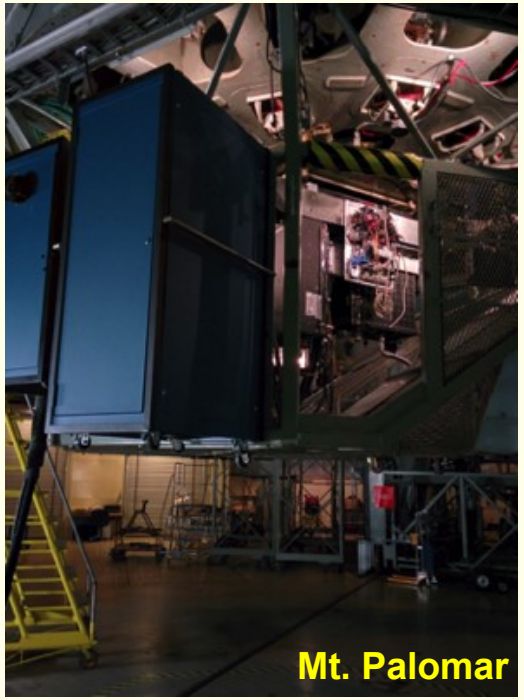
AMKID (Bonn, SRON)
350 - 850 GHz



Equivalent of NIKA2 but operating at higher frequencies (sub-mm) - under commissioning -

