

Development of a pixellated Ir-TES for a large format TES array



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Introduction

Applications

X-ray astronomy, Dark matter search
X-ray fluorescence analysis



Imaging spectroscopy with high energy resolution

High energy resolution ~eV
Position sensitivity ~1000pixels

(For astrophysical X-ray spectroscopy mission)

We are developing an **Iridium transition edge sensor (Ir-TES)**.

Good properties of Iridium

- Single element super conductor $T_c = 112\text{mK}$ (bulk)
- Chemical stability
- High Z

New Pixel-imaging TES array

■ SQUID multiplexing

Time domain

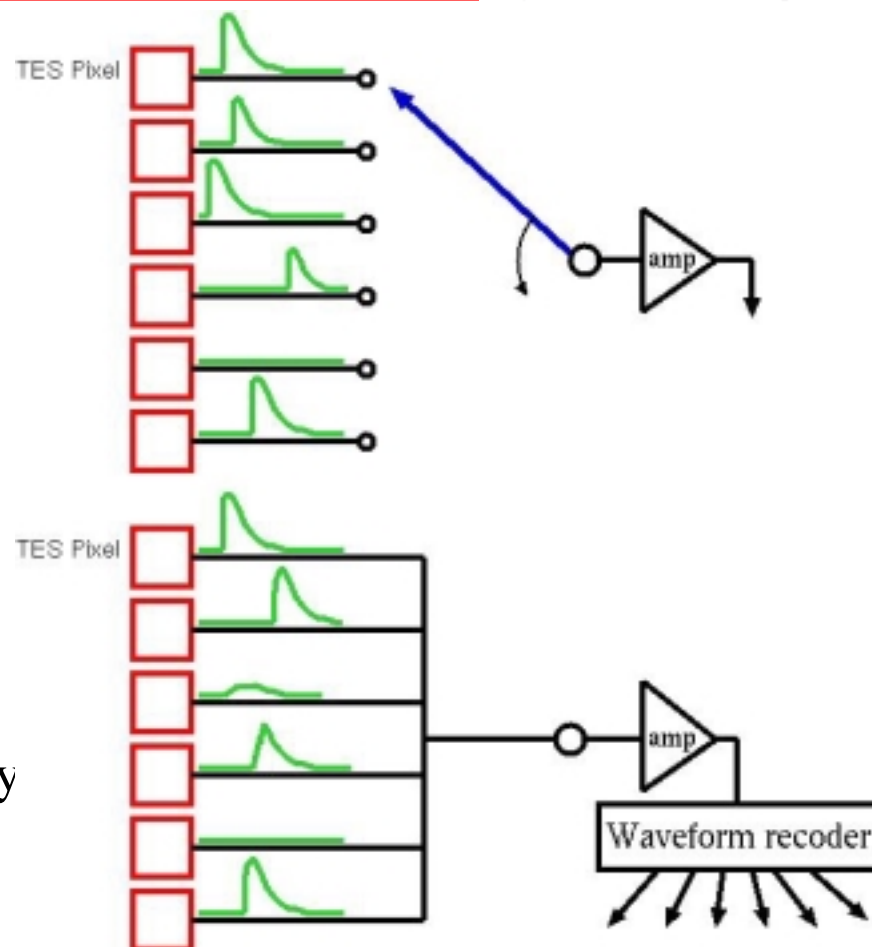
Frequency domain

Demerit Challenging technology

■ New pixel imaging with simply operating

