X-ray Imaging Micro-Calorimeter Spectrometer

Piet de Korte

On behalf of an emerging calorimeter collaboration

SRON
Netherlands Institute for Space Research

Netherlands Organisation for Scientific Research

Contributors

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Mirror Driven Specifications

- **Angular Resolution**

  5 arc sec resolution = 485 - 606 µm for 20 – 25 m focal length

  Proposed Pixel size between 250 – 300 µm

- **Field of View**

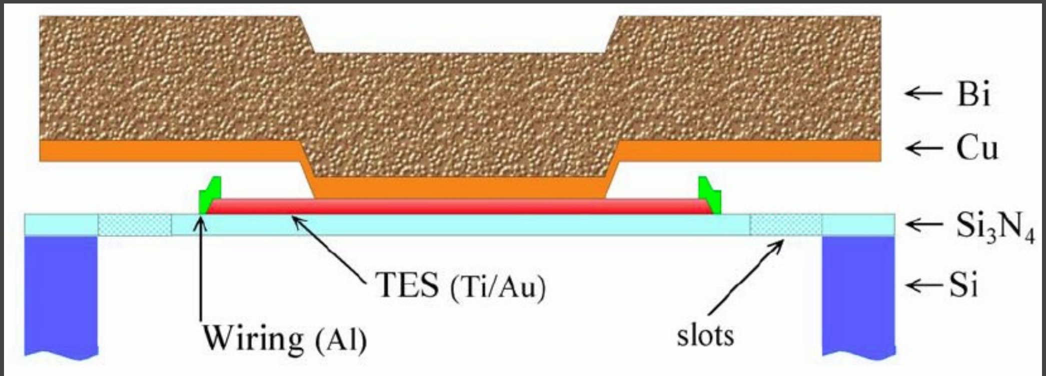
  7 arc min radius = 71 mm

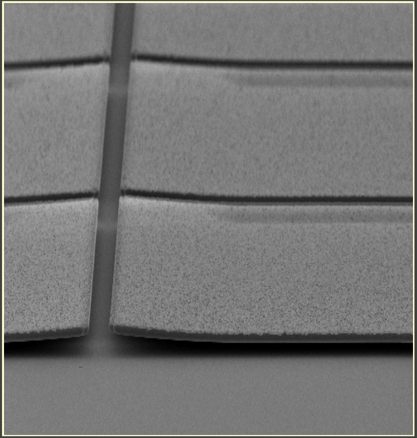
- **Countrate**

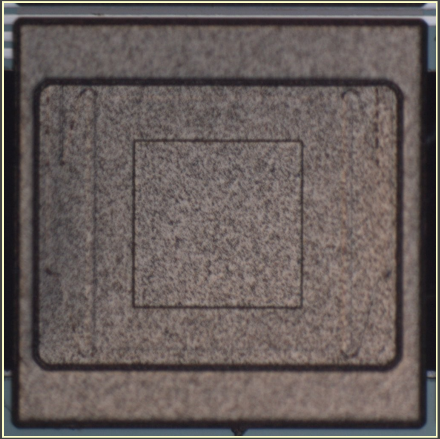
  1mCrab ~ 125 c/sec (May 2008, NASA IXO mirror concept with f = 20 m)

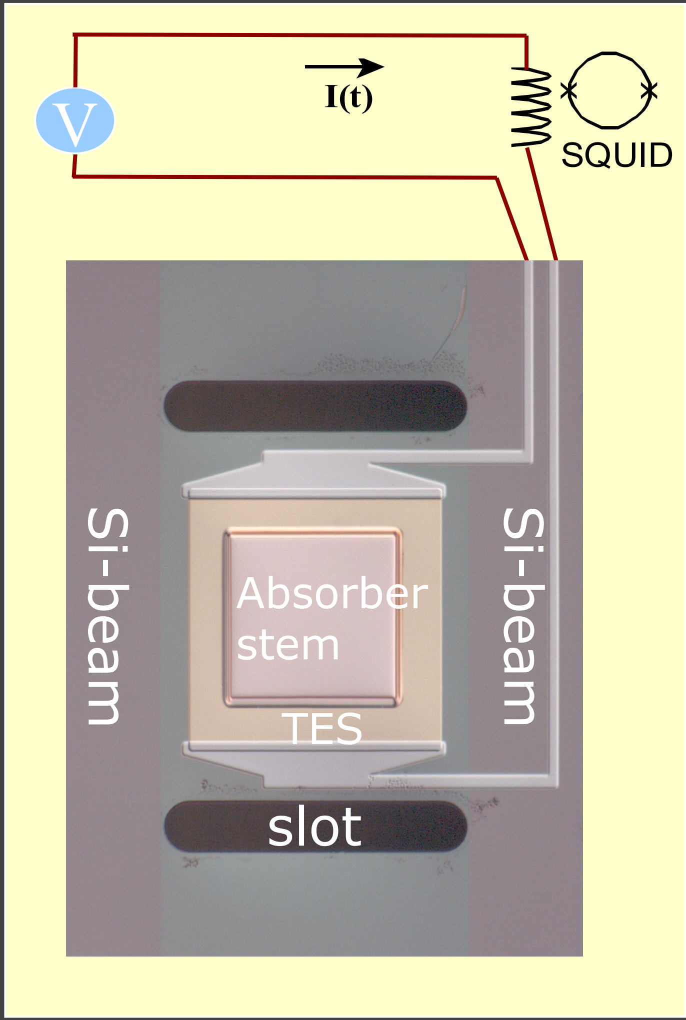
TES-based Micro-Calorimeter

SRON PIXEL DESIGN









Side view

Top view

part of 5 x 5 array

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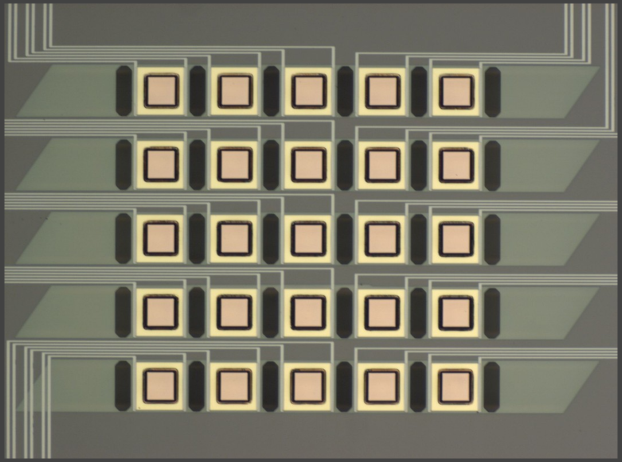
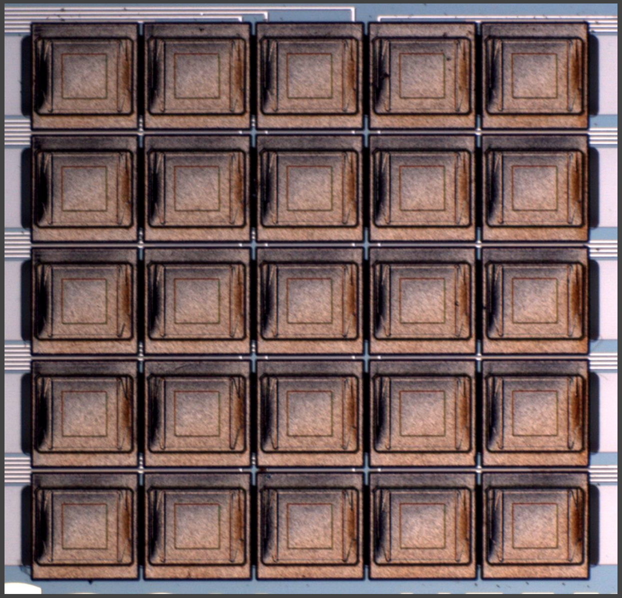
TES-based Micro-Calorimeter

