



TES Microcalorimeter Development for Future Japanese X-ray Astronomy Missions

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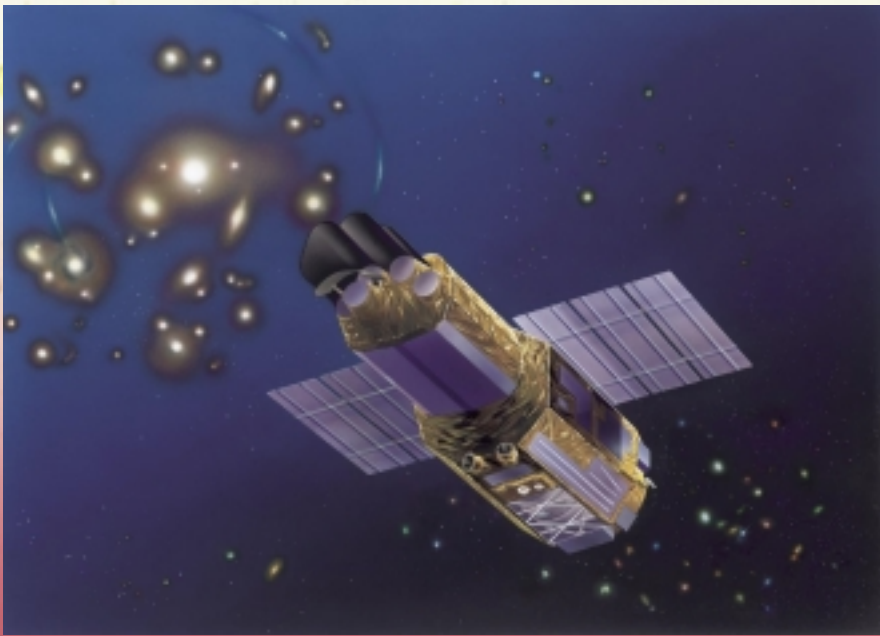
Institute of Space and Astronautical Science (ISAS)