Merit based on existing technology

Demerit Count rate restriction

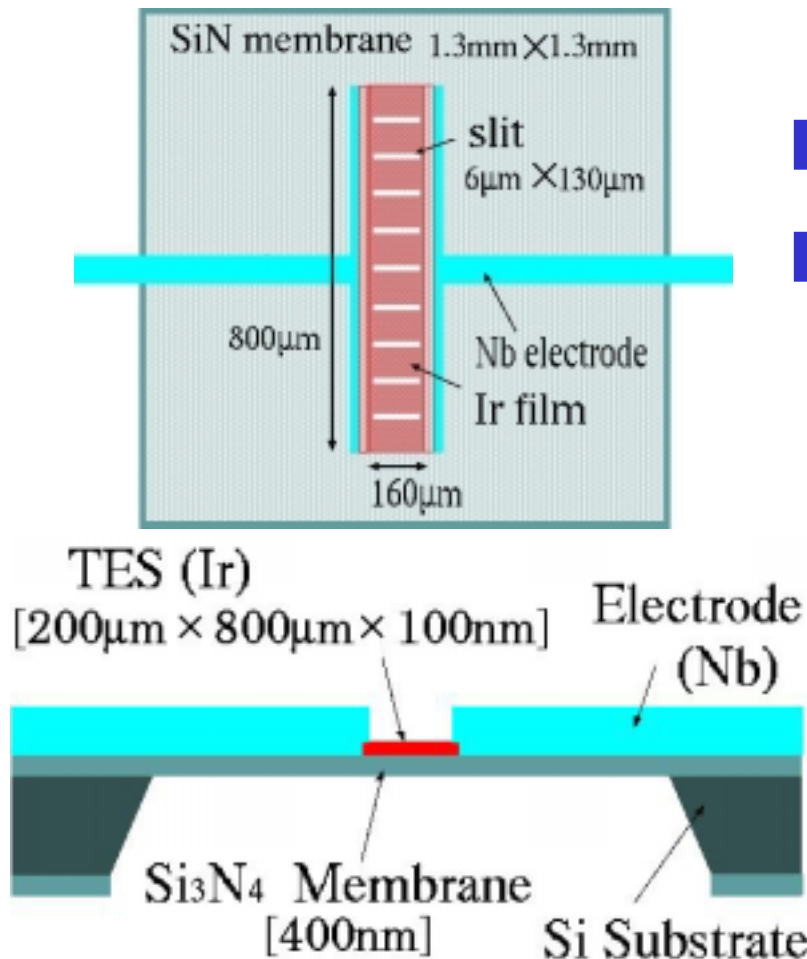


LTD-10

Each pixel-TES is voltage biased at the same time.
The signals of all pixels are read out by one SQUID-array.

Fabrication of Pixel-type TES geometry

Ir film is fabricated on a $1.3\text{mm} \times 1.3\text{mm}$ silicon nitride membrane



TES configuration

- 1-D array of TES pixels
 - 10 pixels defined by 9 slits
- Pixel size $74\mu\text{m} \times 160\mu\text{m}$

Ir 100nm thick

by magnetron sputtering

$T_c = 130\text{mK}$

Si₃N₄ 400nm thick

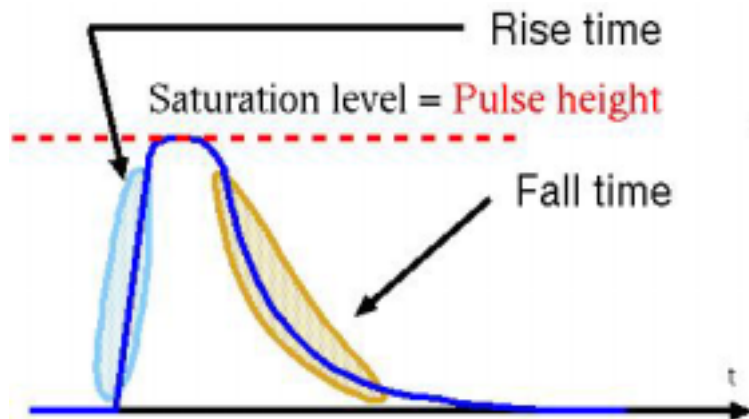
by LPCVD

Pixel operation

Higher resistivity of Ir-TES



Parallel biasing scheme

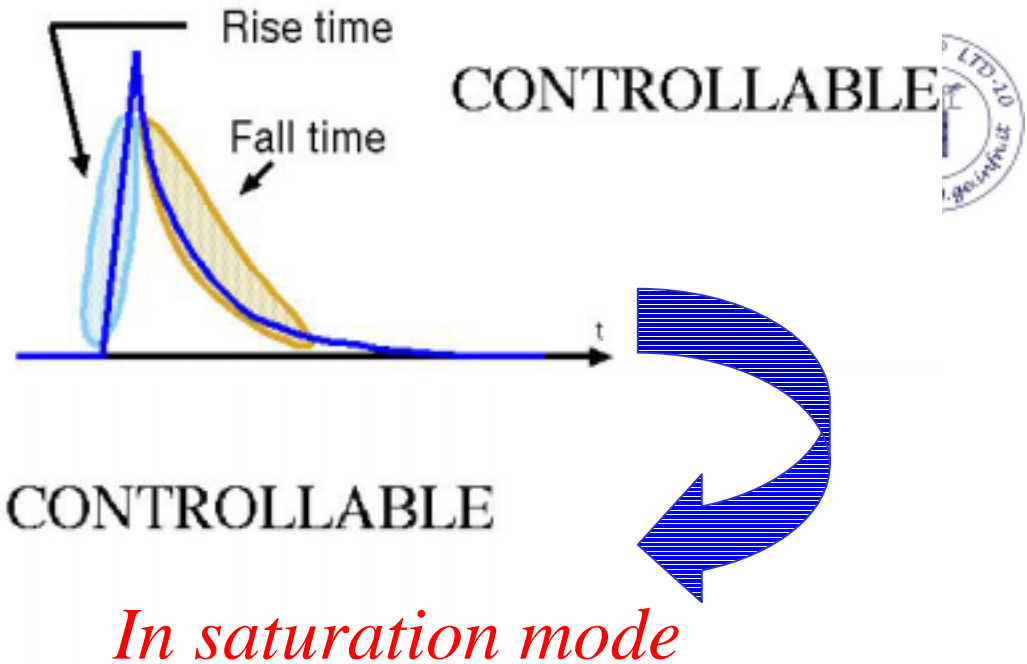


The bias point is different in every pixel.