SRON ARRAYS



5 x 5 array

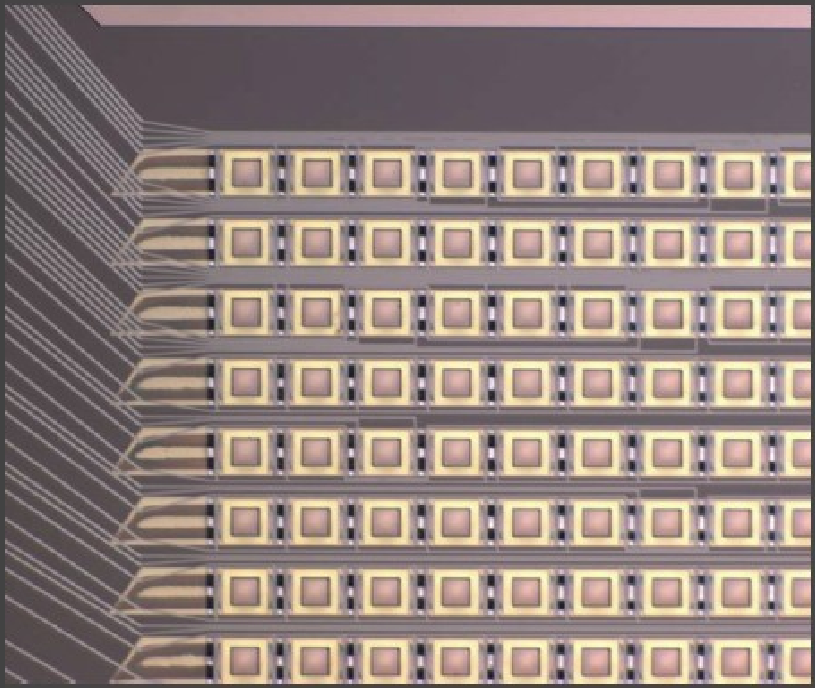
with Cu stems



5 x 5 array

with Cu/Bi

absorbers

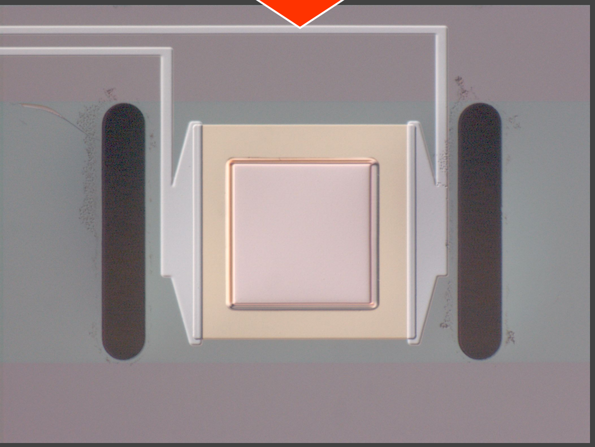


Close-up of 32 x 32 array

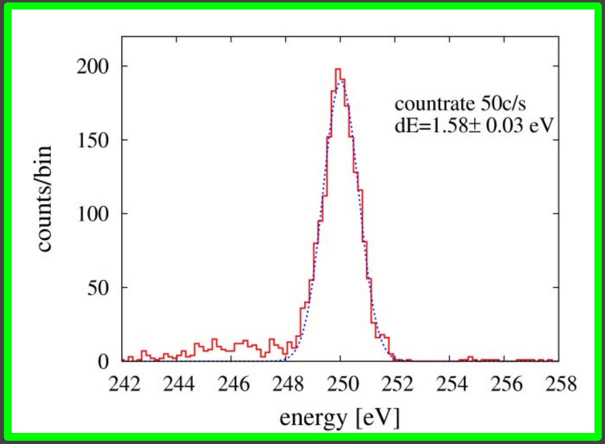
TES-based Micro-Calorimeter

PERFORMANCE for SRON PIXELS from 5 x 5 arrays

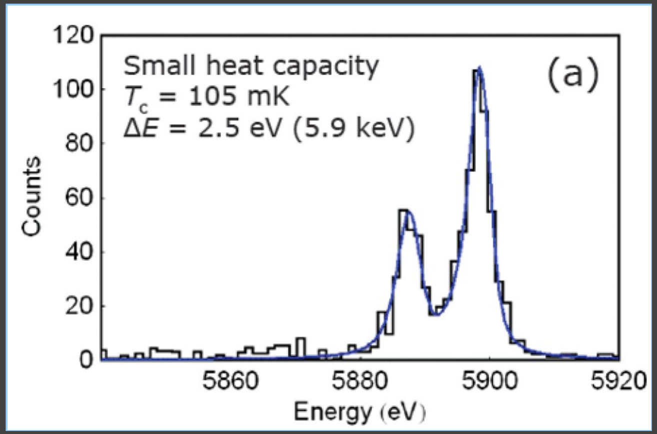
$\Delta E_{TDL} \approx 3.1$ eV $T_C = 105$ mK