Astro-E2 satellite

Japanese 5th X-ray astronomy satellite, Japan-US international collaboration

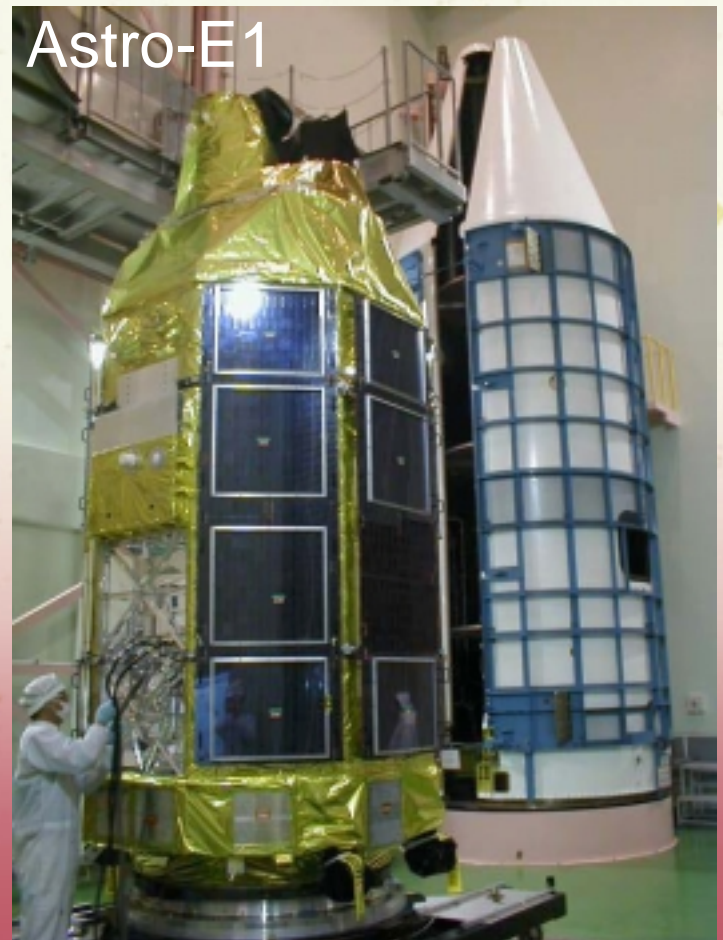
Recovery mission of Astro-E1

Will be launched in early 2005



July 7-11, 2003

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XRS onboard Astro-E2

First microcalorimeter array in orbit

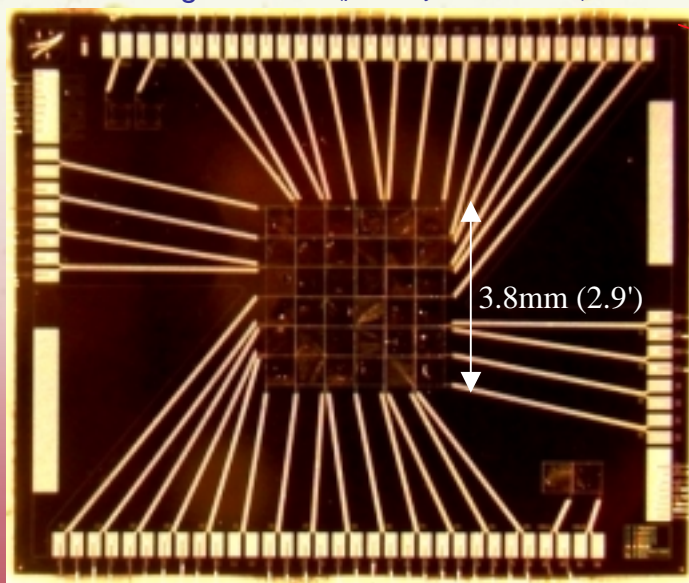
$\Delta E = 6$ eV at 6 keV, 6x6 format

cryogen (SNe/LHe) lifetime: 2.5-3.5 years

sensor, ADR, He tank, signal processor developed by NASA/GSFC

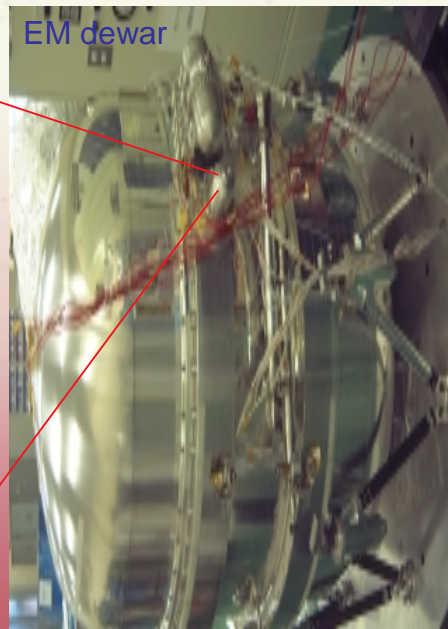
Ne dewar and mechanical cooler developed by ISAS

Astro-E2 flight sensor (photo by NASA/GSFC)