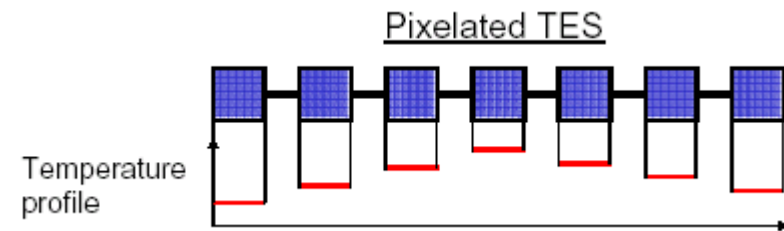
Pulse shape analysis



Pixel position identification

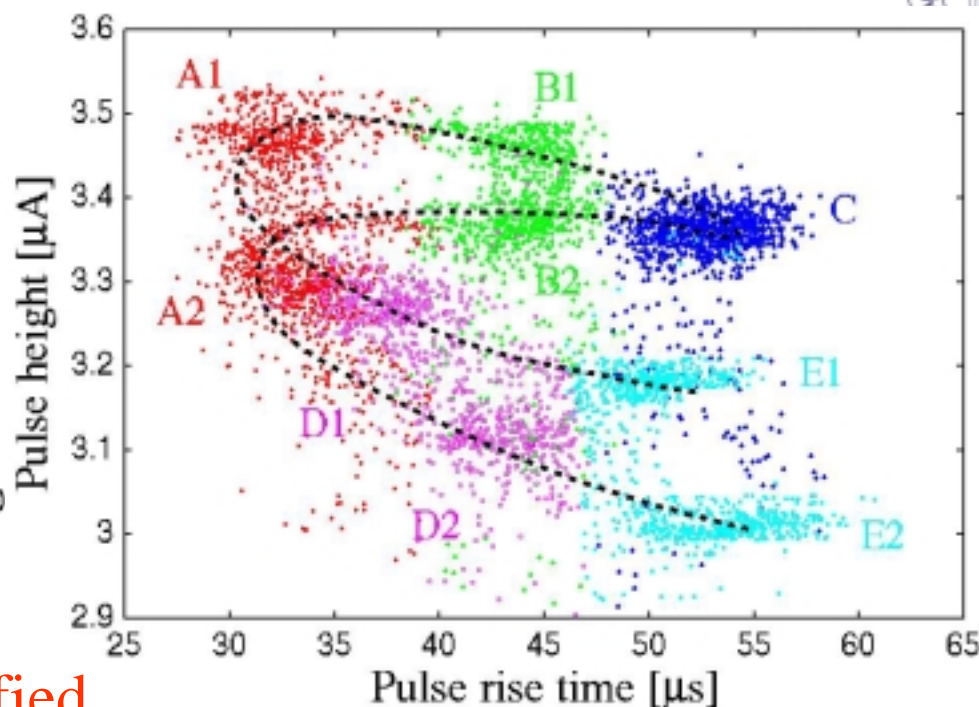
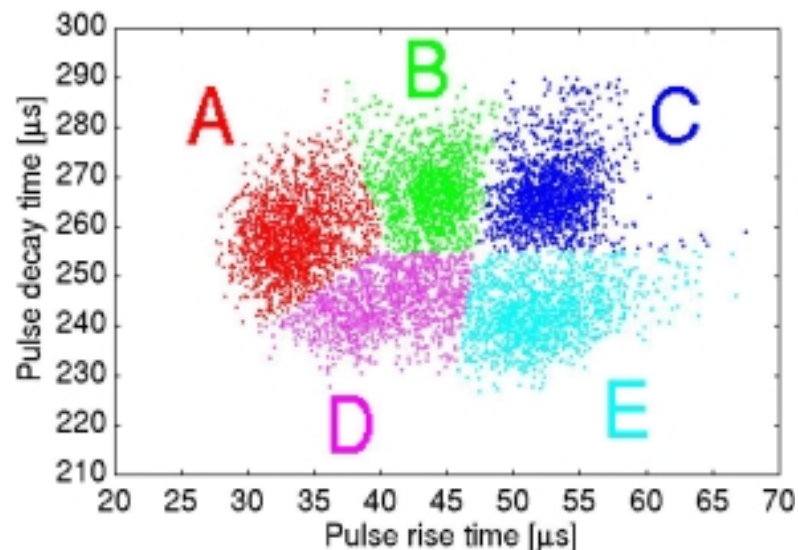


In saturation mode



Relation between the rise time and the pulse height

X-ray from ^{55}Fe source were incident on the entire area of 10pixel TES.

