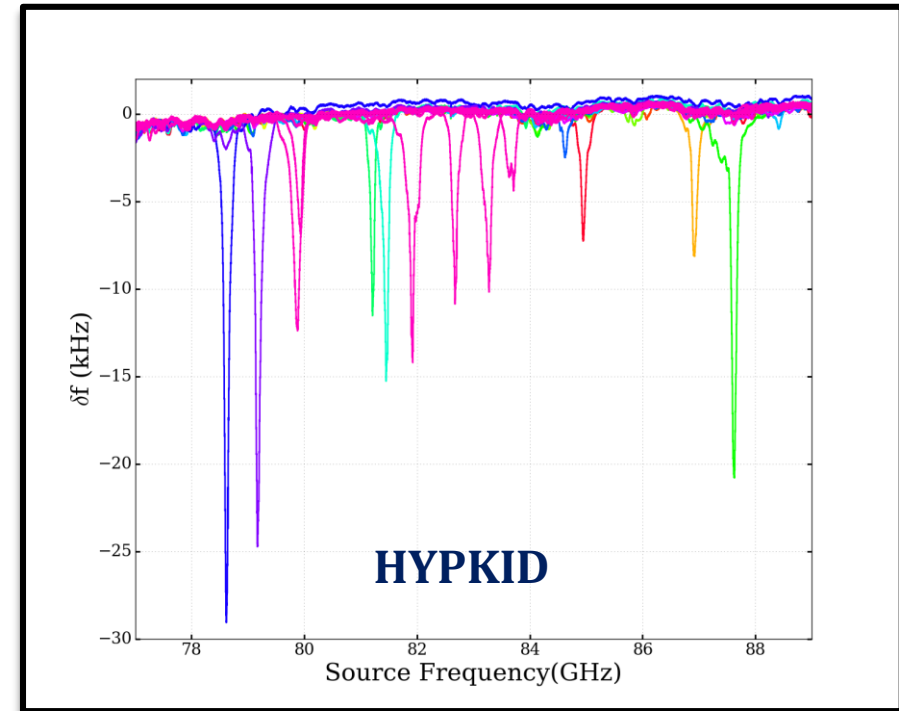
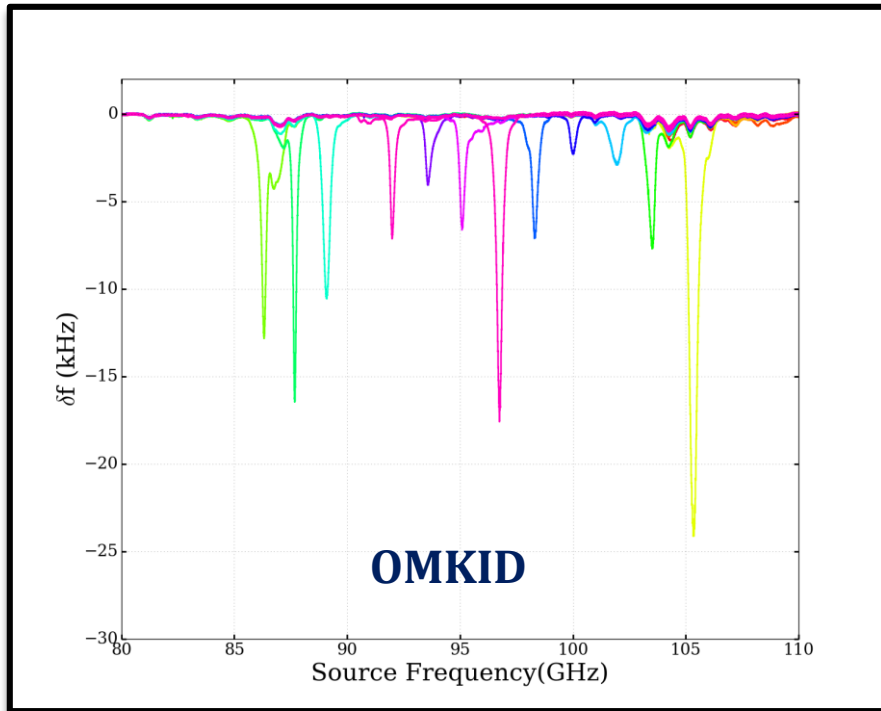
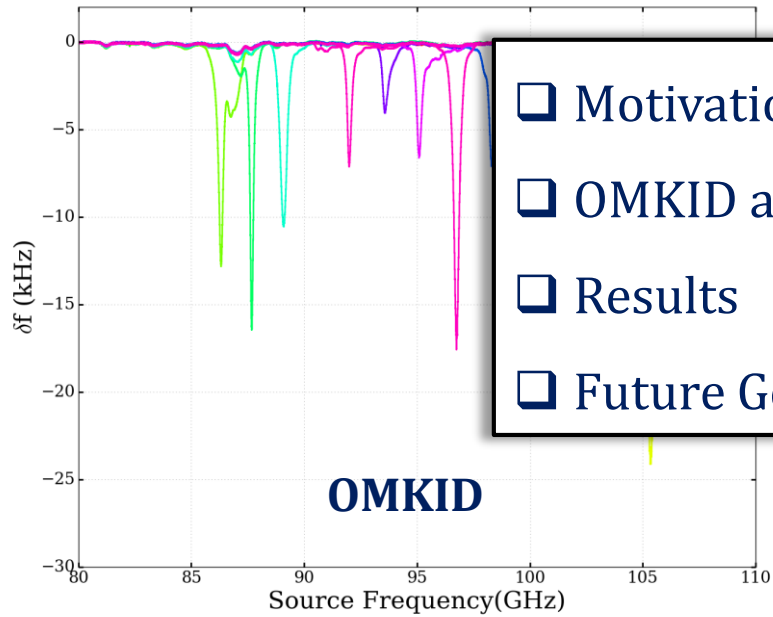


Spectrometers based on Kinetic Inductance Detectors

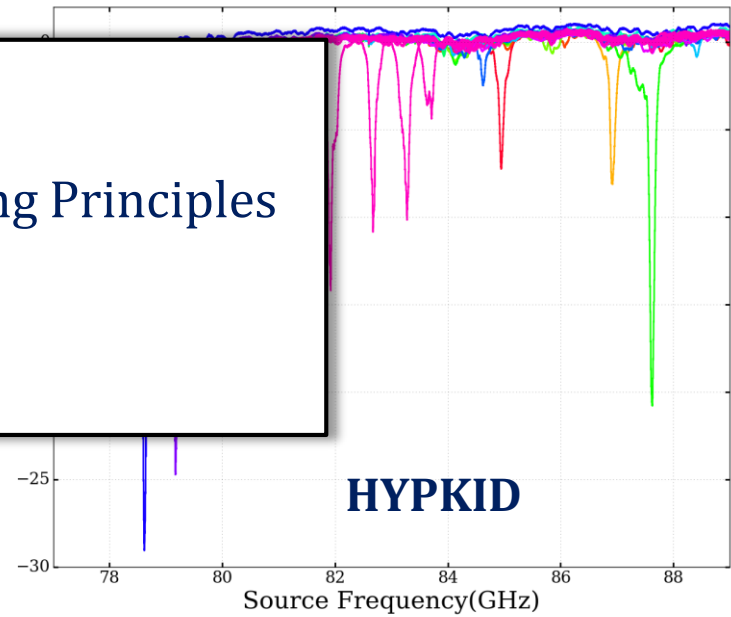
Usasi Chowdhury



Outline



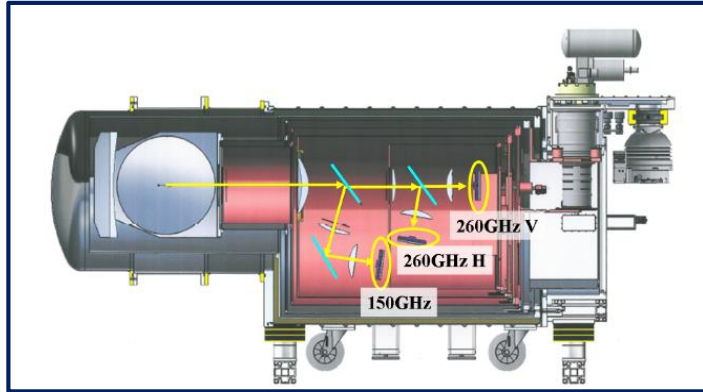
- Motivation
- OMKID and HYPKID: Working Principles
- Results
- Future Goals



Motivation

Photometric Cameras

High mapping speed and FOV
Low Spectral Resolution



NIKA2 Camera, $R = 3 - 5$

Observation of the sky
in (sub) mm wavelength

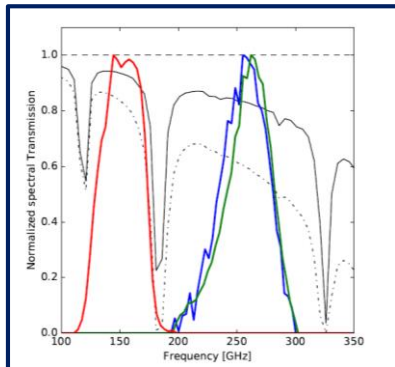
Missing: Intermediate
spectral resolution
with medium mapping
speed !!!
($R = 100-1000$)

Interferometry

High Spectral Resolution, Small FoV

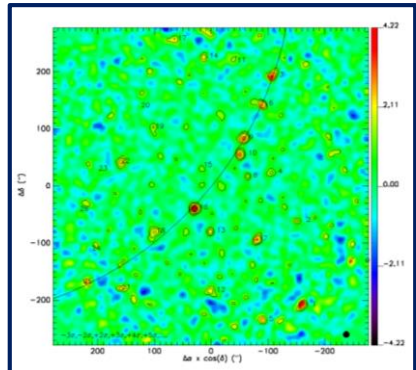


NOEMA, $R = 10^5$



Adam et al., 2018

NIKA2 spectral bands
150 and 260 GHz

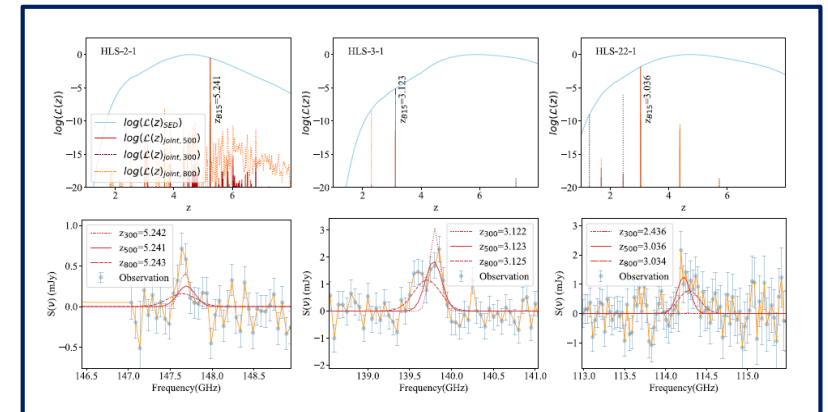


Lestrade et al., 2022

GJ526 NIKA2 map at
1.15mm

Solution!!!