Cu-absorber



$\Delta E = 1.6$ eV @ 250eV



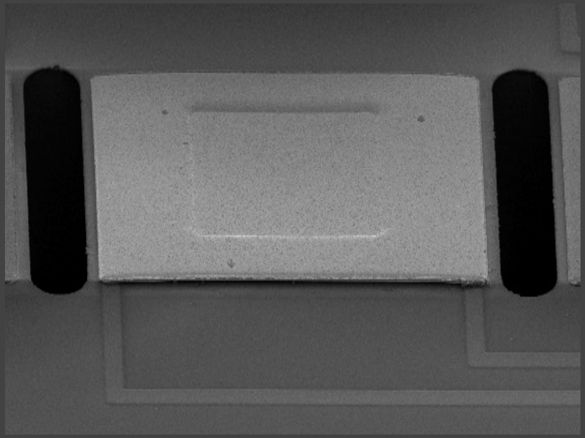
$\Delta E = 2.5$ eV at 5.9 keV

100 μs fall time

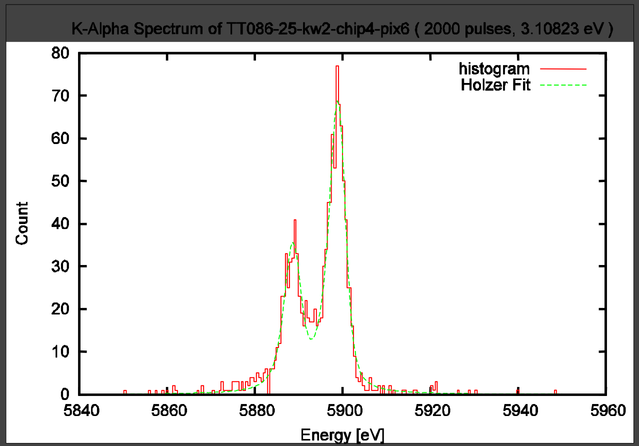
$\Delta E_{TDL} \approx 3.6$ eV

$T_C = 116$ mK

$$\Delta E_{TDL} = 2.35\sqrt{k_B T^2 C}$$



Cu/Bi-absorber 0.3/3 μm



$\Delta E = 3.1$ eV @ 5.9 keV

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GSFC TES approach

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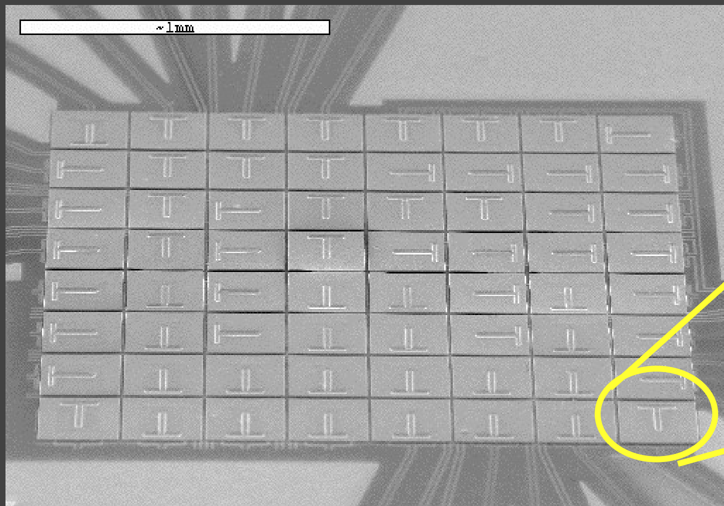
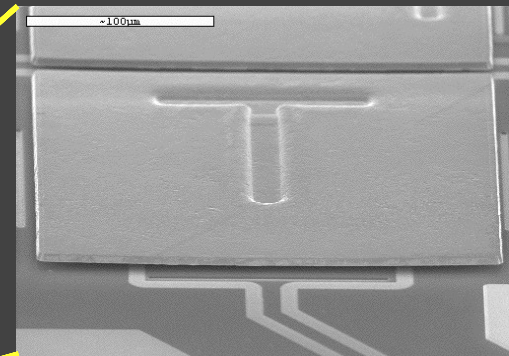
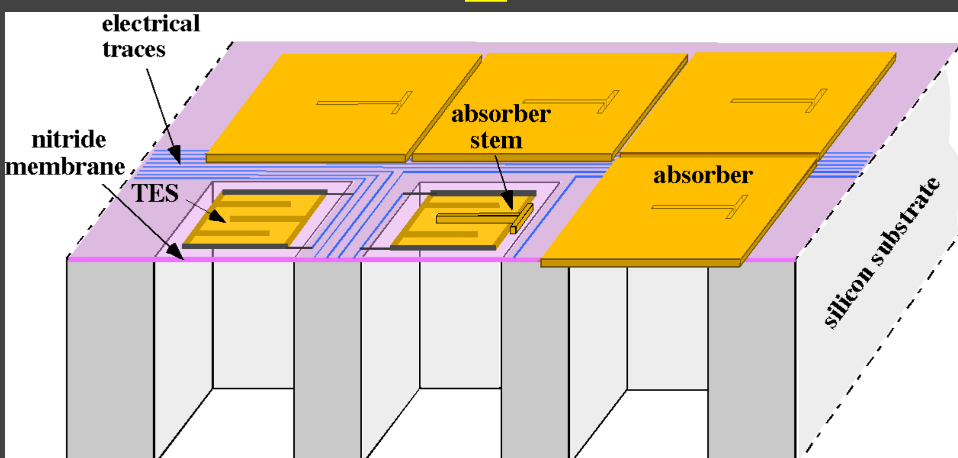
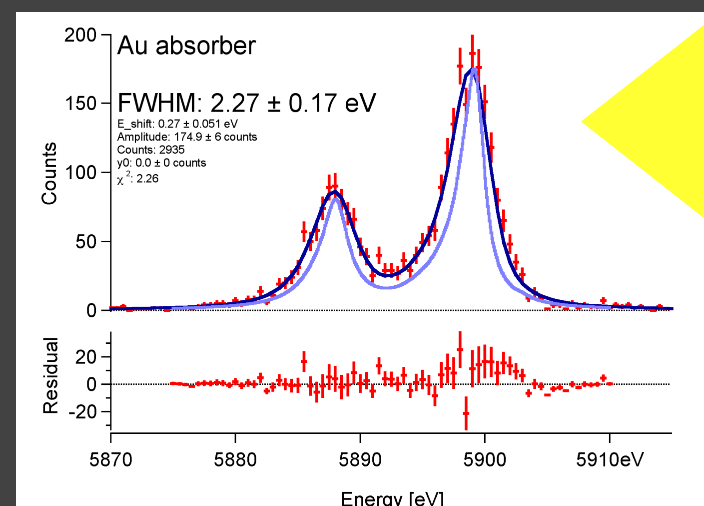




250 μ m





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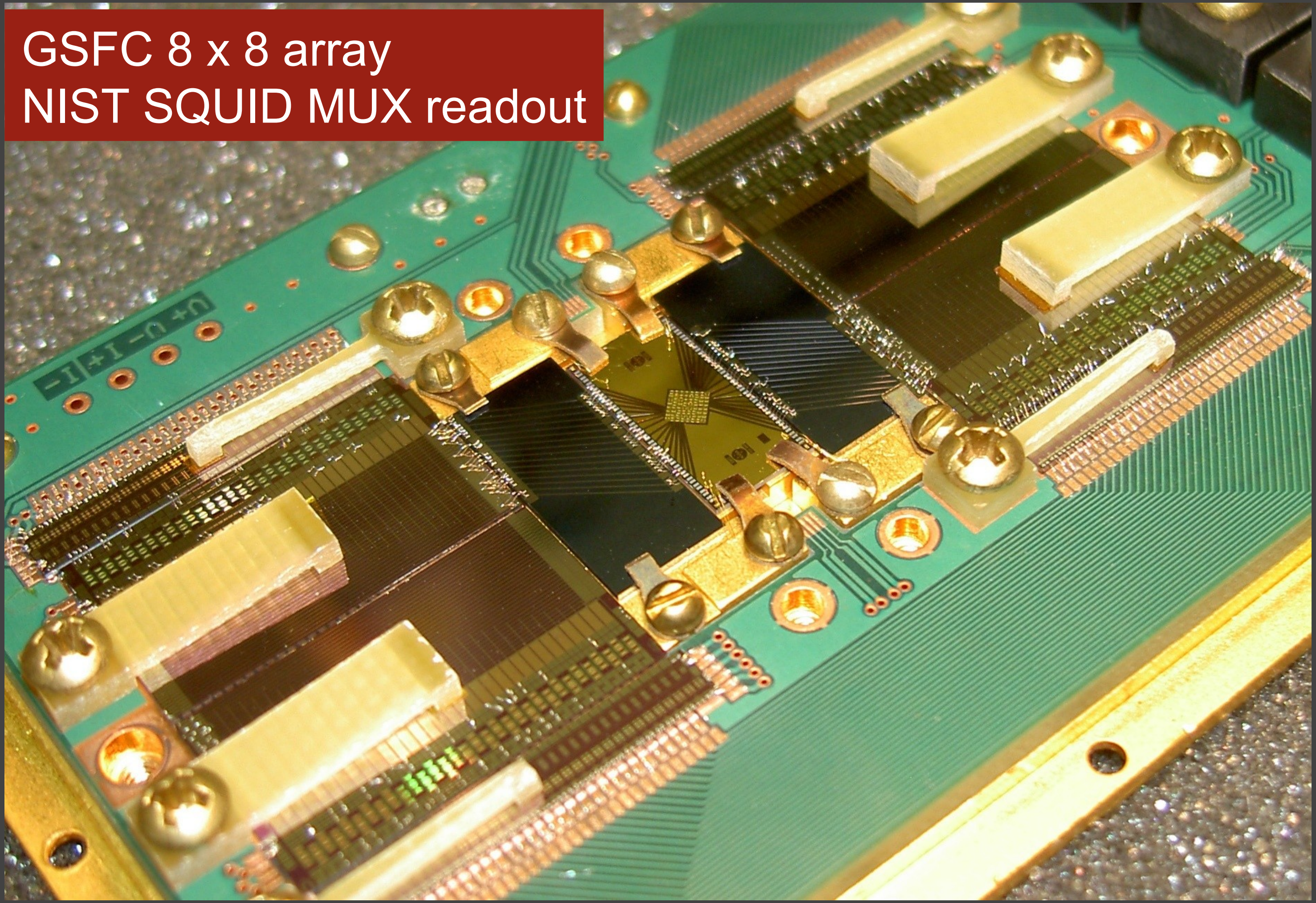
Facility Science Team - GSFC

Multiplexed TES calorimeter array



Also developed de-MUX software and we are now working on implementing real-time pulse height analysis

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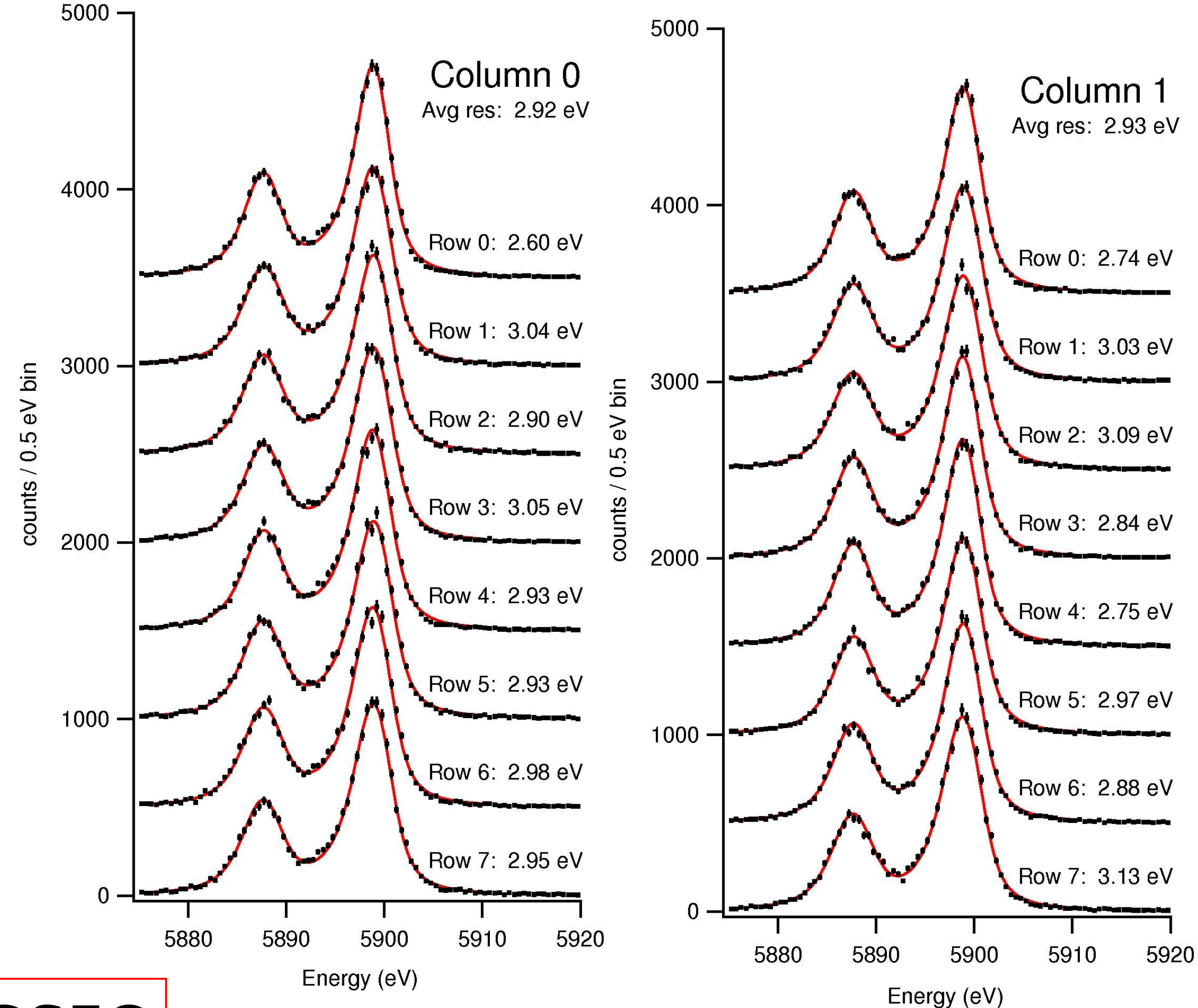
2 x 8 pixels read out with SQUID MUX