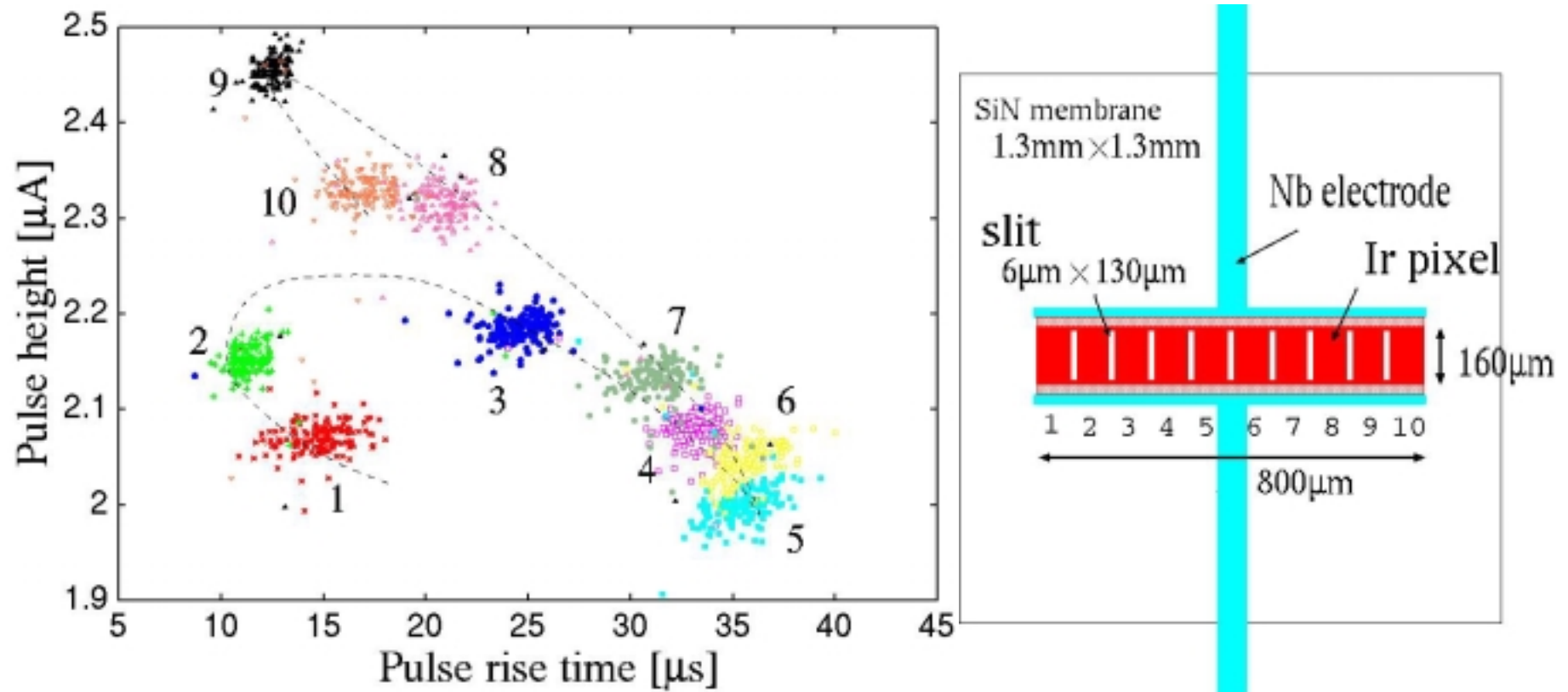


Incident pixel position is identified via the rise time, decay time, and pulse height.

A1	26.0eV	A2	28.3eV	B1	28.4eV	B2	28.6eV	C	28.9eV
D1	29.6eV	D2	26.7eV	E1	29.0eV	E2	27.1eV		

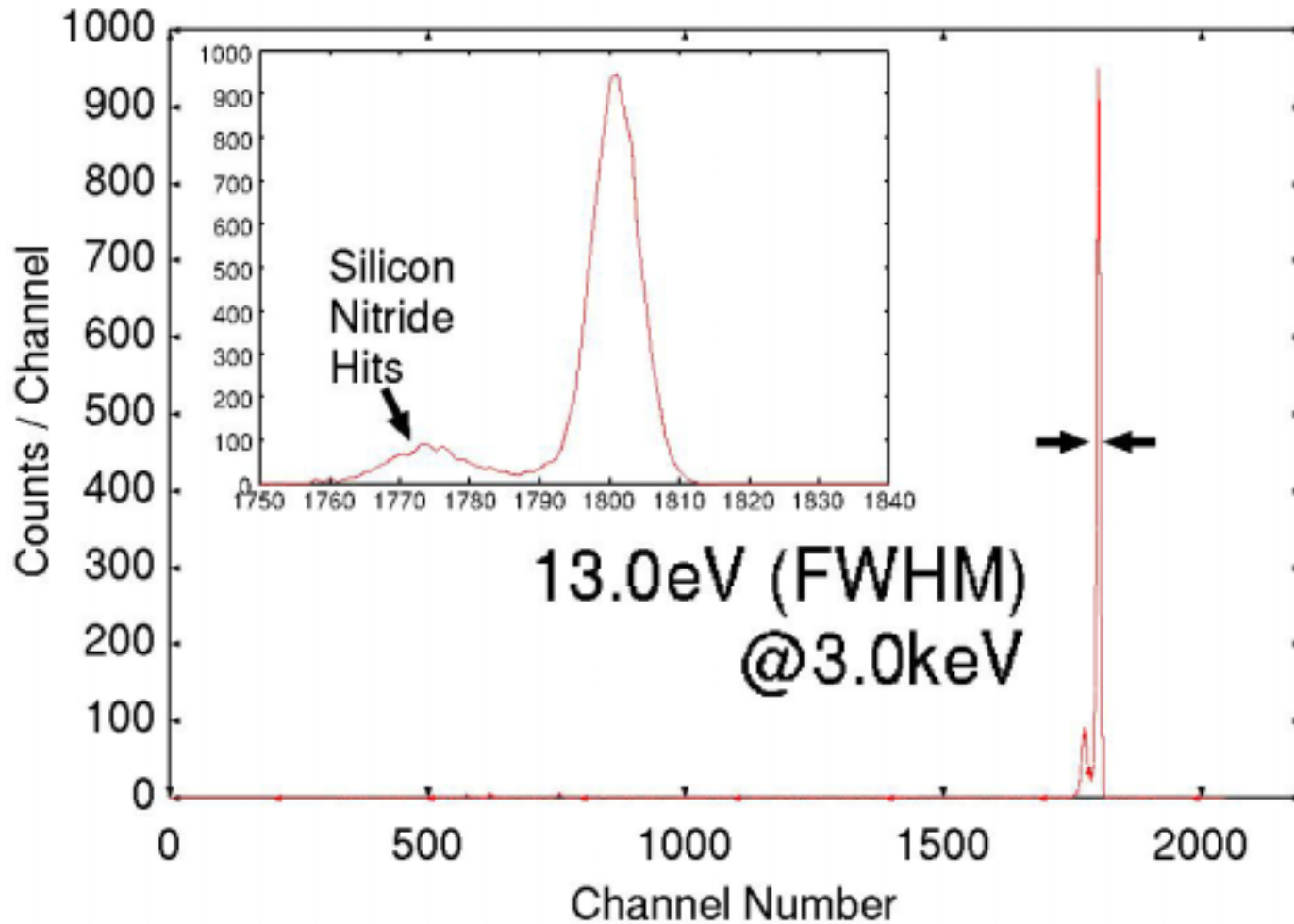
Identifying of the incident pixel position