On chip Spectrometer
FTS



Bing et al. 2021

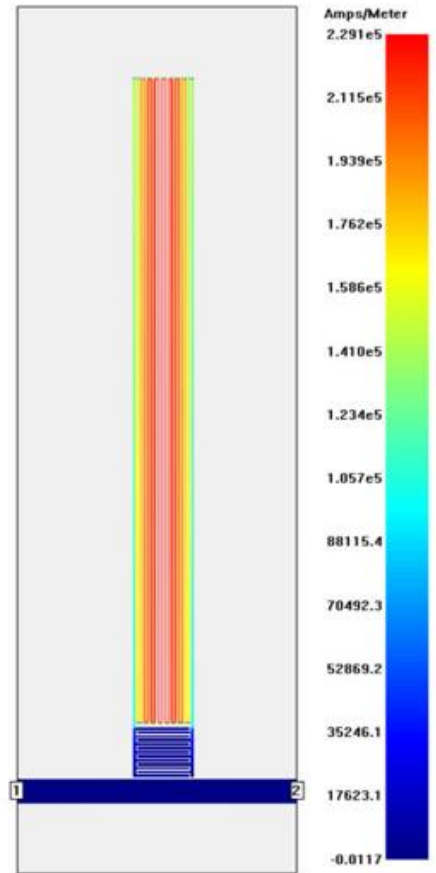
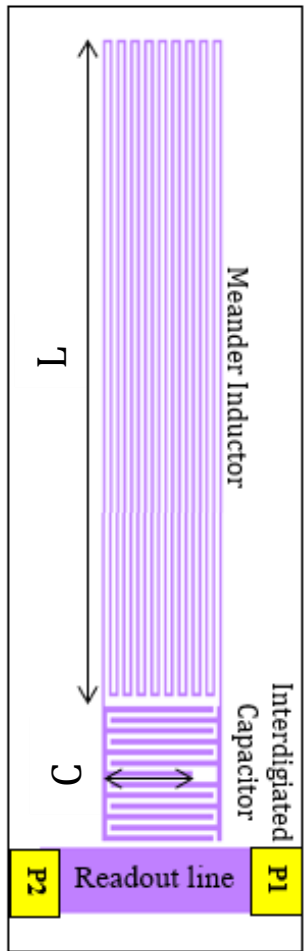
Typical Line Width ~ 0.5 GHz

(Lumped Element) Kinetic Inductance Detectors: Basic Working Principles

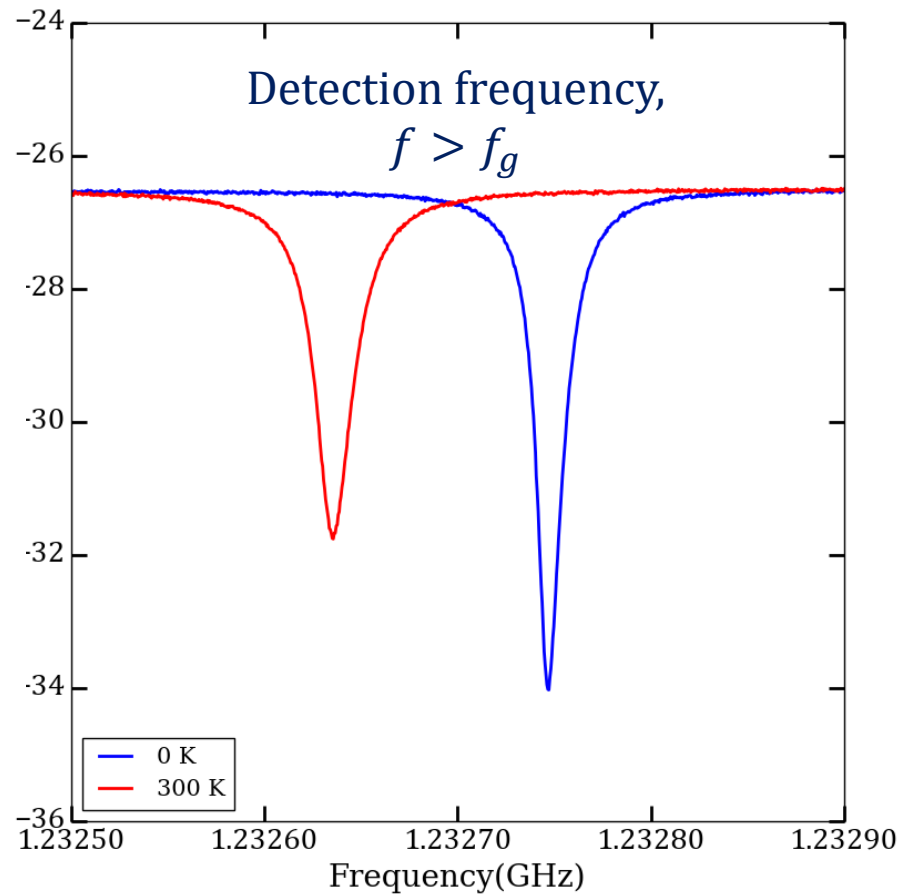
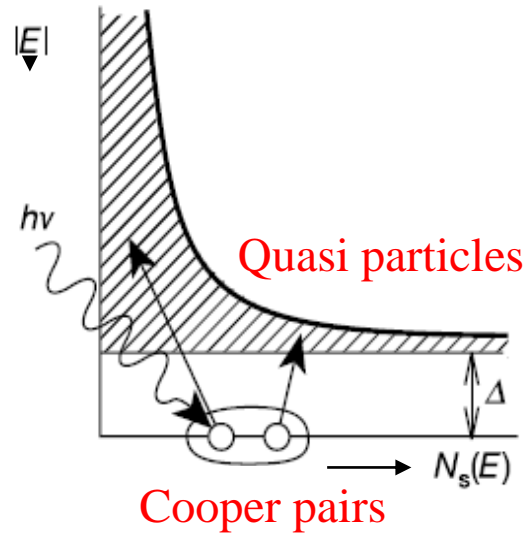
$T < T_c, f < f_g$

At resonance,

$$f_r \propto \frac{1}{\sqrt{LC}}$$

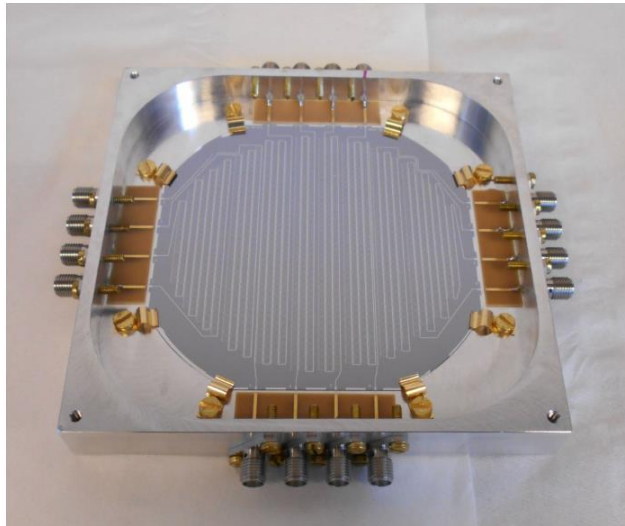


High Quality factor, $\approx 10^5$



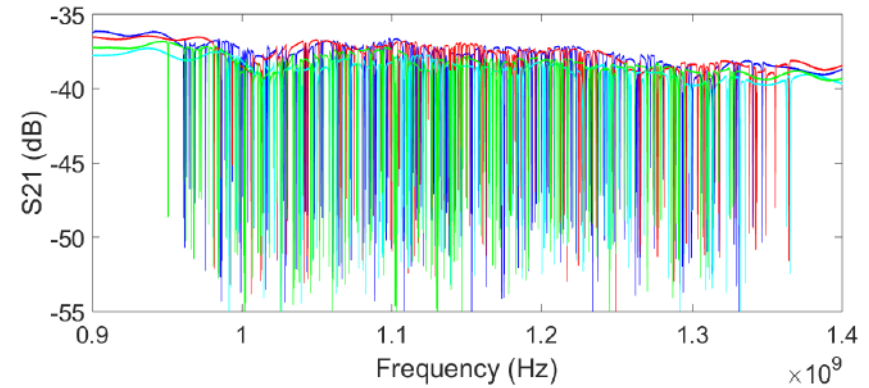
(Lumped Element) Kinetic Inductance Detectors: Basic Working Principles