~30,000 counts per pixel from ^{55}Fe source

~500,000 total

$\tau_{\pm} = 280\ \mu s$ (critically damped)

2x8 MUX:
$\langle \Delta E_{FWHM} \rangle =$
2.93 ± 0.02 eV

GSFC

NIST National Institute of Standards and Technology

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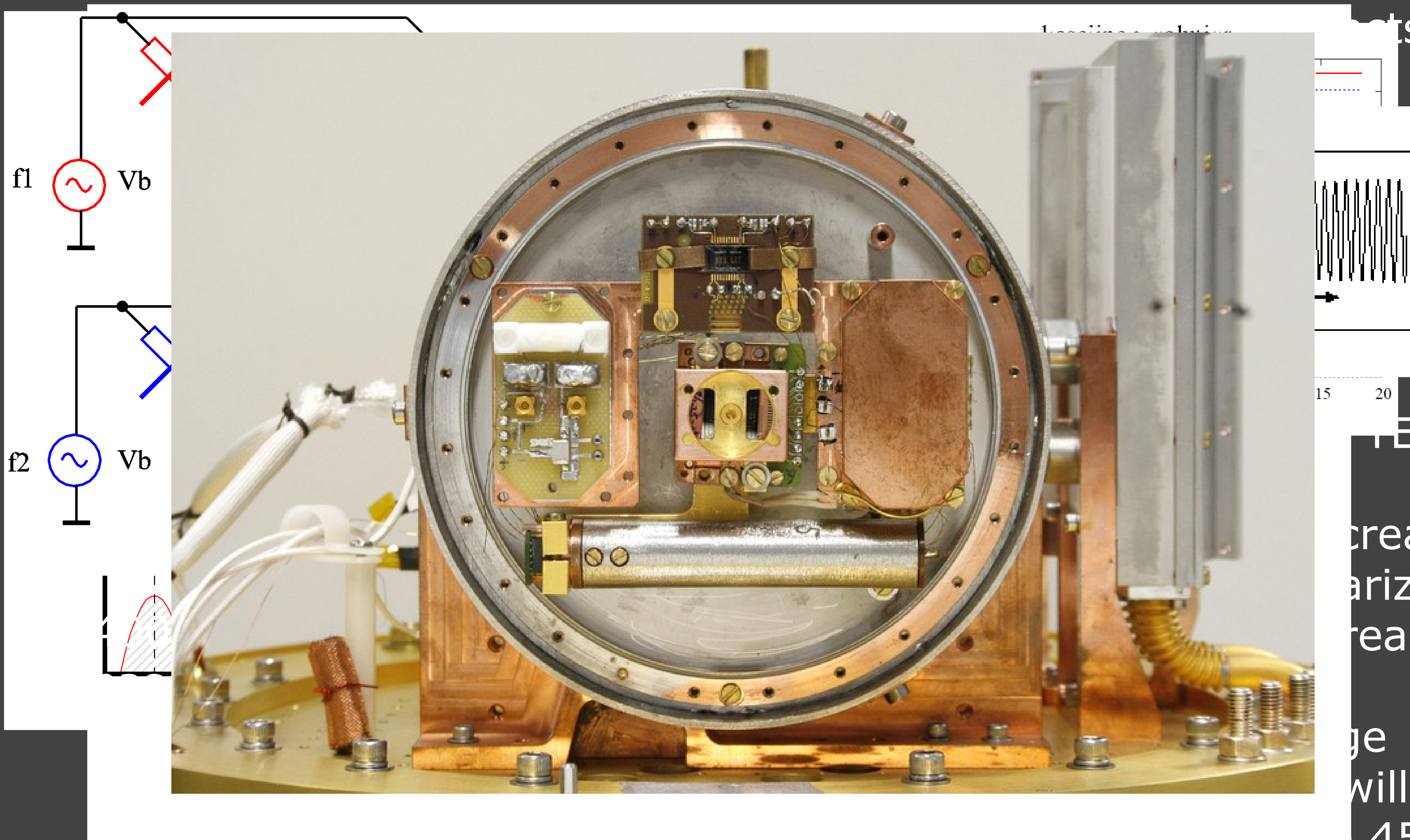
FREQUENCY DOMAIN MULTIPLEXING CURRENT SUMMING TOPOLOGY