Scanning along each pixel by a 3keV X-ray beam ($20\mu\text{m}\Phi$)



The energy spectrum of collimated X-ray ($20\mu\text{m}\Phi$, 3keV)

Collimated X-rays are incident on the one point of Ir-TES.



To the next stage

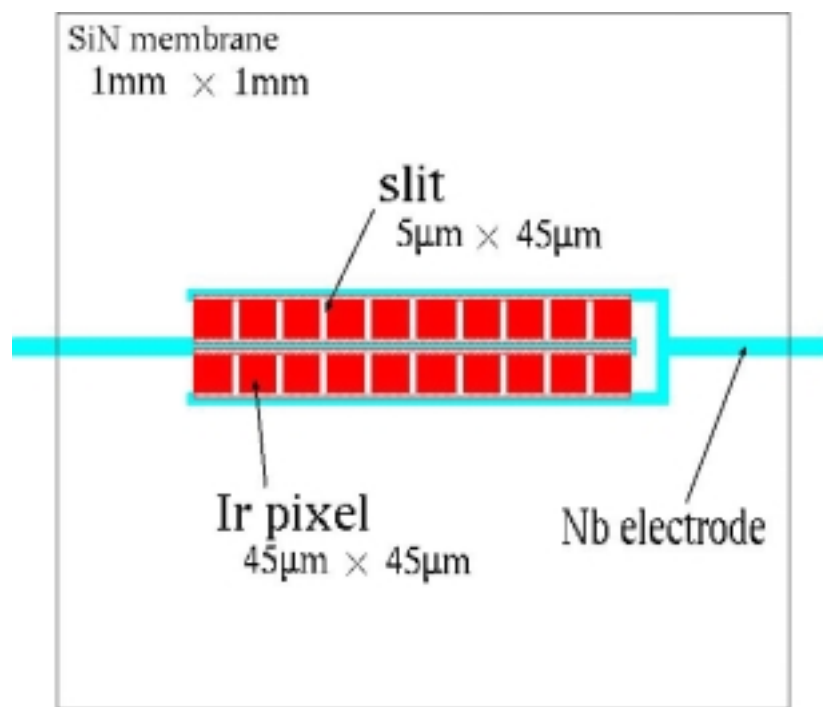
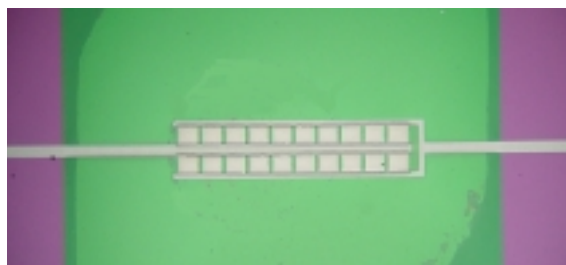