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EM dewar



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Astro-E1

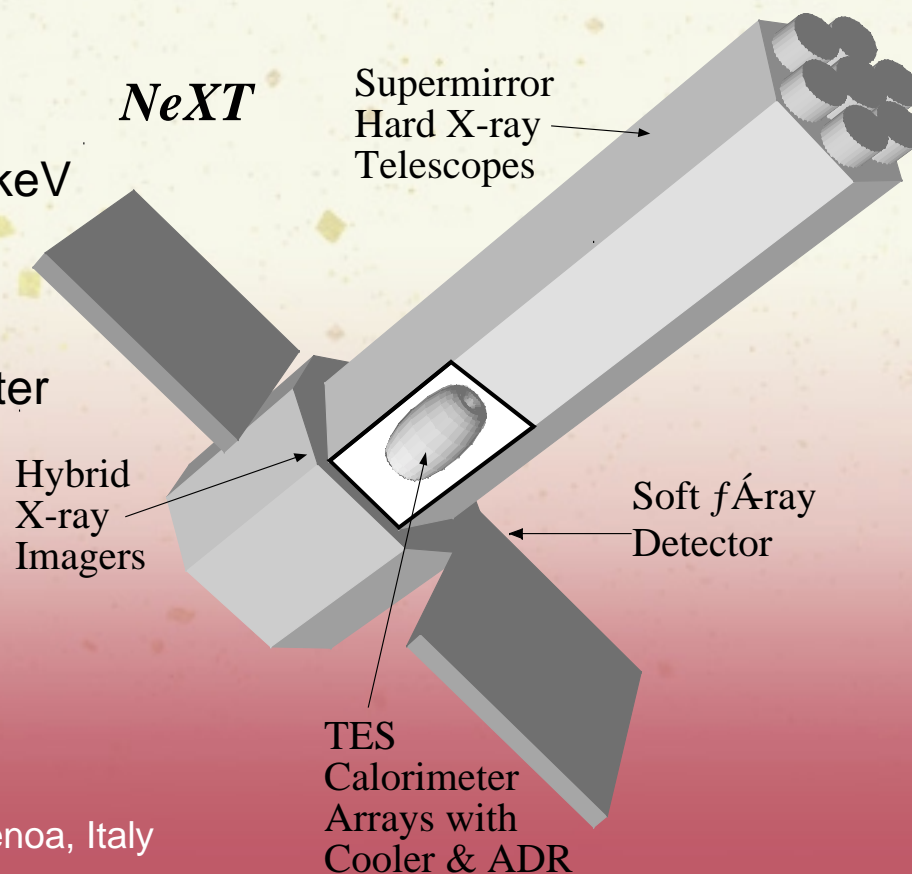


NeXT (New X-ray Telescope Mission)

Next X-ray astronomy project in Japan
launch target: ~2010

Concept

- ❖ super-mirror sensitive up to 80keV
+ hard X-ray imager
-> CCD+CdTe?
- ❖ soft X-ray (<10keV) spectrometer
with imaging capability
-> TES array?



NeXT SXS (Soft X-ray Spectrometer)



Requirement & Goal

- ❖ $\Delta E = 2\text{--}5\text{ eV}$
- ❖ format: 12×12 -- 32×32
- ❖ array size: $12 \times 12\text{ mm}^2$ -- $16 \times 16\text{ mm}^2$
pixel size: $0.5 \times 0.5\text{ mm}^2$ -- $1.0 \times 1.0\text{ mm}^2$
- ❖ focal length $\sim 7\text{ m}$ (FOV $> 6' \times 6'$)

large geometrical area, moderate spatial resolution

large $S\Omega$, sensitive to extended emission



Collaborators

ISAS

Tokyo Metropolitan University

Waseda University

Mitsubishi Heavy Industries, LTD.

+ Panasonic Communications Co., LTD.

Seiko Instruments Inc.