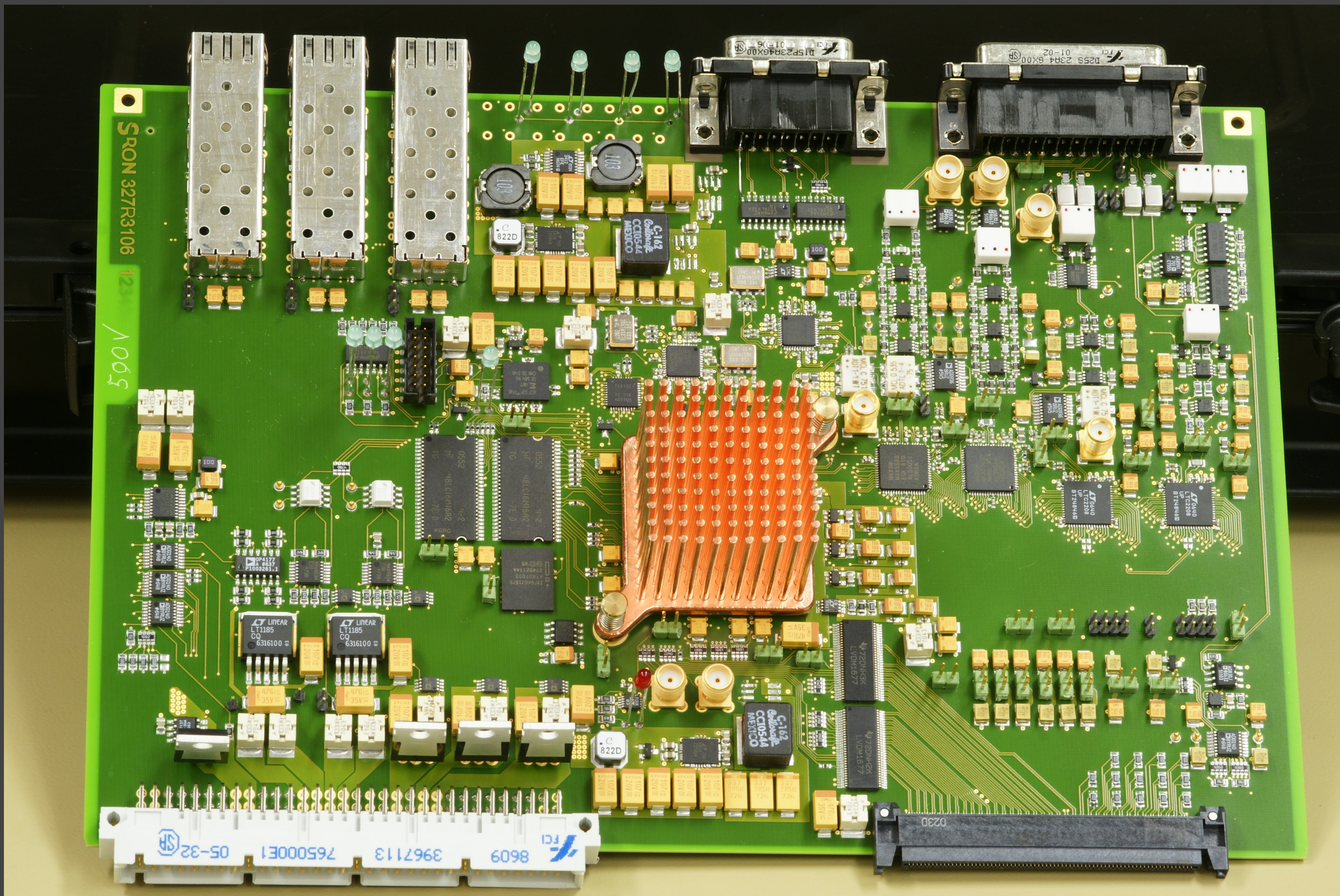
cts

TES

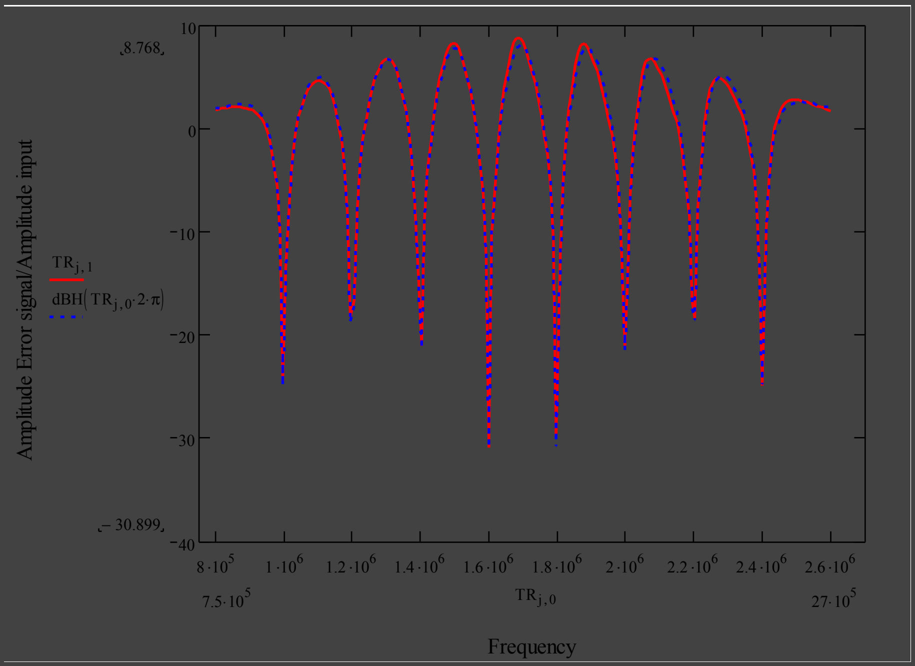
crease
arize
rease

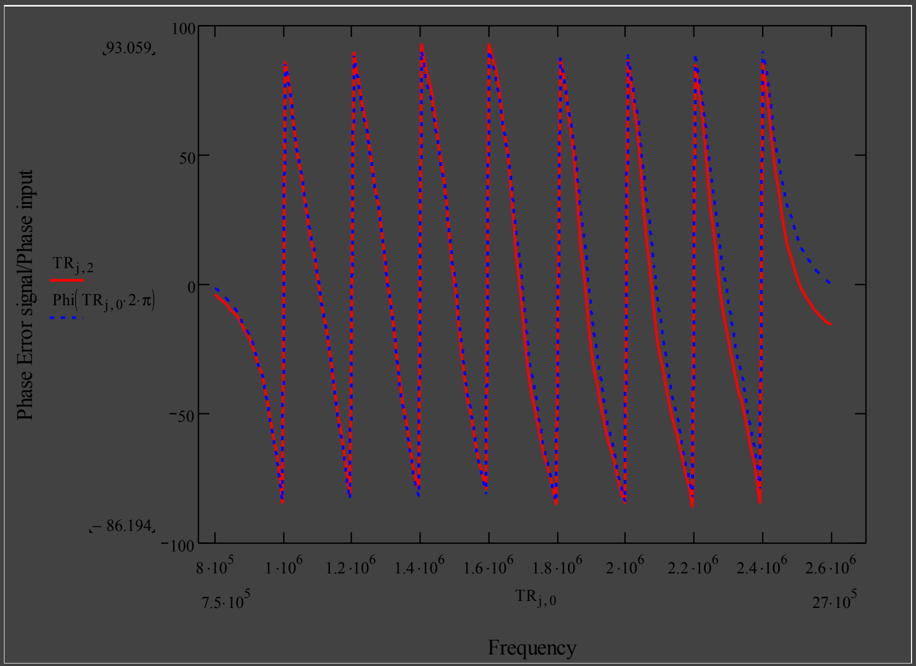
ge
will
45
pixels/channel

BBFB electronics board realization



Amplitude and Phase measurements/model of BBFB On a commercial Xilinx breadboard





Amplitude: red-data blue-model

Phase: red-data blue-model

Gain-bandwidth of 35 kHz for 200 kHz spacing and 830 ns delay

FLL-gain of 3.5x at highest signal frequency (10 kHz) and 22 x at 1.6 kHz (100 μs pulse decay time)

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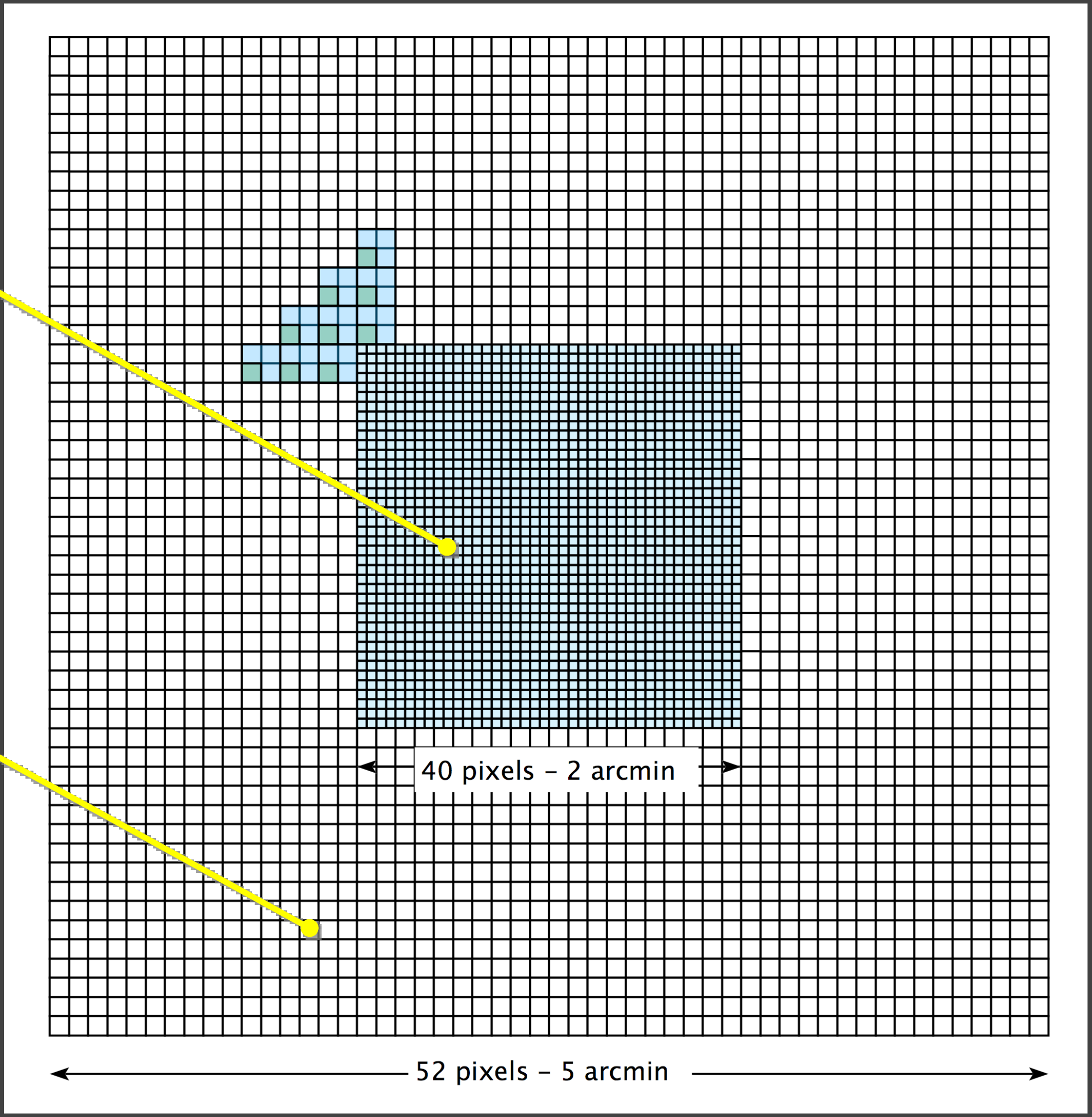
Focal Plane Array Layout (from Con-X→IXO)