NIKA2 Array: 260 GHz



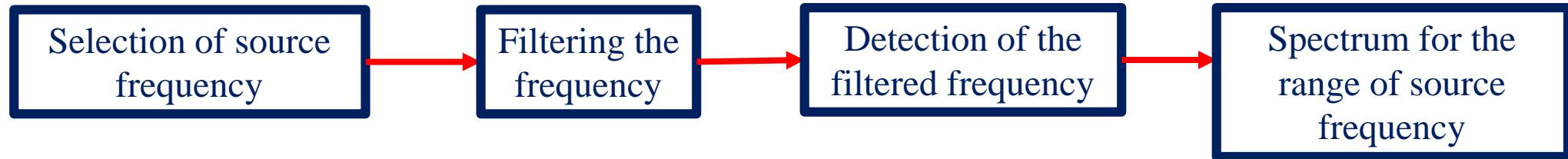
Frequency Multiplexing

616 pixels

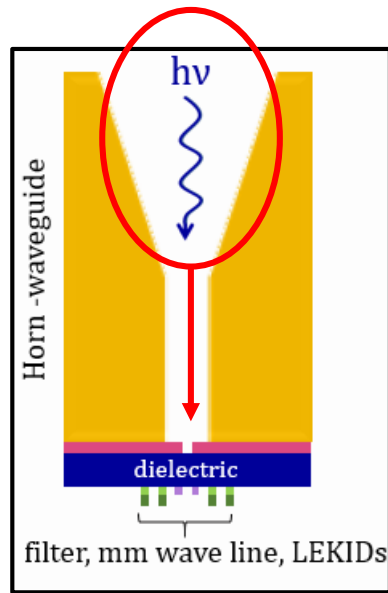


Readout all frequencies simultaneously through only one readout line

Concept of on-chip spectrometer








Device Description: *OMKID*

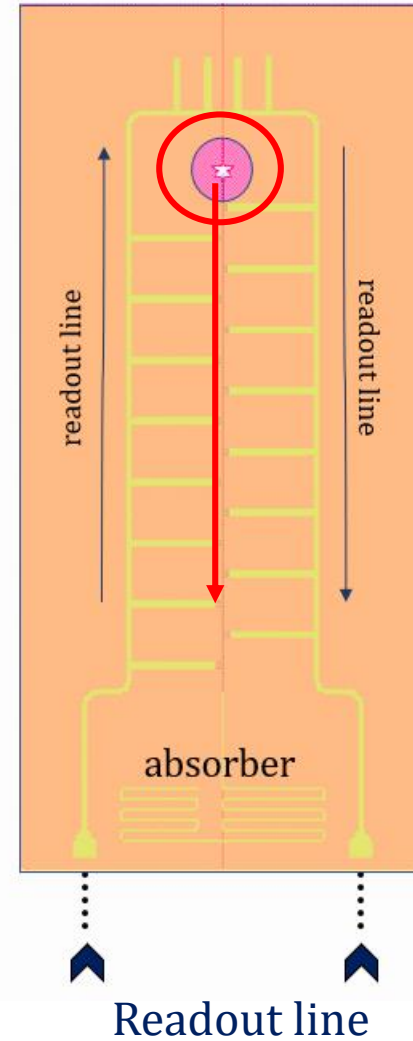


Side view

Selection of source frequency

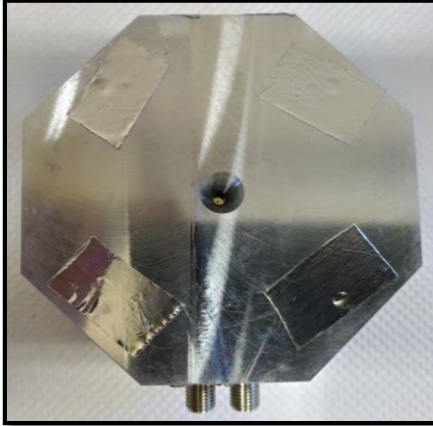
	Bulk Al
	10 nm + 25 nm TiAL bilayer
	20 nm Al
	Sapphire/Silicon
	450 nm AlTiAu trilayer

Overview of *OMKID*

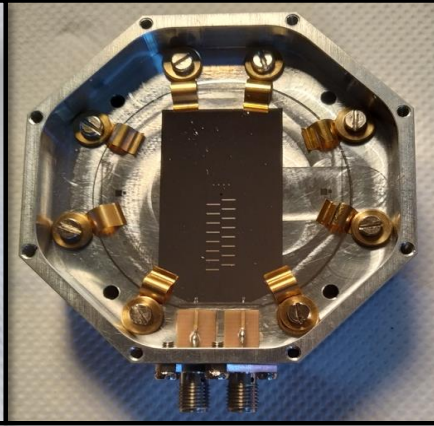


Device Description: *OMKID*

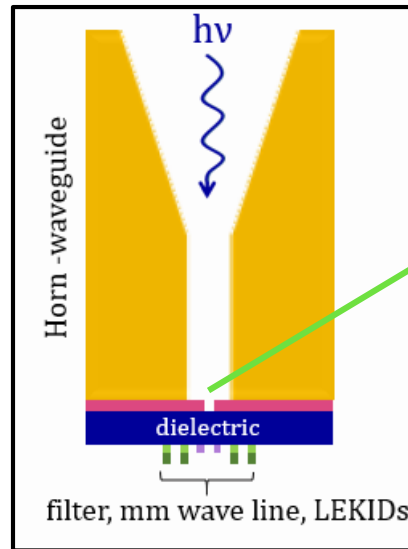
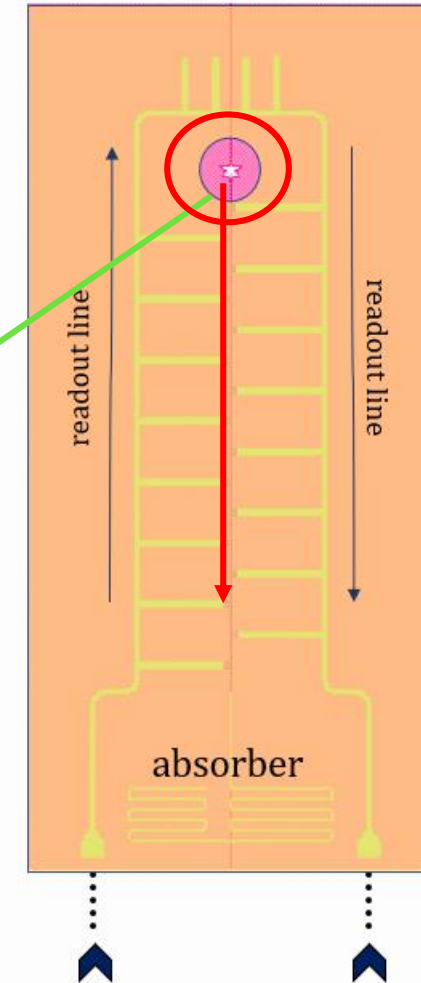
Top view



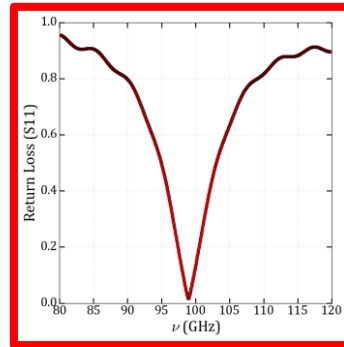
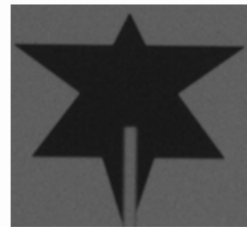
Back view