Ti/Au TES Calorimeter

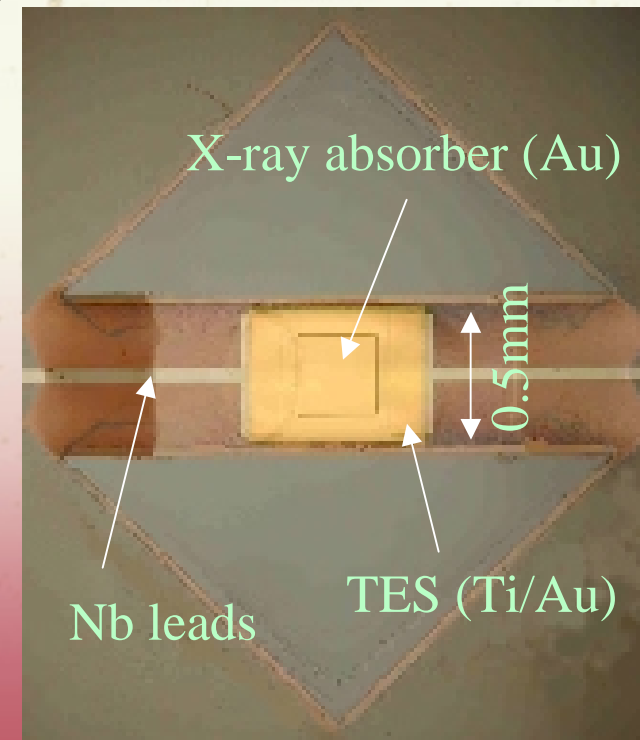
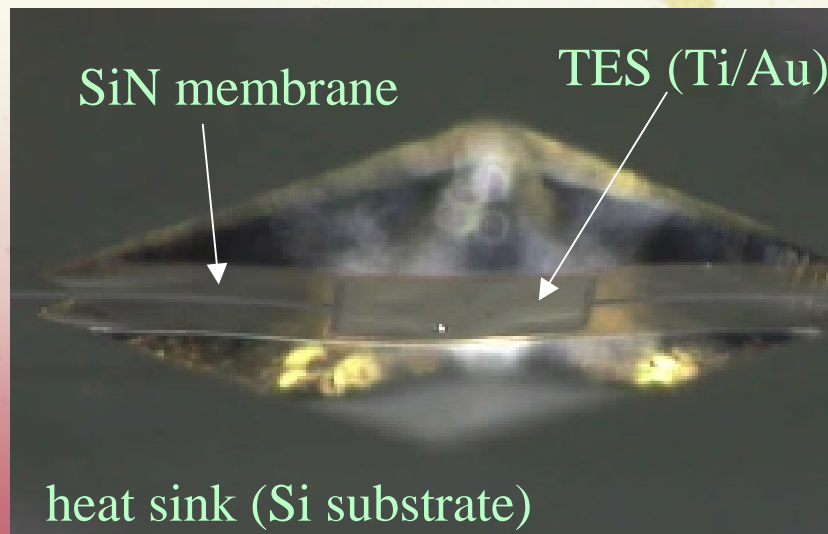
✉ T04 Morita, R07 Takei

Bridge type (Tanaka et al. 2000)

❖ All processes are performed from front side,
compatible with SOI wafer. (Developed at Seiko Instruments.)

$T_c = 151 \text{ mK}$, $C \sim 1.7 \text{ pJ/K}$, $G \sim 1 \text{ nW/K}$

$\tau = 74 \mu\text{s}$, $\Delta E = 6.6 \text{ eV @ } 6 \text{ keV}$
(Ishisaki et al. 2003)