Central, core array:

- Individual TES - one absorber/TES (40 x 40)
- 2 arcmin FOV
- 2.5 eV resolution (FWHM)
- Fast (< 300 μ sec time constant)

Outer, extended array

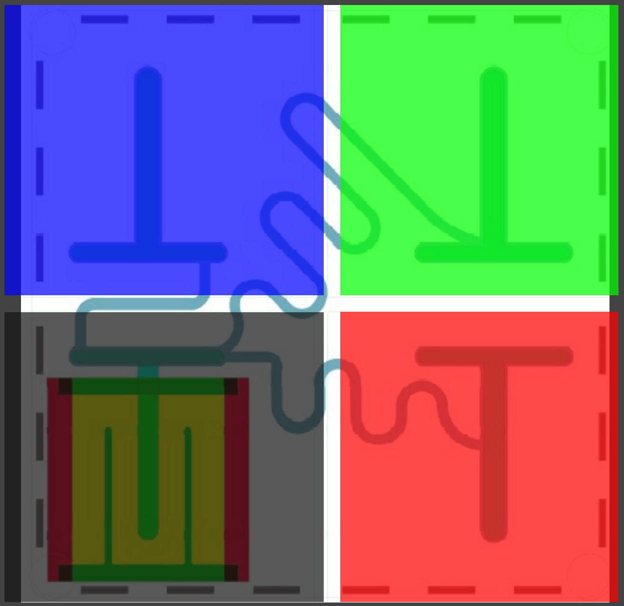
- 4 absorbers/TES
- Extends array to 52 x 52 pixels for a total of 2176 readout channels
- 5.0 arcmin FOV
- < 10 eV resolution
- ~ 2 msec time constant

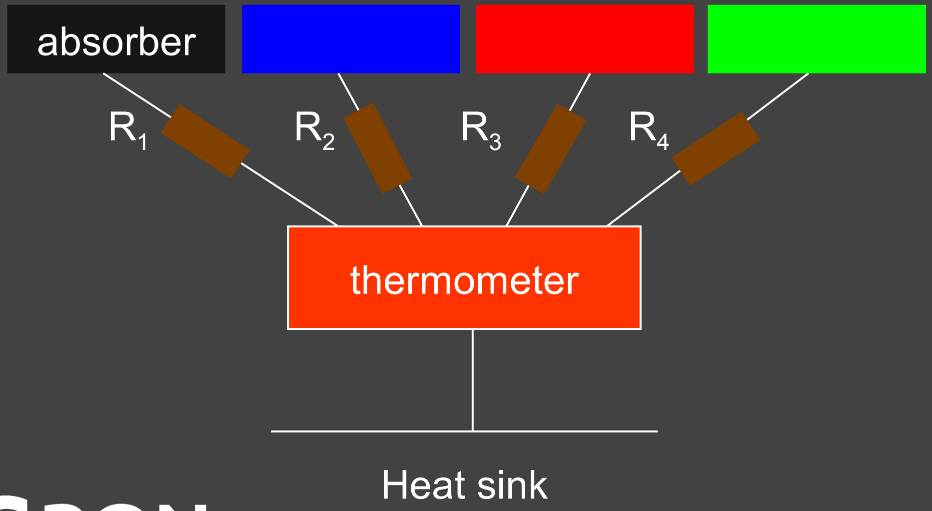


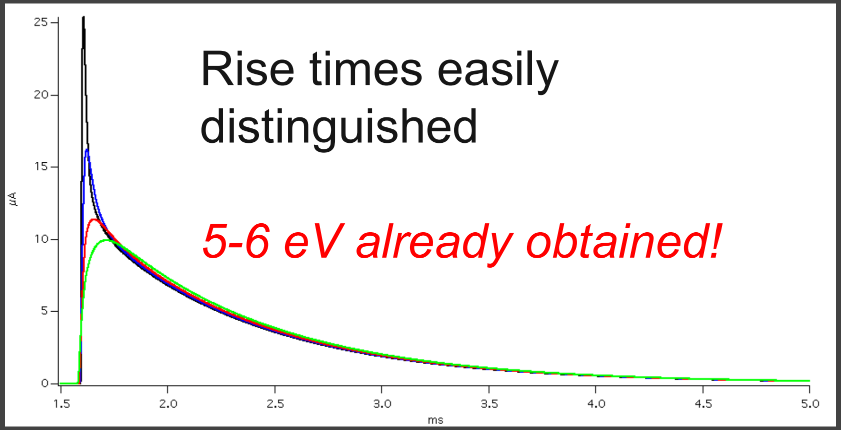
Multi Absorber TES - 1 TES, 4 absorbers

Simple approach:

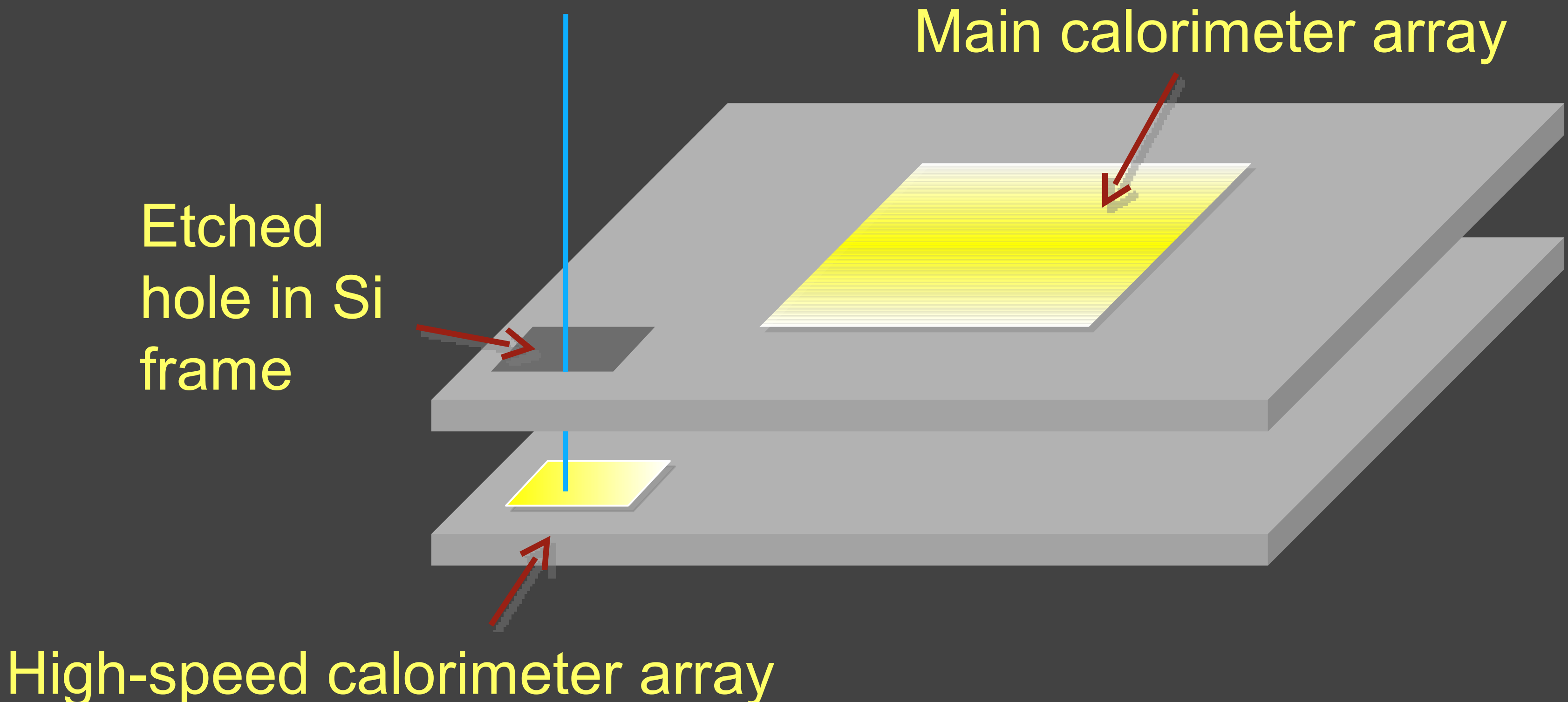
Separate absorbers (e.g., 4) connected to a single TES, each with a different thermal conductance.