Overview of *OMKID*



Side view

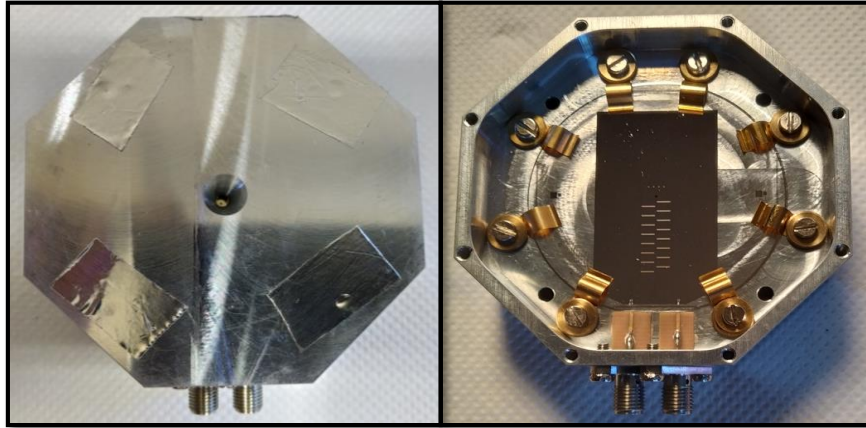


Selection of source frequency, 80-110 GHz

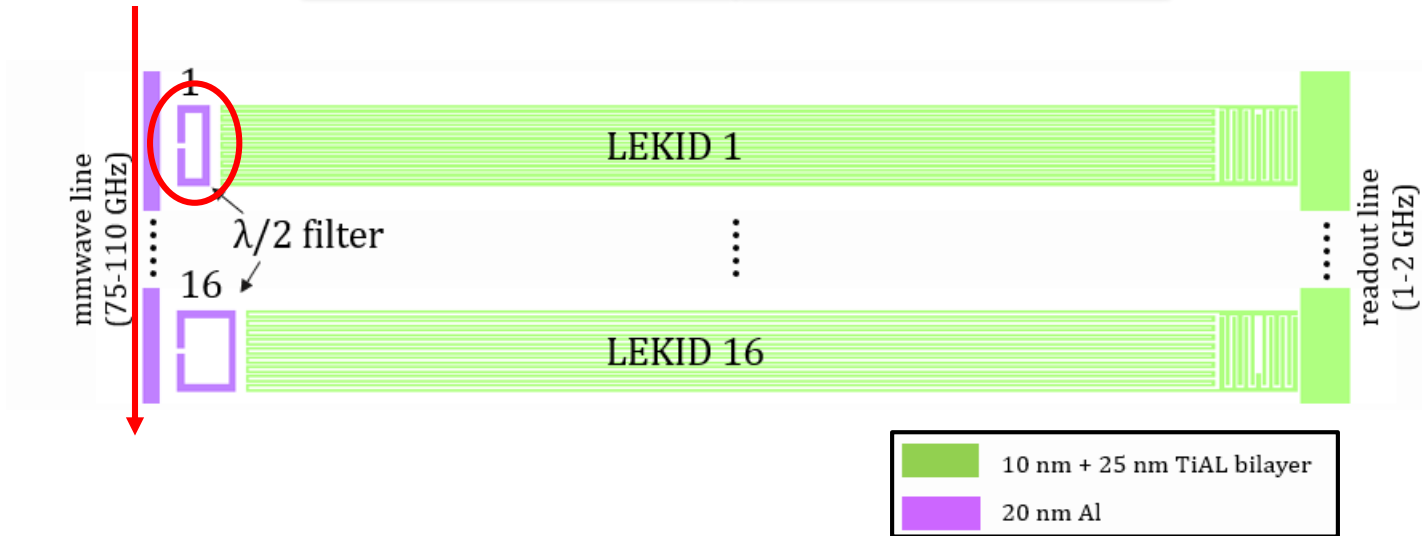
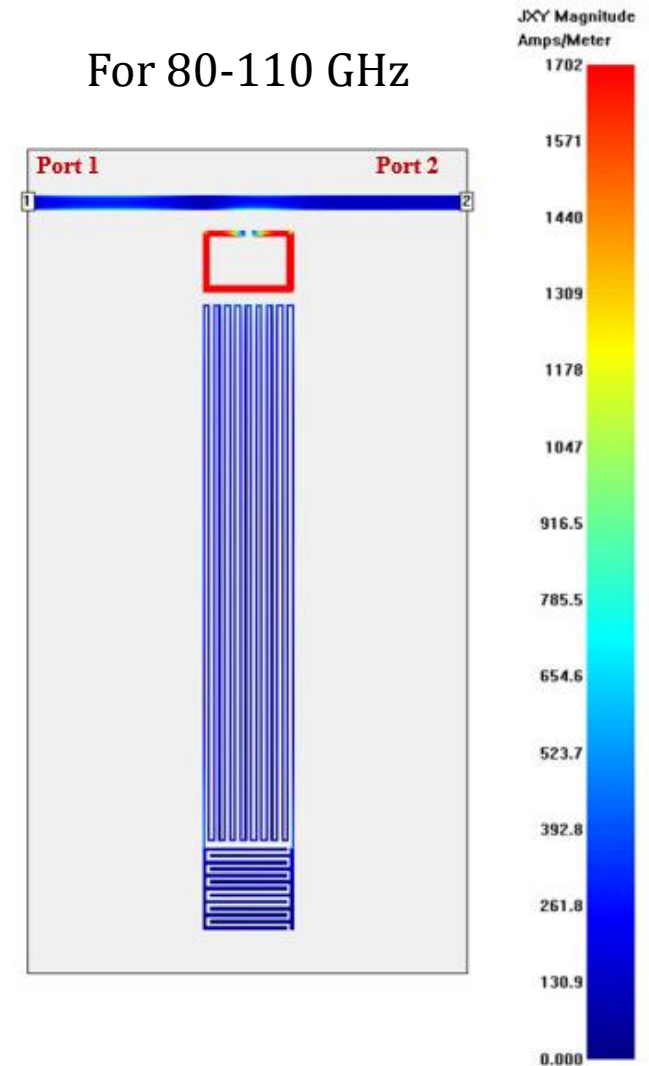
Device Description: *OMKID*

Top view

Bottom view



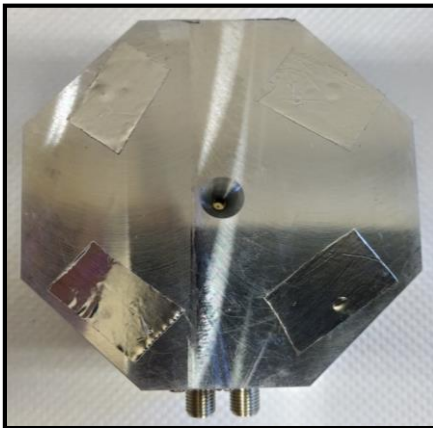
For 80-110 GHz



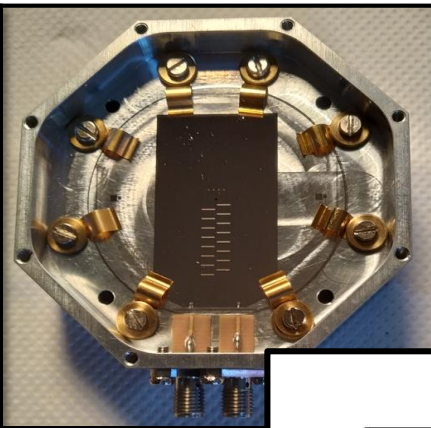
Filtering the frequencies with filters

Device Description: *OMKID*

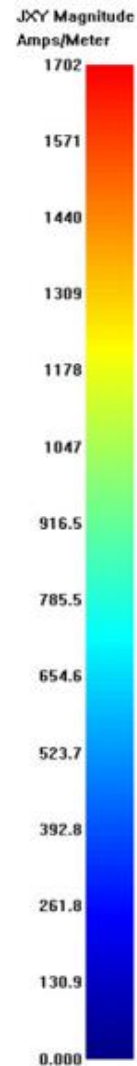
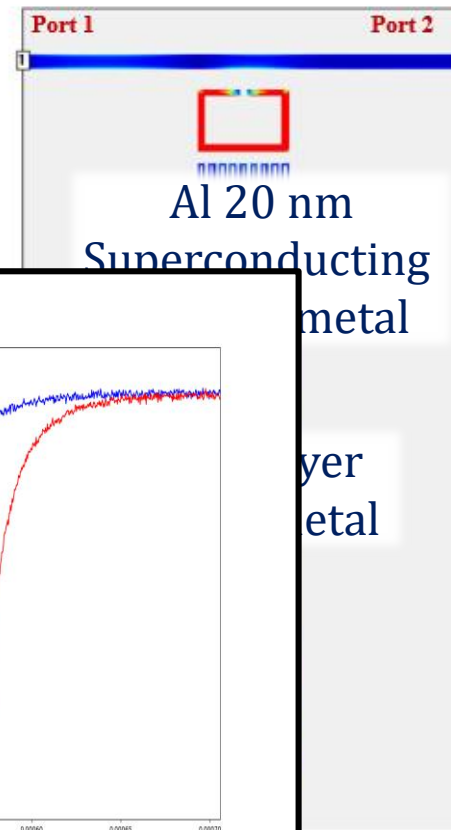
Top view



Bottom view

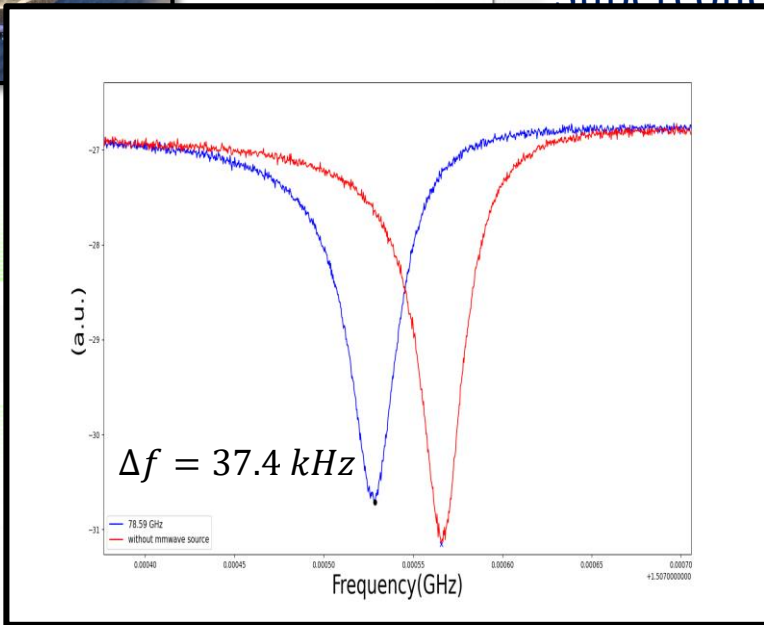
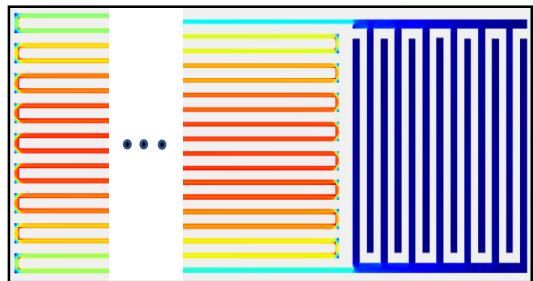


At resonance frequency of the c-shaped filter



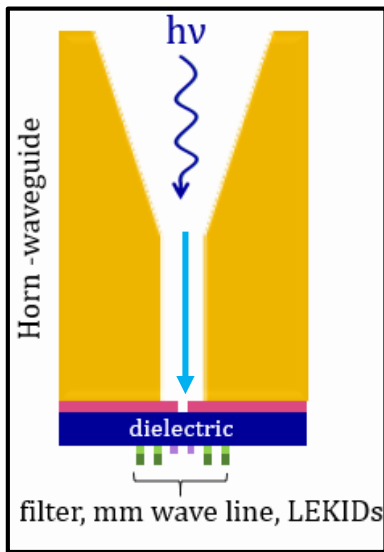
Detection of each of the frequency

LEKIDs current distribution

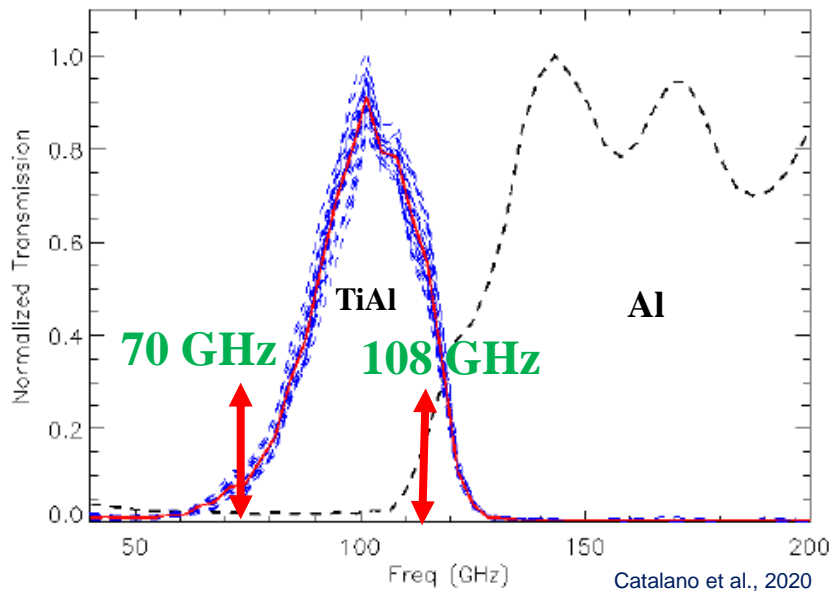
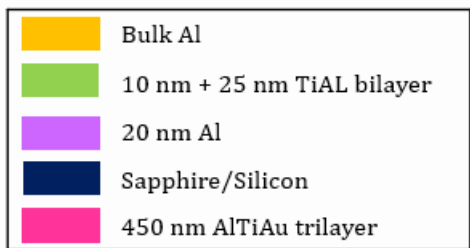


We read out the resonances of the LEKIDs in 1-2 GHz.