- The principle of our new pixel Ir-TES is confirmed.
- Further development

Pixel number	10	➡	20
Imaging dimensions	1-D	➡	2-D

20 pixel Ir-TES

Ir film is fabricated on a 1.0mm×1.0mm silicon nitride membrane



TES configuration

Fork-style array

- 2-D array of TES pixels

All pixels are parallel biased

- 2 rows of 10 pixel array

Each 10 pixel array is defined by 9 slits

Pixel size $45\mu\text{m} \times 45\mu\text{m}$

Normal resistance

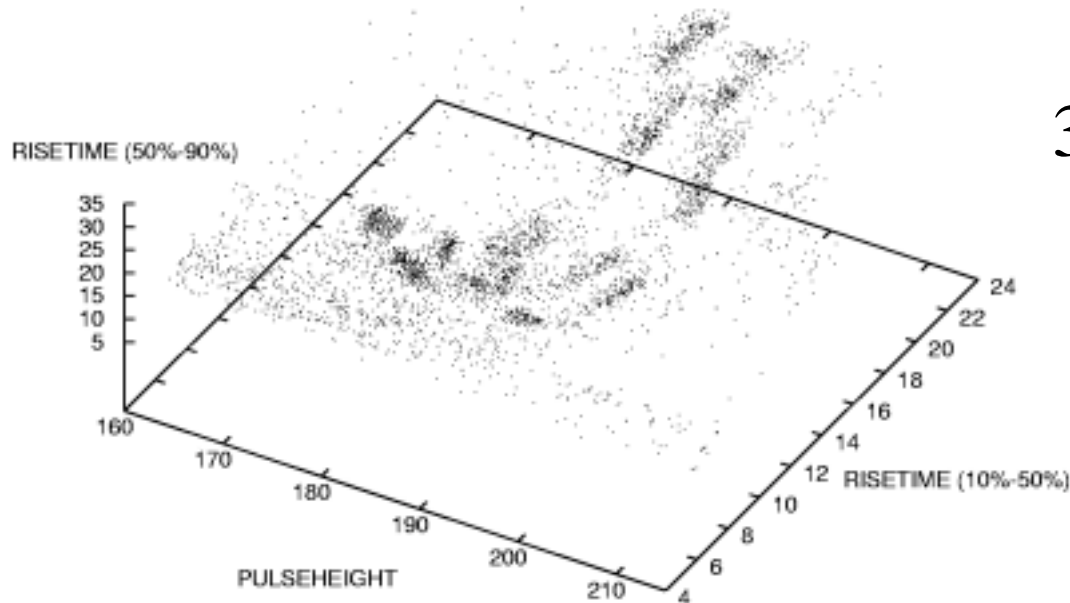
$$R_n = 50\text{m}\Omega$$

Shunt resistance

$$R_s = 3\text{m}\Omega$$

Pixel identification of 20 pixel Ir-TES

X-ray from ^{55}Fe source were incident on the entire area of 20pixel TES



3-D plots for
the risetime (10%-50%)
the pulse height
and
the risetime (50%-90%)

We can recognized **More than 15 groups**.
(but missed 5 other groups)

Symmetrical pixel arrangement causes difficulty
in identifying each incident pixel position

Further improvement of pixel identification

Optimization of the TES array

- Pixel resistance, Width/Length ratio
- The number of slits, etc.

We intend to control the bias point.

- *Each pixel size is slightly changed.*

 *Easier identification of pixel position*

To realize the large format TES array

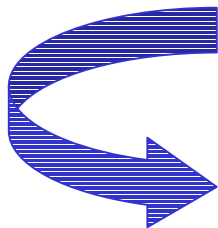


Compatible with other multiplexing technology

-- for example, with 64ch SQUID multiplexer --

- More than 1000pixels
- 10kHz count rate

Our pixel device should be run at only 160Hz
(or 6ms interval).



The decay time of 20 pixels device $140\mu\text{s}$

(Our device has already achieved 1kHz)

Conclusion



We have proposed a new pixel X-ray microcalorimeter with high energy resolution and position sensitivity by using an Ir transition edge sensor.

New pixel geometry

1-D TES array of 10 pixels

$74\mu\text{m} \times 160\mu\text{m}$

2-D TES array of 20 pixels

$45\mu\text{m} \times 45\mu\text{m}$ (pixel size)