Darkness (UC Santa Barbara)
800 – 1400 nm

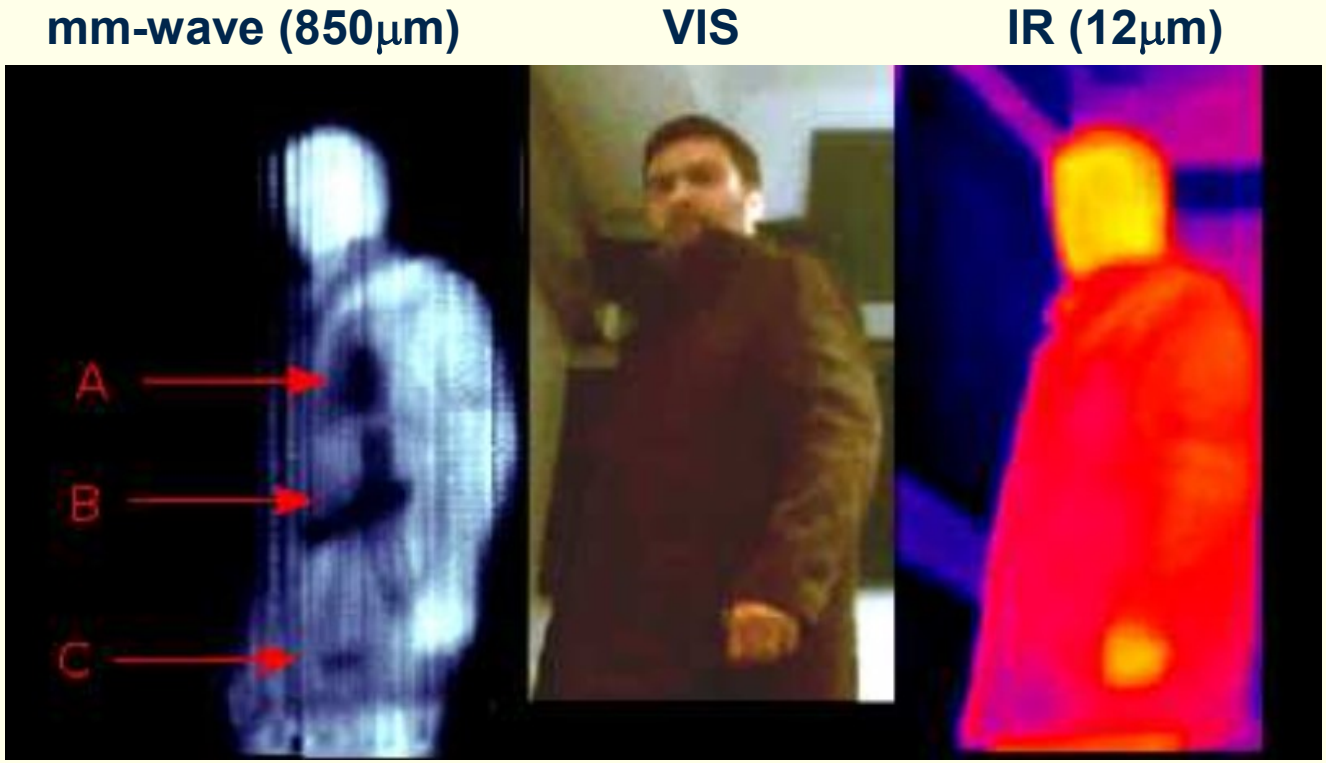




10k pixels operating at VIS-NIR !!
Hunting exo-planets

Non-astronomical applications

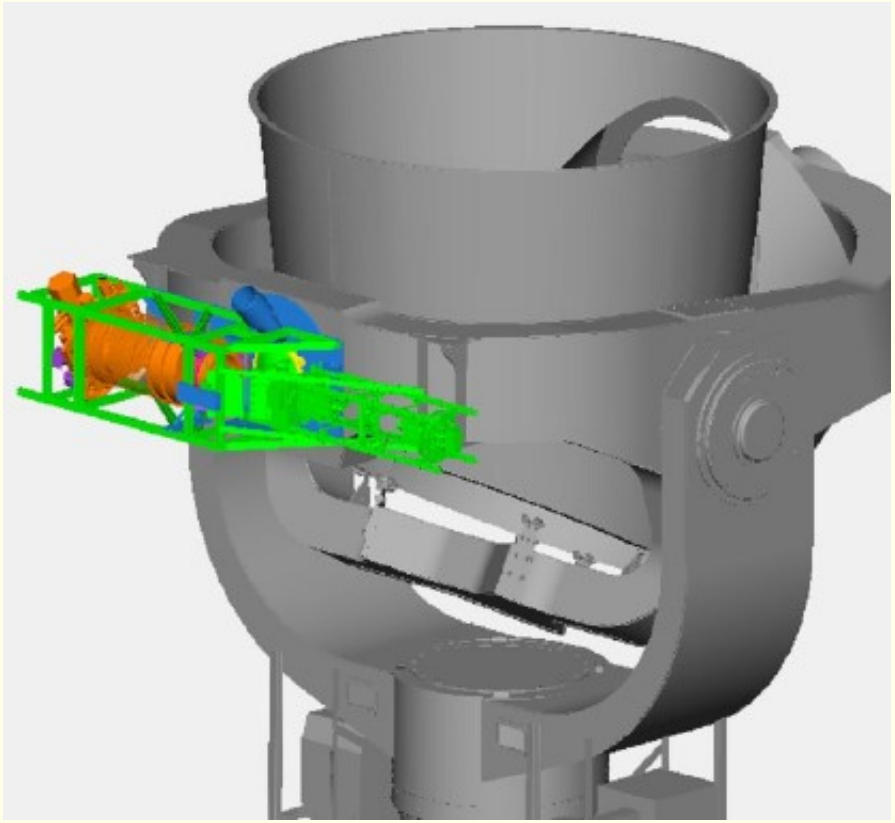
KIDCAM Project (Cardiff AIG & QMC)



Taken from: S. Rowe et al., Rev. of Scient. Instrum. 87, Issue 3, 033105 (2016)

KISS at Tenerife (2018)

SZ clusters observations



See movie of the interferometer

KID to space ?

Would work ideally and in my opinion
for e.g. LiteBird
but out-of-subject today

Summary

The KID seem to me **a natural candidate in Europe**. Many labs active in the field now in **France, NL, UK, Italy, Spain, Germany** and surely other countries has started or are starting. There is already **a fully european KID camera targeting SZ**

Thanks !

Just a bunch of us at the telescope ….

See the **Néel Astrophysics Instrumentation group (NAI)** at:

http://neel.cnrs.fr/spip.php?rubrique158