Device Description: *OMKID*

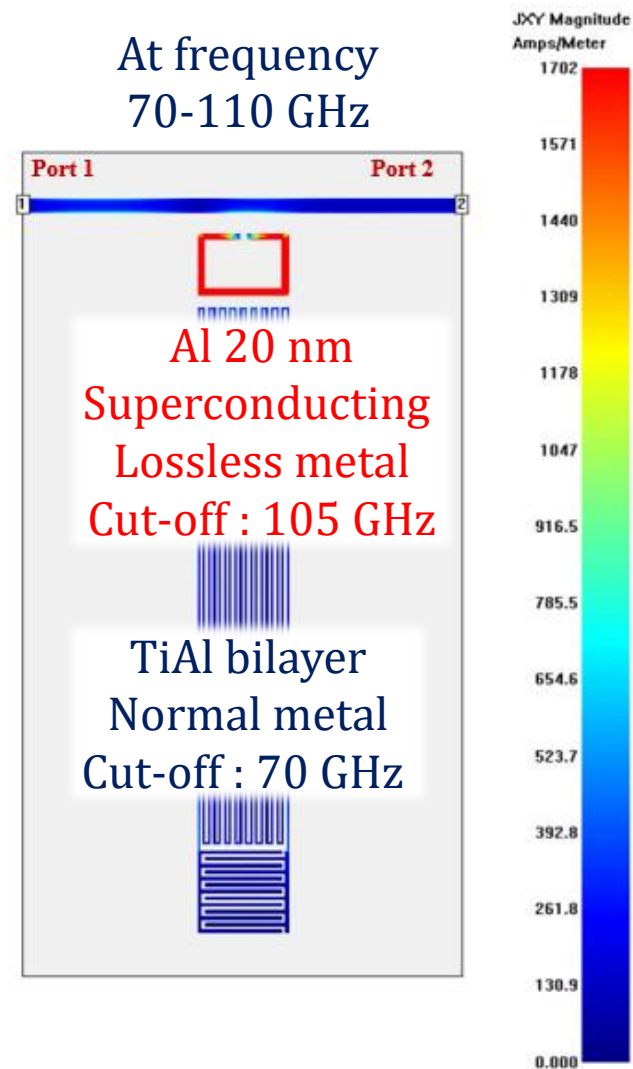


Side view



$$\text{Gap frequency, } f_g = \frac{2\Delta}{h} = 73.5 T_c \text{ (GHz)}$$

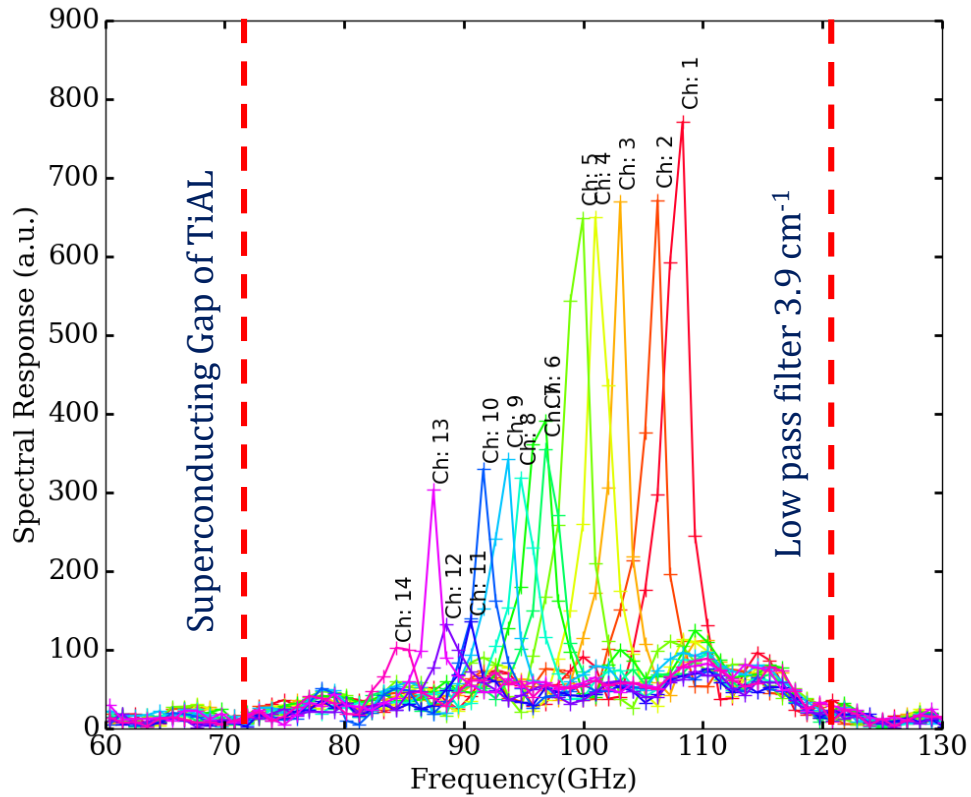
At frequency
70-110 GHz



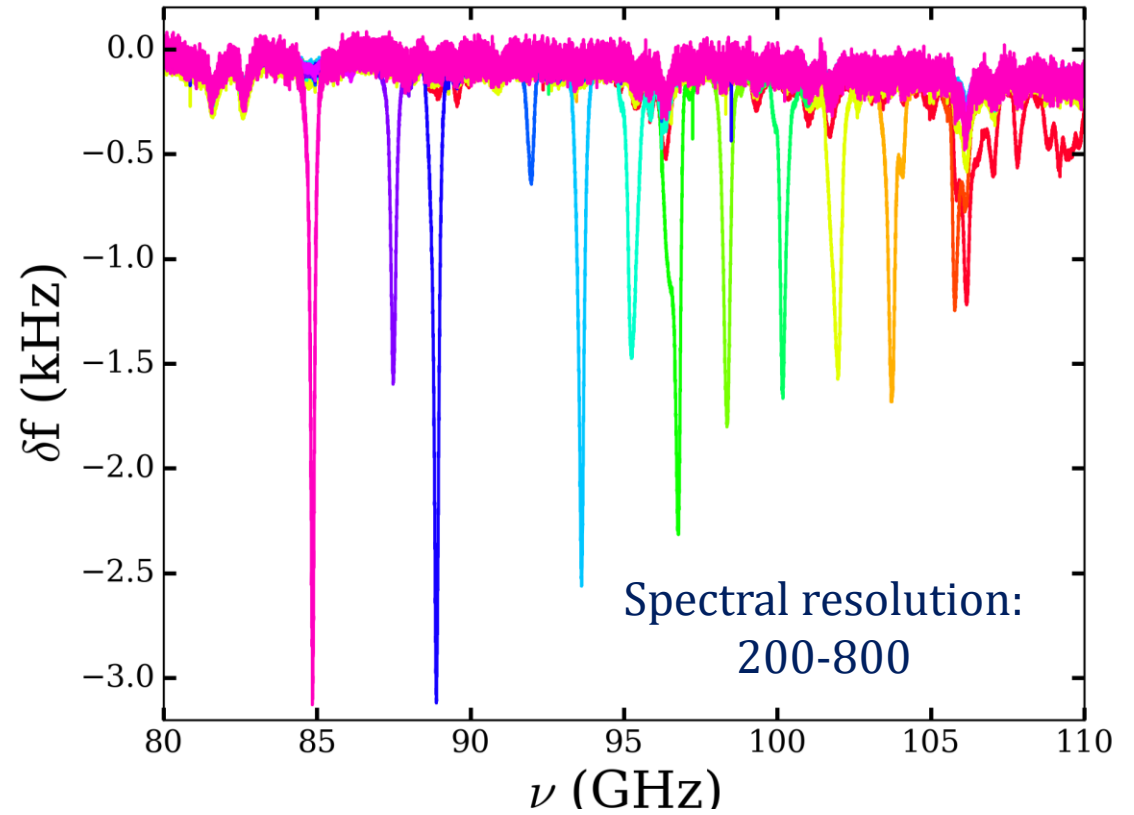
At low frequency, 1-2 GHz, TiAl bilayer
acts as perfect superconductor

Relevant results: *OMKID*

Martin Puplett Interferometer

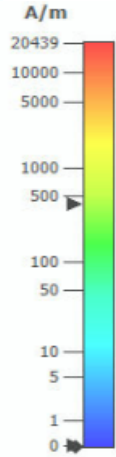
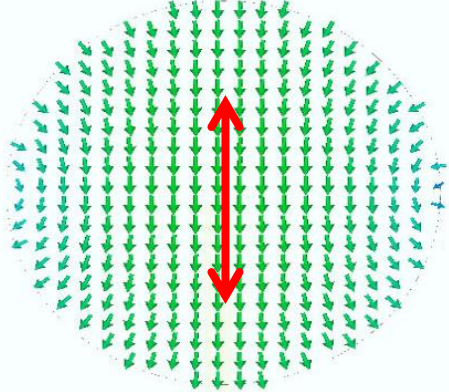
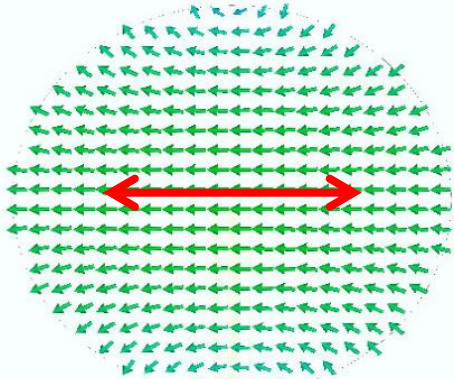


mm wave Source (75-110 GHz)