■ Position sensitivity

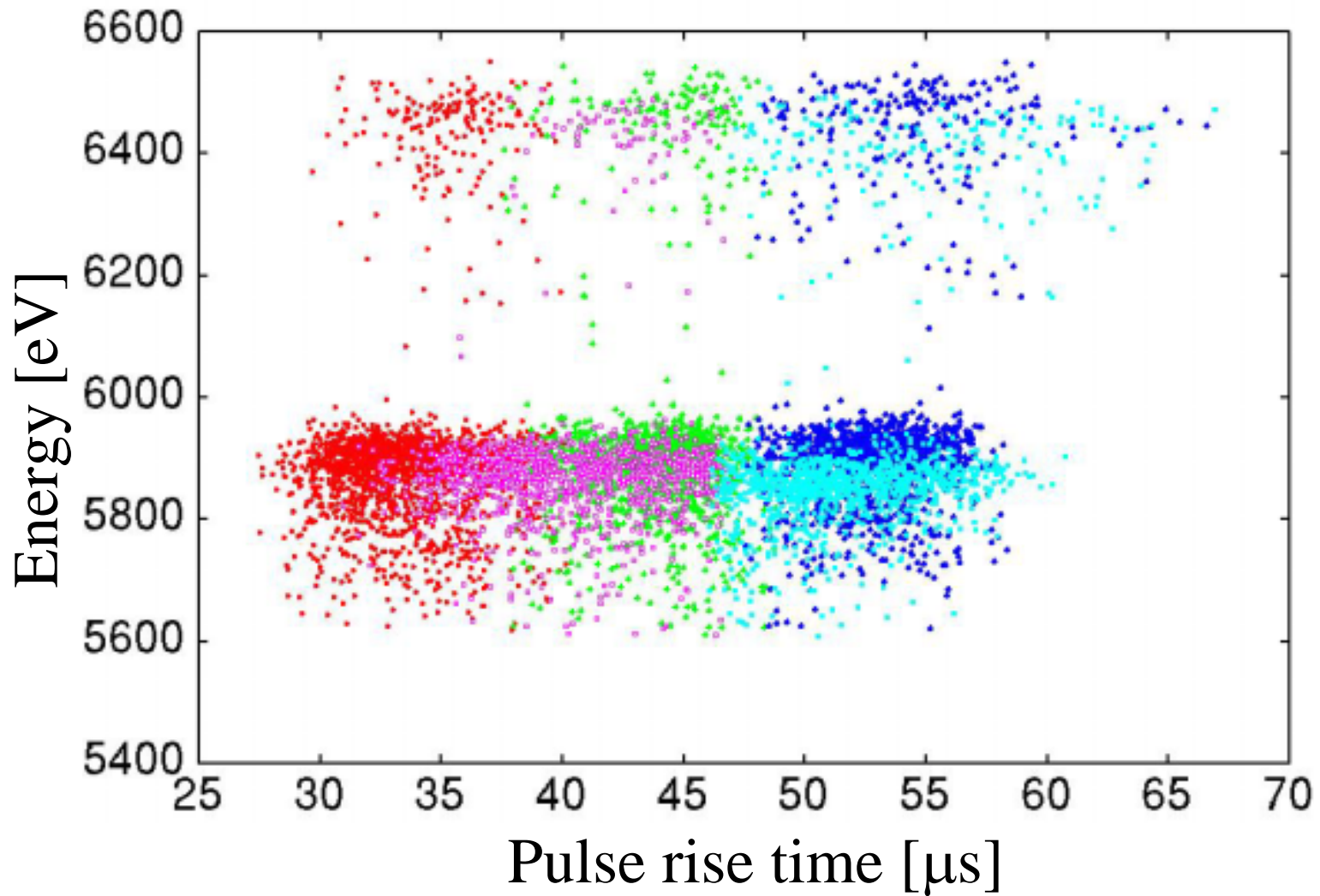
We can identify the incident pixel position by analyzing the pulse shapes.

■ Energy resolution (in 10pixel device)

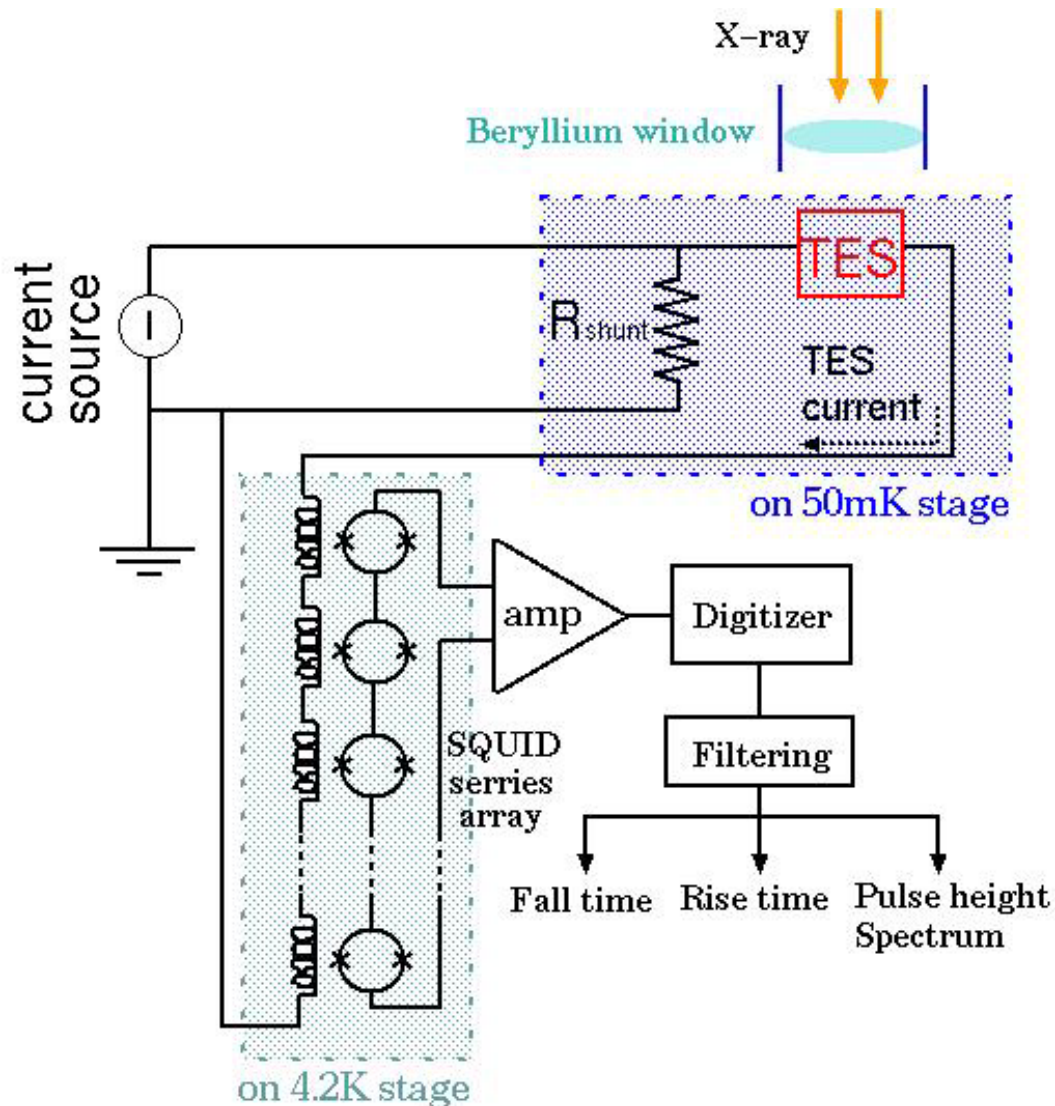
$26.0\text{eV} \sim 29.6\text{eV}$ (FWHM) @ 5.9keV in each pixel