Ti/Au TES Calorimeter

✉ Y16 Ishisaki, Y17 Arakawa

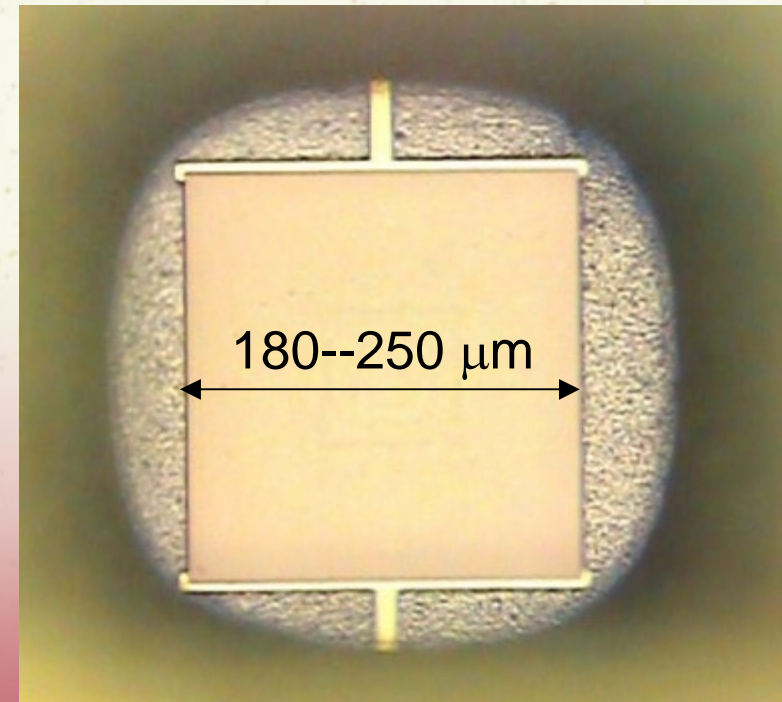
Conventional type

❖ etching (DRIE) from backside

$C=2-3\text{pJ/K}$

$\tau\sim 50\mu\text{s}$, saturated

$\Delta E=6.3\text{eV @ } 6\text{keV}$



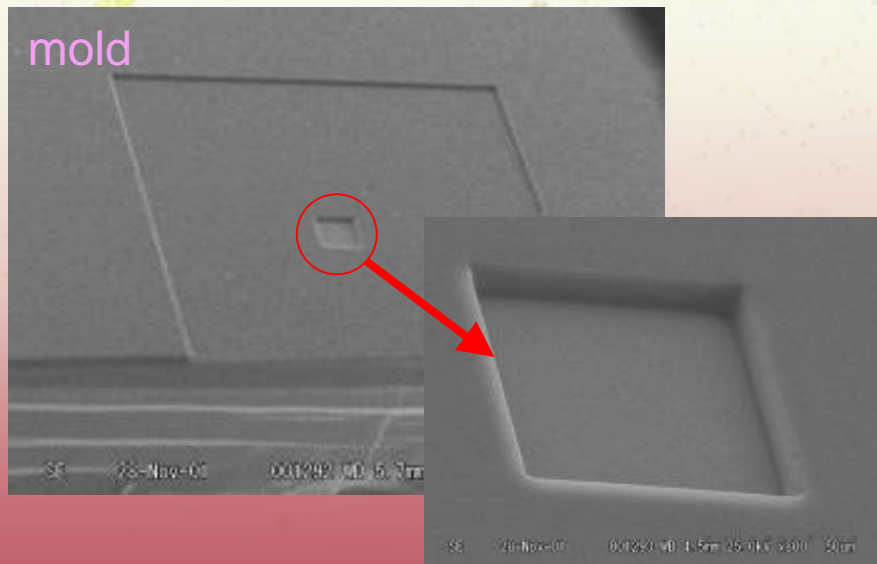
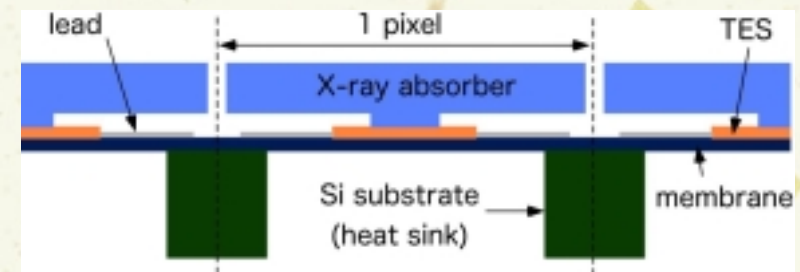
Mushroom-shaped X-ray absorber

✉ Y16 Ishisaki, Y17 Arakawa

To achieve large filling factor and uniform response, fabrication of mushroom-shaped X-ray absorber is essential.