Device Description: *HYPKID*

Excitation Modes



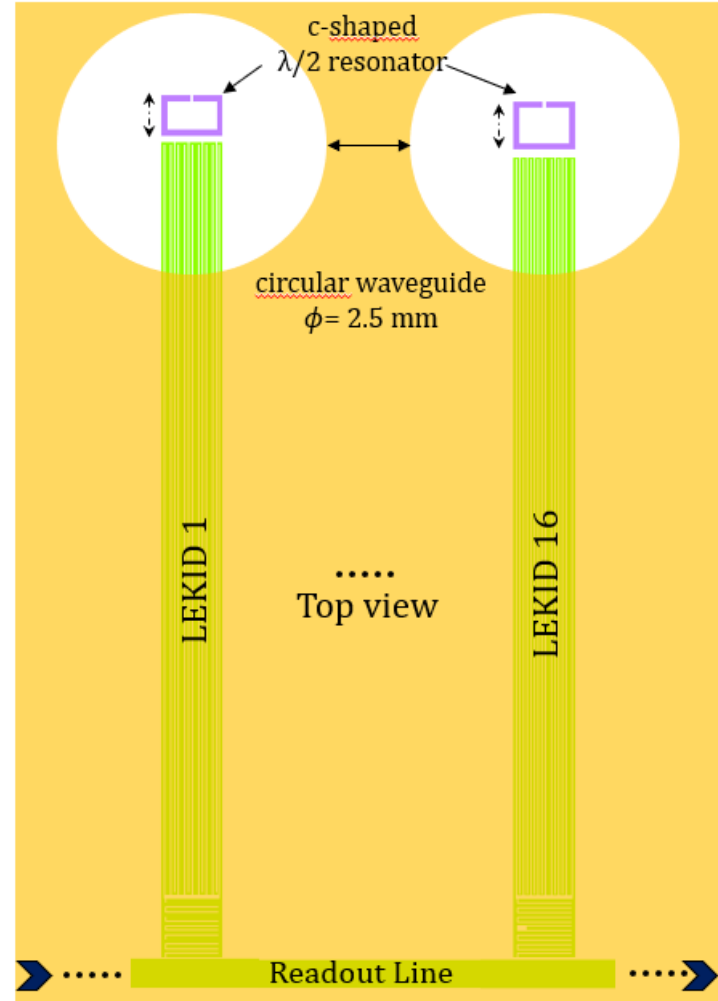
At tuned frequency of
the c-shaped filter

75-110 GHz



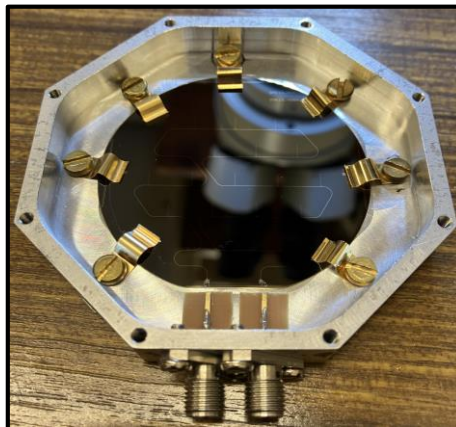
Filter Activated

Filter not activated

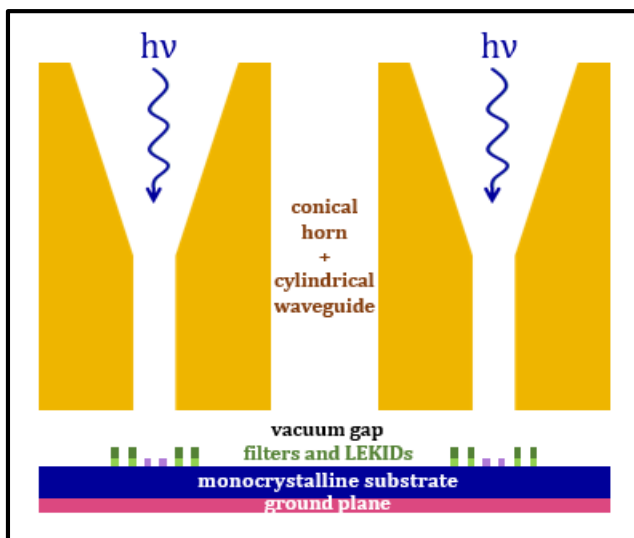
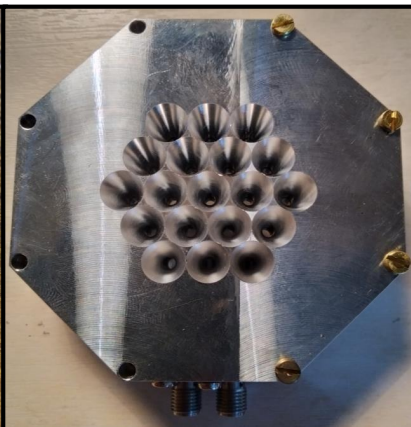