13eV @ 3.0keV collimated beam ($20\mu\text{m}\Phi$)

Relation between the rise time and current integral



Block diagram of the entire system



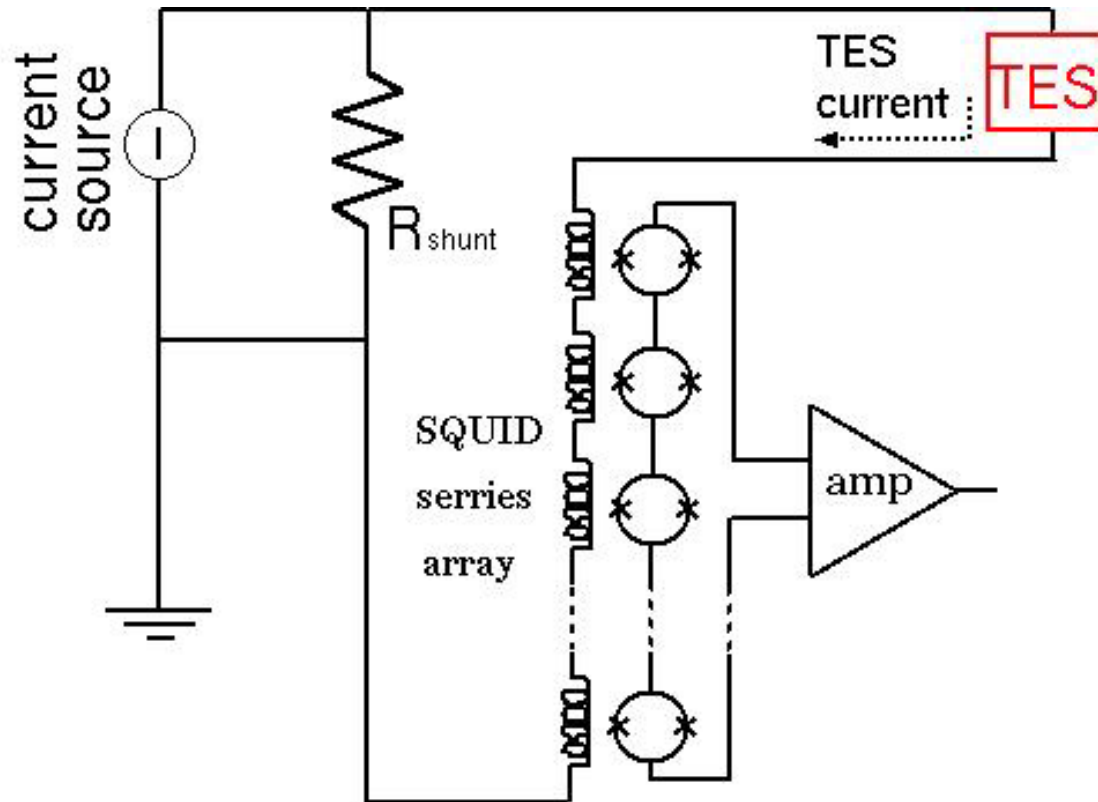
One stage SQUID
current amplifier

200 series-array dc-SQUID

Filtering
optimal filter

Current integral
Pulse height

Electronic circuit



Normal resistance
of TES

$$R_{TES} = 200\text{m}\Omega$$

Shunt resistor

$$R_{shunt} = 10\text{m}\Omega$$

Time constant

$$L/R < 3\mu\text{s}$$

($L = 0.3\mu\text{H}$)

Noise from SQUID

$$19.2\text{pA}/\sqrt{\text{Hz}} \quad @1\text{kHz}$$

Scanning the pixel TES by the collimated X-ray beam



The Ir-TES film is scanned along each pixel by a 3keV X-ray beam collimated to a diameter of $20\mu\text{m}$.

The signal pulses are recorded together with the collimator position.