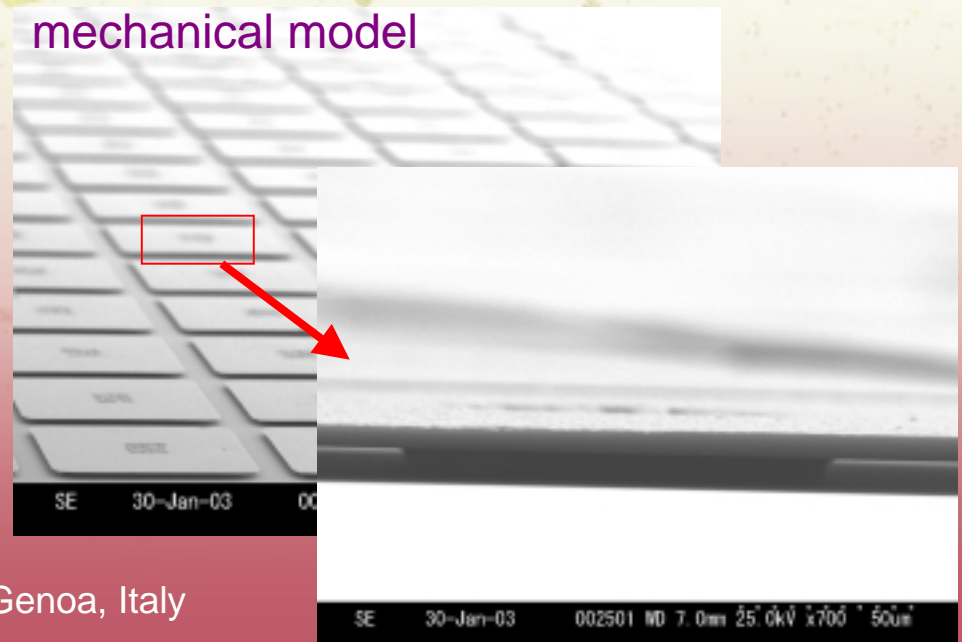
We are developing electrodeposition technique.

- ❖ kept $<130^{\circ}\text{C}$ through the process
 - ♦ prevent Ti from alloying/migration
- ❖ two-layer photoresist as a mold
- ❖ Sn and Bi as absorber material



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Sn Absorber

Fabrication of Sn absorber with electrodeposition was established.

However, decay time of X-ray pulse was very long (\sim ms), compared with effective time const (\sim 50 μ s).

- ❖ Due to long quasiparticle lifetime? (e.g., Stahle et al. 1993)
- ❖ Relation with grain size?



Bi Absorber

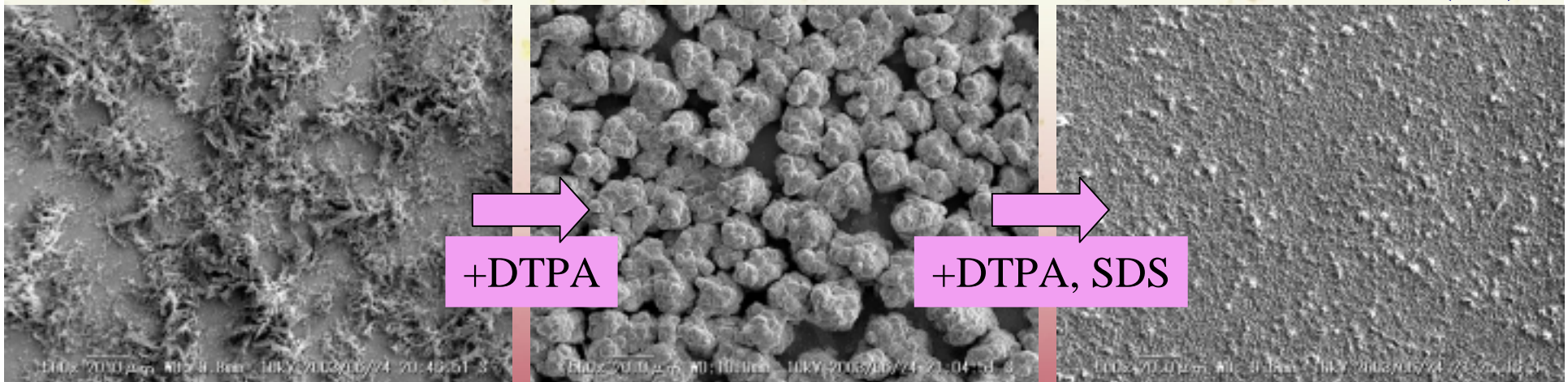
Electrolyte was optimized to produce uniform and homogeneous deposition.