Device Description: *HYPKID*

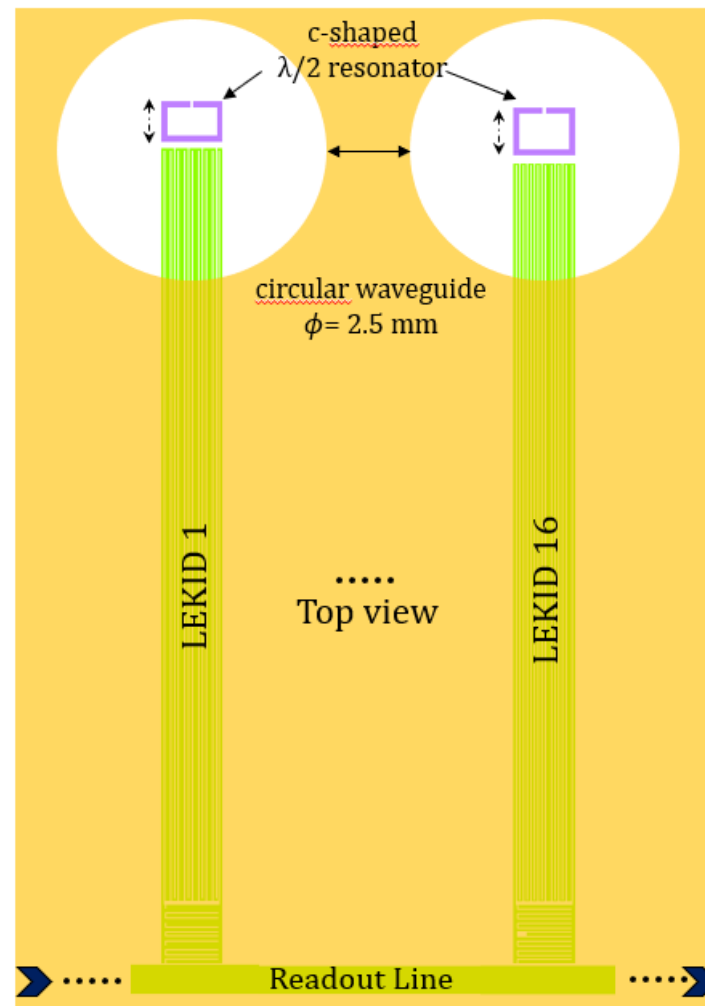
Top view



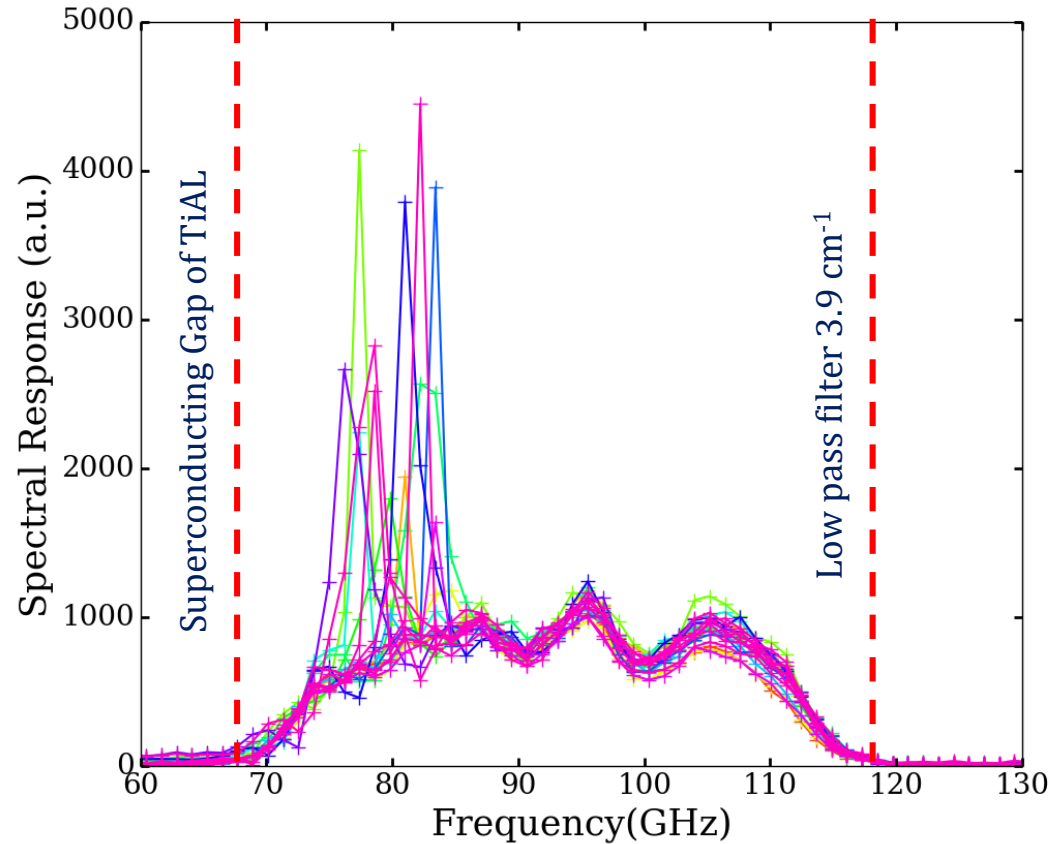
Bottom view



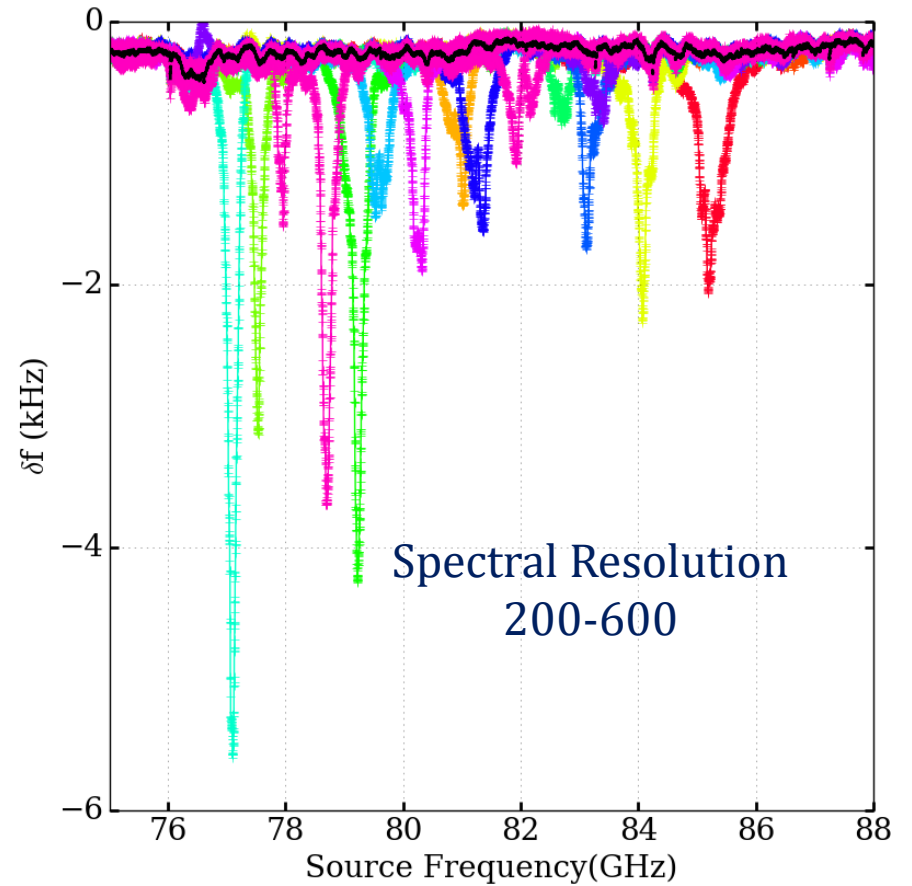
	Bulk Al
	10 nm + 25 nm TiAl bilayer
	20 nm Al
	Sapphire/Silicon
	450 nm AlTiAu trilayer



Relevant results: *HYPKID*

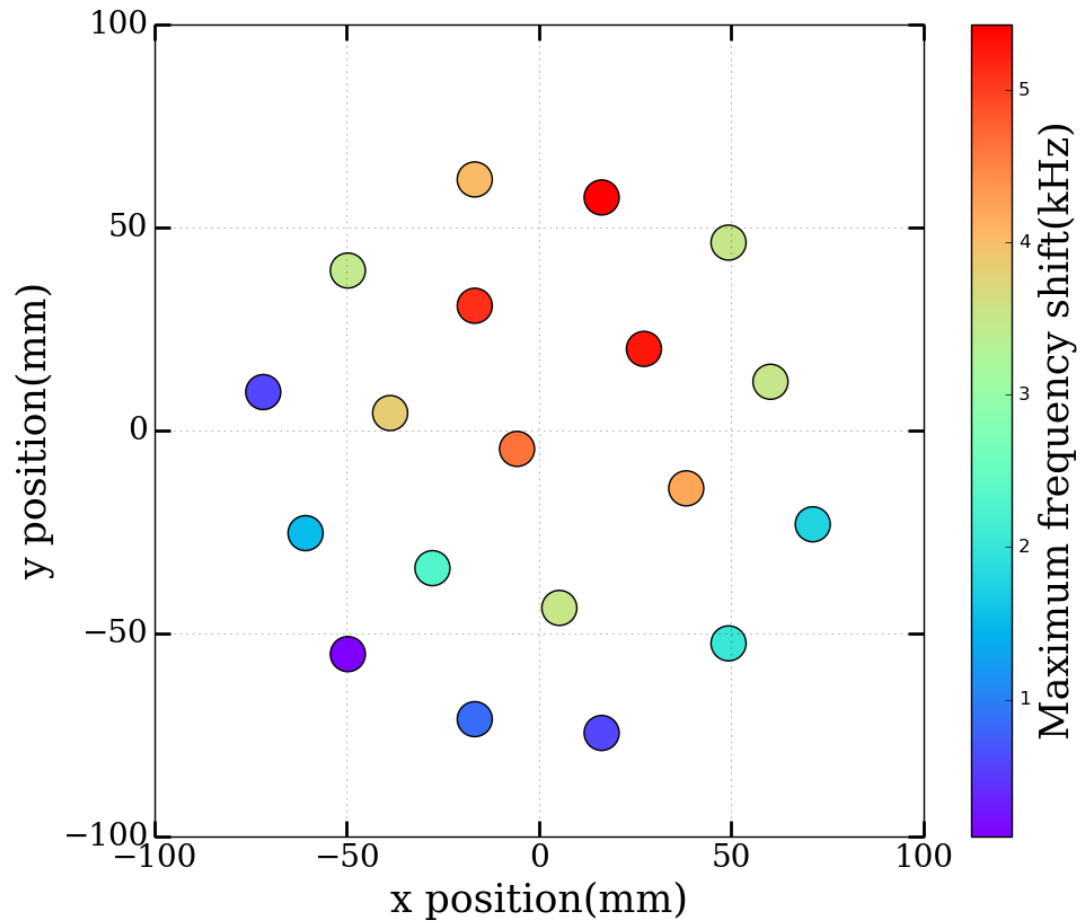


Martin Puplett Interferometer

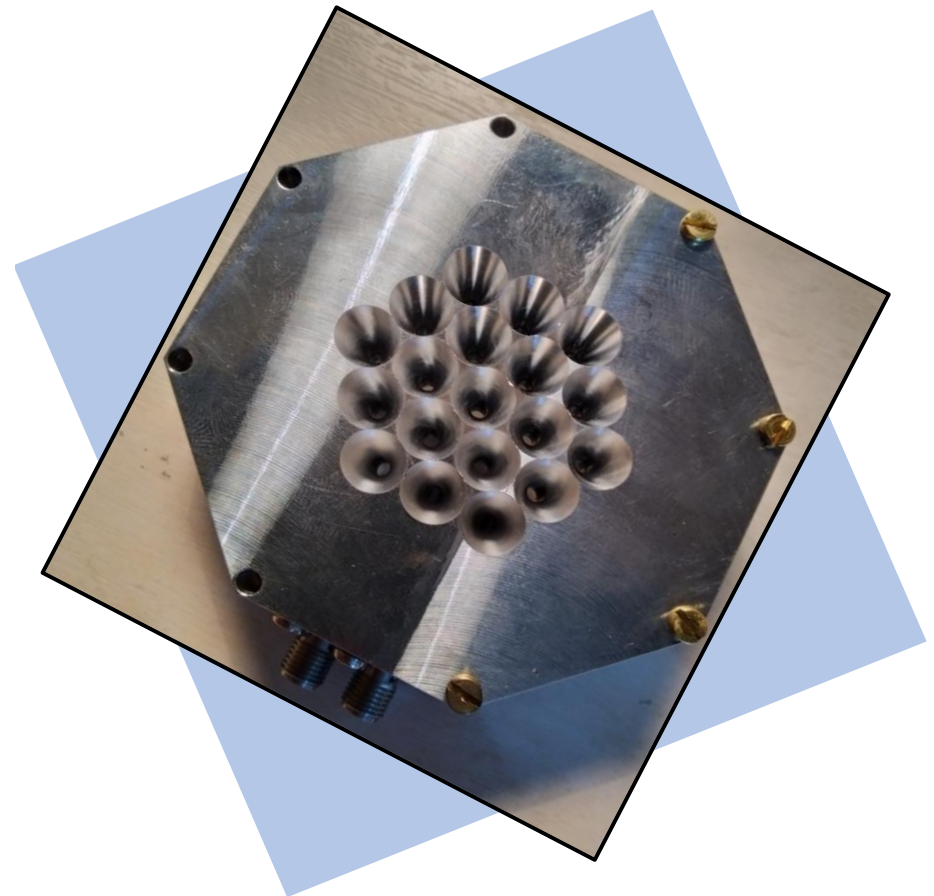


mm wave Source (75-110 GHz)