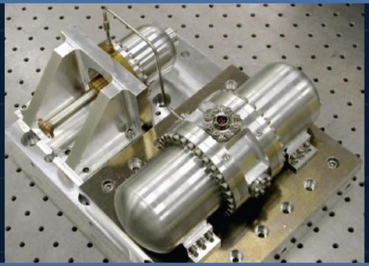
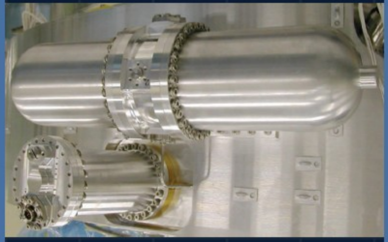
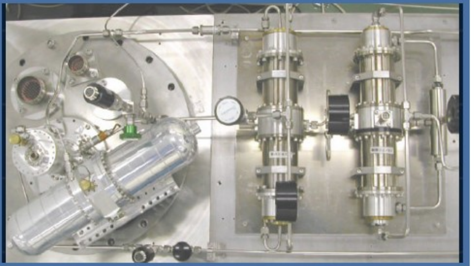


Optimized high-speed array (GSFC)



- 20 x 20 array of 1 arcsec pixels
- Distribute counts over ~ 10 times more pixels
- Use direct coupling to Si substrate for higher speed (~ 10's of micro-sec.)

ISAS/JAXA COOLING CHAIN

Cooler	1ST (100K)	2ST (20K)	2ST+^{4}He JT (4K)	2ST+^{3}He JT (2K)
				
Specification	2W@80K 50W, 4.2kg	325mW@20K 90W, 9.5kg	20mW @4.5K 120W, 23kg	16mW@1.7K 190W, 25kg
Ground test status	Life time test > 5 years (still running)	Life time test > 4 years (still running)	1 year test was done. A new lifetime test in preparation	Lifetime test in preparation
Mission status	Suzaku, in orbit 3.1 years	Akari, in orbit 2.5 years	FM for SMILES assembled	EM for SPICA & Astro-H(NeXT) assembled

Last stage cooler developments in Europe

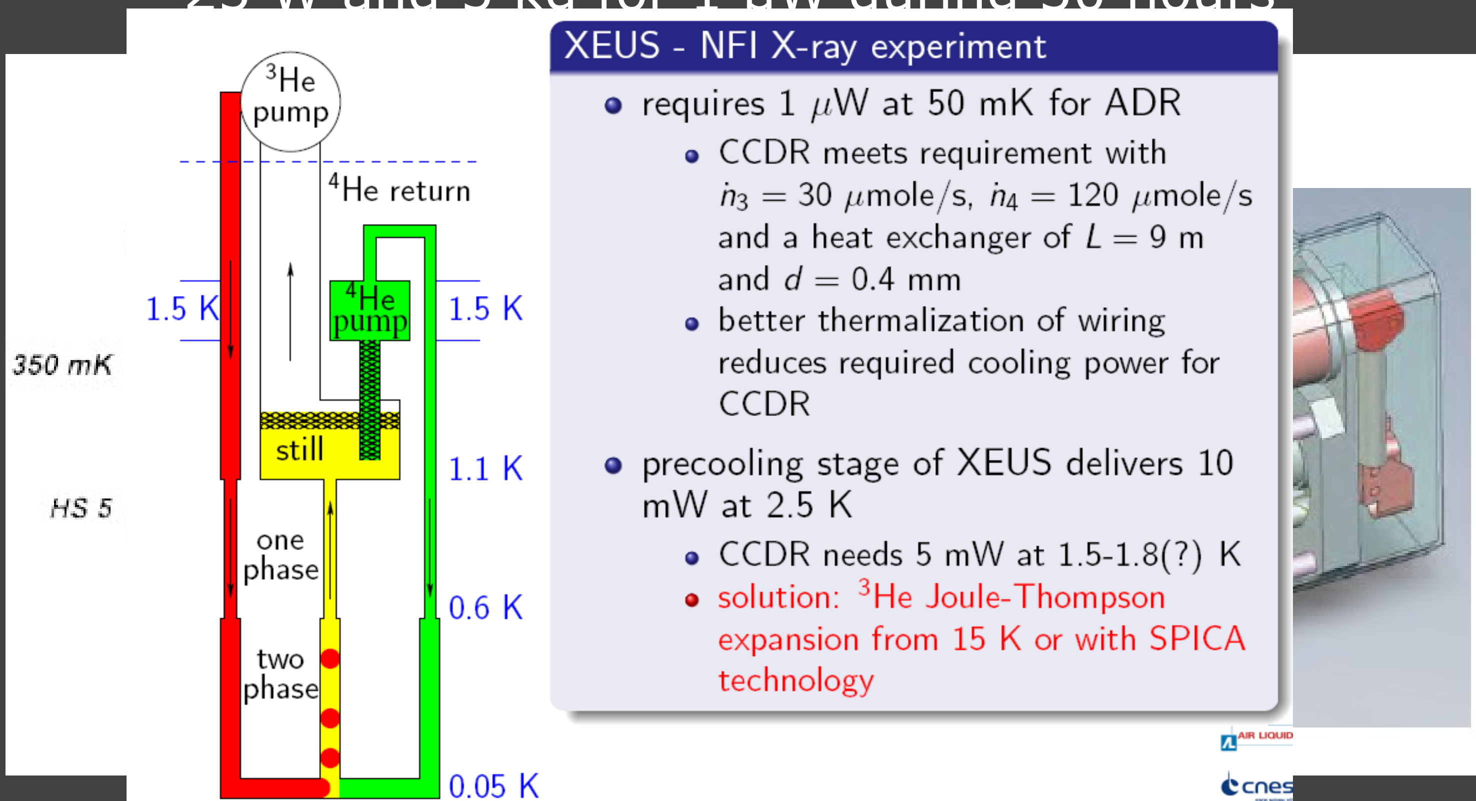
Interface with satellite cryostat at 2.5 K with 10 mW cooling power

Options under development:

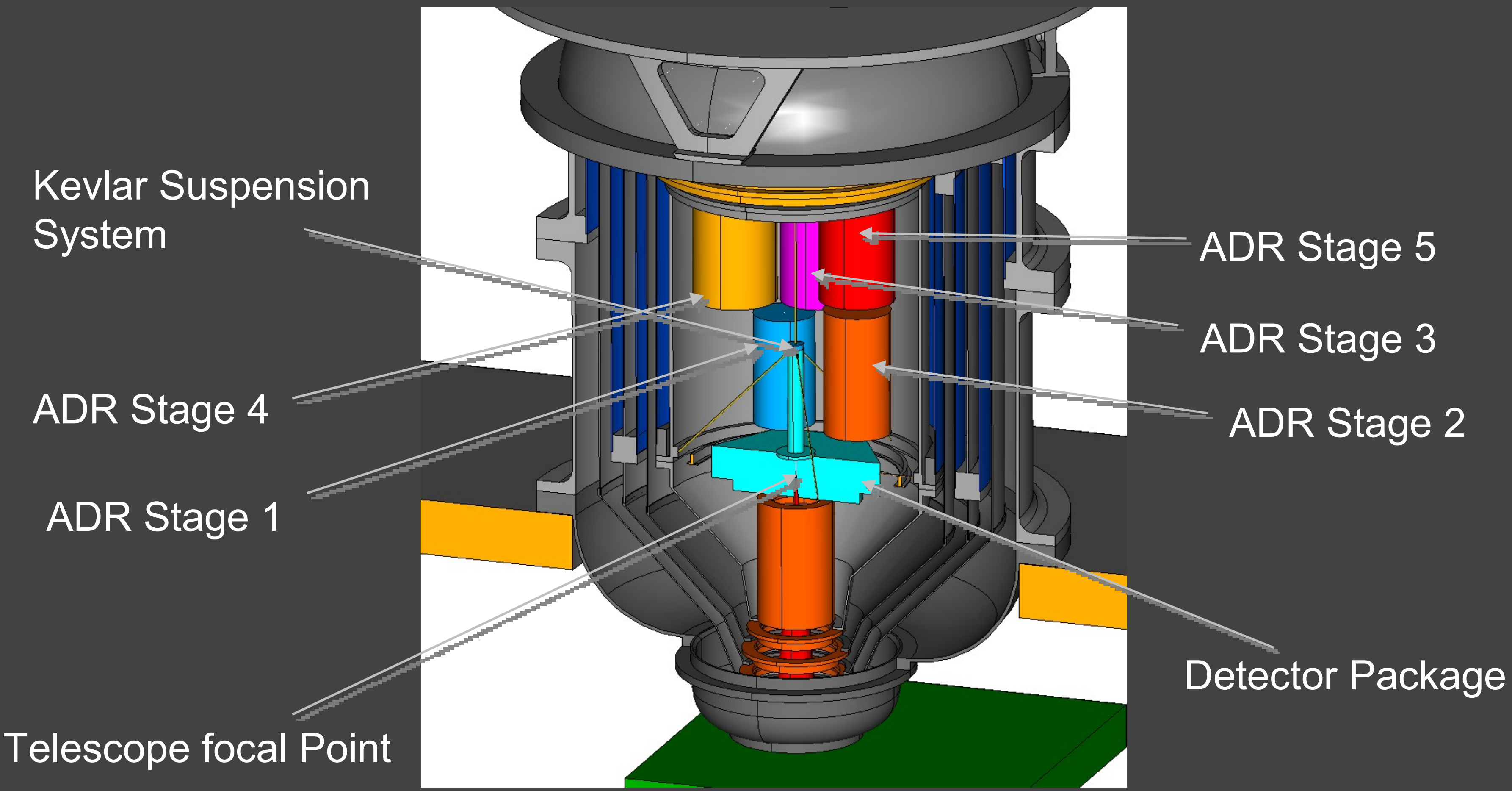
He3 sorption/1 stage ADR (CEA-Grenoble)

30 W and 31 kg for 1 µW during 30 hours

25 W and 5 kg for 1 µW during 30 hours



Cryostat design adopted for recent IDL study at GSFC



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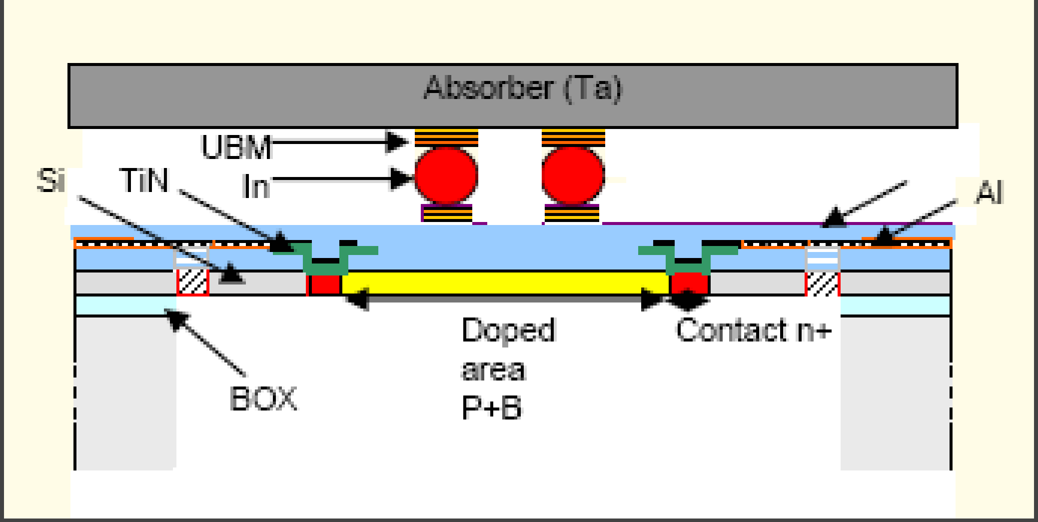
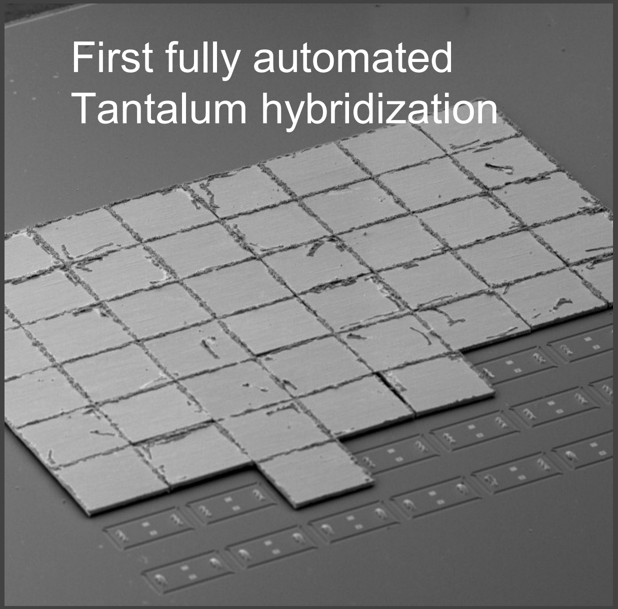
Si-doped X-ray Micro-calorimeter at CEA-Saclay

Herschel heritage: Developments by CEA-Saclay and LETI, Grenoble
Contributed paper by Claude Pigot
Fully integrated sensor with read-out multiplexer





Results: - Impedance of 8X8 sensor matrix in the right range with good sensitivity

- Integration of absorber matrix onto sensor matrix promising

Next steps: April 2008: First 8X8 array with freed Sensor & Absorber
End 2008: 1st Iteration Cold Electronics

Pro: Fully integrated system with multiplexed read-out
Con: Till now no X-ray performance data, use of Ta-absorbers by other teams failed, potentially slow response, developments late for XEUS.

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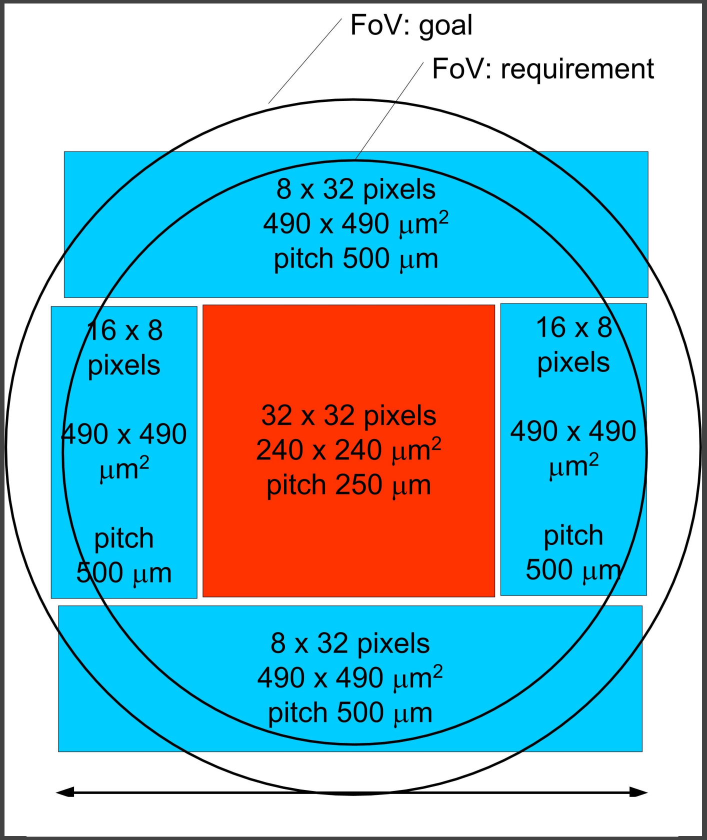
Focal Plane Array Layout for XEUS → IXO



Field of View: 2.75 x 2.75 arcmin

Central pixels: 1.37 x 1.37 arcmin

2.5 x 2.5 arcsec pixels

2 eV @ 2keV

100μs decay time

Surrounding pixels:

5 x 5 arcsec pixels

4 eV @ 2 keV

400μs decay time