Mechanical model was OK. (on Si substrate)

Contact of Bi/Au with TES and/or resist during the process is not good yet. Further optimization is required.



100nm
↔

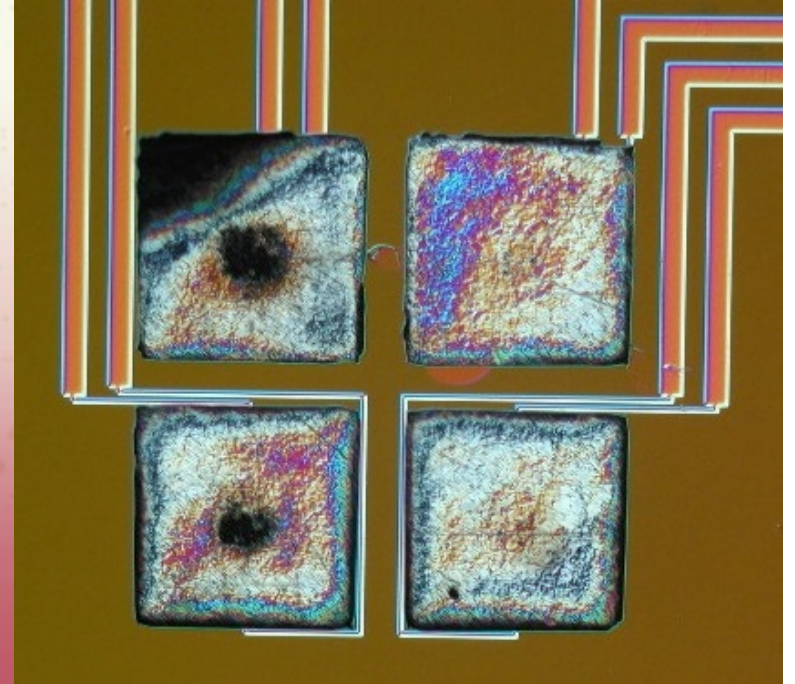
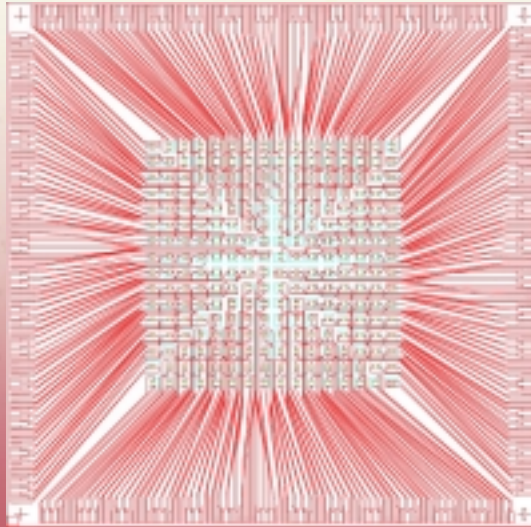


Calorimeter Array

Fabricated 2x2 calorimeter arrays.

- ❖ Sn: mechanically OK, but performance was not good due to long lifetime of QPs.
- ❖ Bi: optimization is underway.

Planning 16x16 array.