Relevant results: *HYPKID*



Array geometry with Sky simulator

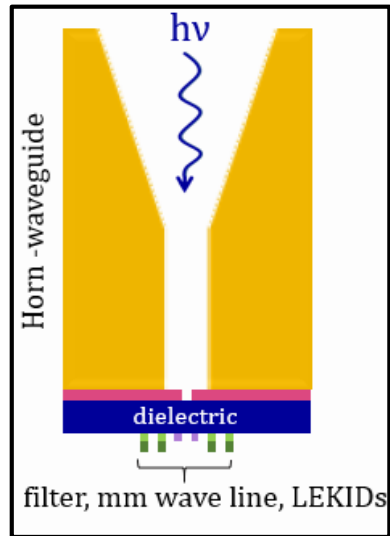


Position of the loaded *HYPKID*

Results

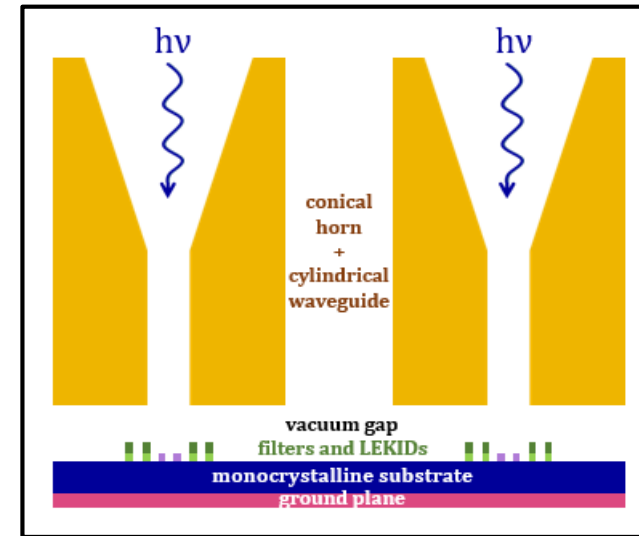
OMKID

- ✓ 16 spectral channels
- ✓ Thin Monocrystalline Dielectric, Sapphire
- ✓ Simple fabrication process
- ✓ NEP: Range of 10^{-16} W/ $\sqrt{\text{Hz}}$



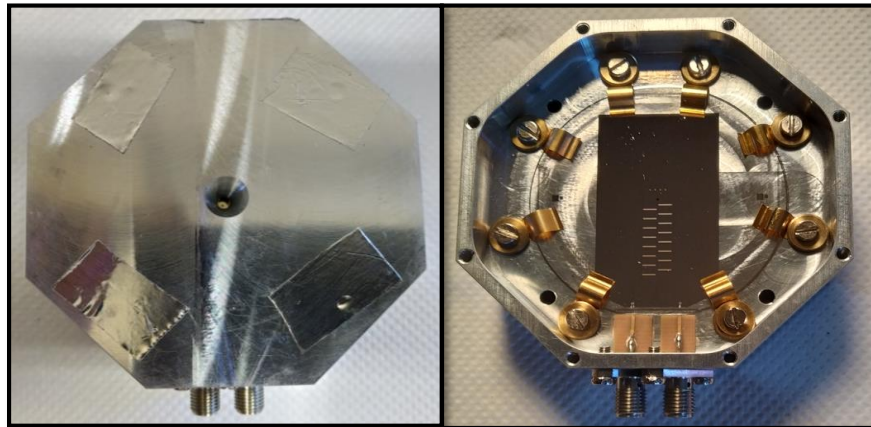
HYPKID

- ✓ 16 spectral channels
- ✓ Thin Monocrystalline Dielectric, sapphire and silicon
- ✓ Direct illumination, no microstrip loss
- ✓ NEP: 10^{-17} W/ $\sqrt{\text{Hz}}$; NET: ≈ 10 mK/ $\sqrt{\text{Hz}}$

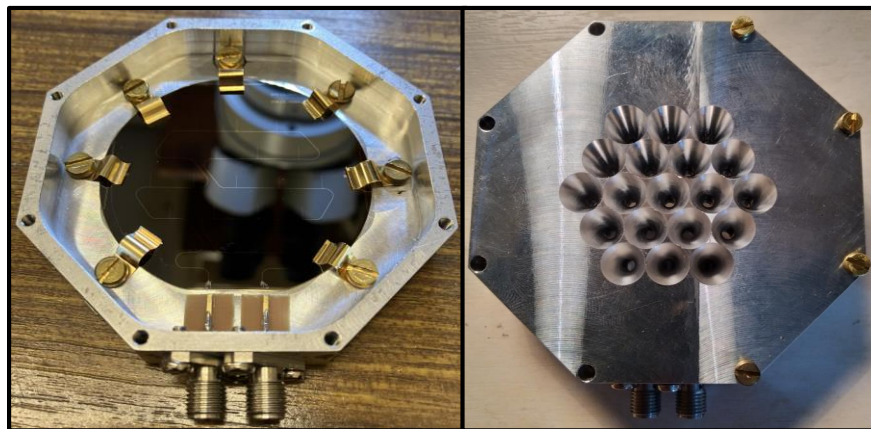


Future Perspectives

Prototypes for 3 mm

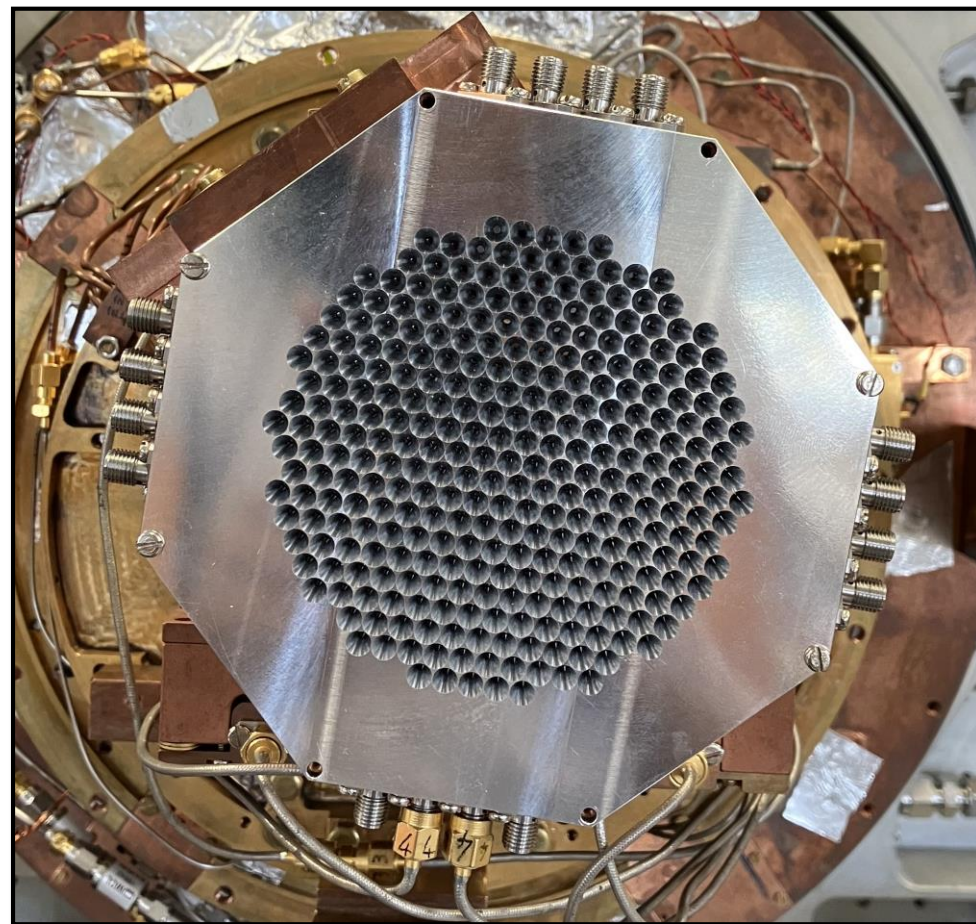


OMKID_v0

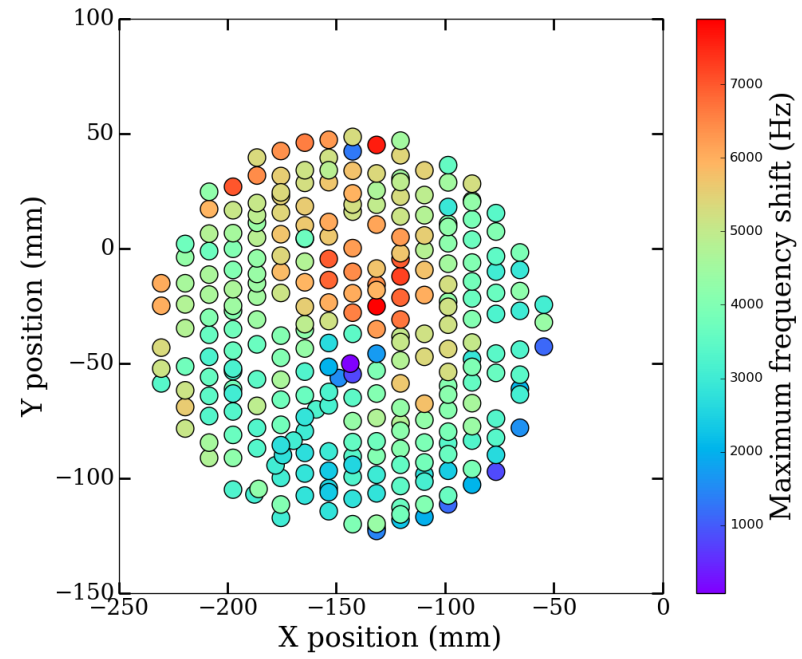


HYPKID_v0

UPCOMING prototypes for 2 mm and 1 mm



HYPKID_v1
300 spectral channels



Thank you for your attention!



Articles

OMKID

- ✓ 16 spectral channels
- ✓ Monocrystalline Dielectric, Sapphire
- ✓ Simple fabrication process
- ✓ NEP: Range of 10^{-16} W/ $\sqrt{\text{Hz}}$

HYPKID

- ✓ 16 spectral channels
- ✓ Monocrystalline Dielectric, sapphire and silicon
- ✓ Direct illumination, no microstrip loss
- ✓ NEP: 10^{-17} W/ $\sqrt{\text{Hz}}$; NET: ≈ 10 mK/ $\sqrt{\text{Hz}}$

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**Astronomy
&
Astrophysics**

A horn-coupled millimetre-wave on-chip spectrometer based on lumped-element kinetic inductance detectors

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A millimetre-wave superconducting hyper-spectral device

U. Chowdhury,^{1,2} M. Calvo,^{1,2} J. Goupy,^{1,2} F. Levy-Bertrand^{1,2} and A. Monfardini^{1,2}  ^{1,2}★

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