Multiplex Readout

✉ E07 Iyomoto

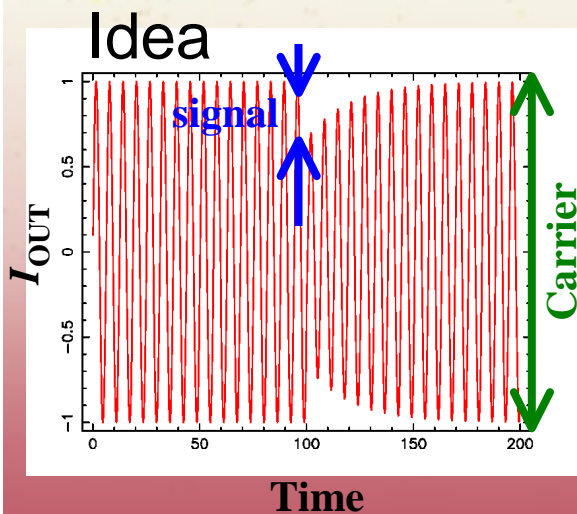
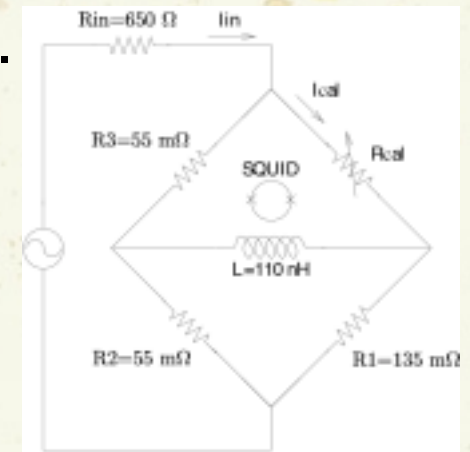


Working on frequency-domain multiplexing.

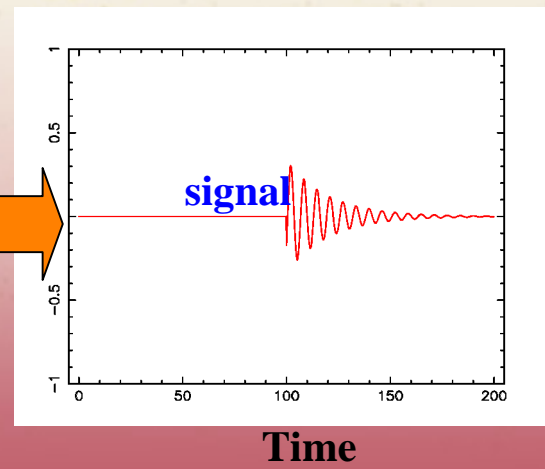
❖ CABBAGE: TES is put in a bridge circuit, to null carriers.

Succeeded in reading two calorimeters simultaneously.

Learned AC characteristics of TES.

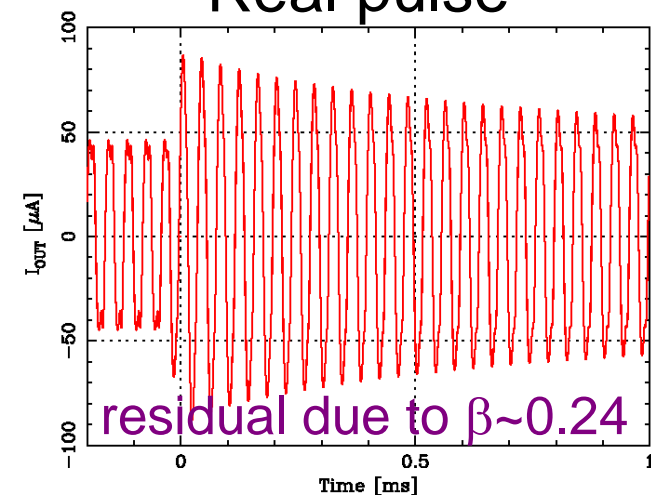


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Real pulse



Summary

We are developing a TES microcalorimeter array for future Japanese X-ray astronomy missions (NeXT).

- ❖ Goal: $\Delta E = 2\text{--}5\text{eV}$, 100-1000 pixels

Single pixel Ti/Au TES calorimeter achieved $\Delta E \sim 6\text{eV}$.

Electrodeposition of mushroom-shaped absorber.

- ❖ Sn: mechanically OK, performance not good due to QPs.
- ❖ Bi: contact during the process is not good yet. Further optimization is required.

Fabricated 2x2 arrays. Planning 16x16 array.

Working on frequency-domain multiplexing.

- ❖ Read two pixels simultaneously.
- ❖ Learned AC characteristics of TES.