SOIPIX
Silicon-On-Insulator Pixel Detector Project

Instrument R&D Team
IIRD
Institute of Materials Structure Science
High Energy Accelerator Research Organization,KEK

Synchrotron radiation X-ray experiments for a pulse-counting type SOI pixel for the soft X-ray measurements

KEK IMSS R. Hashimoto, S. Kishimoto, R. Kumai, N. Igarashi

KEK IPNS Y. Arai, I. Kurachi, T. Miyoshi

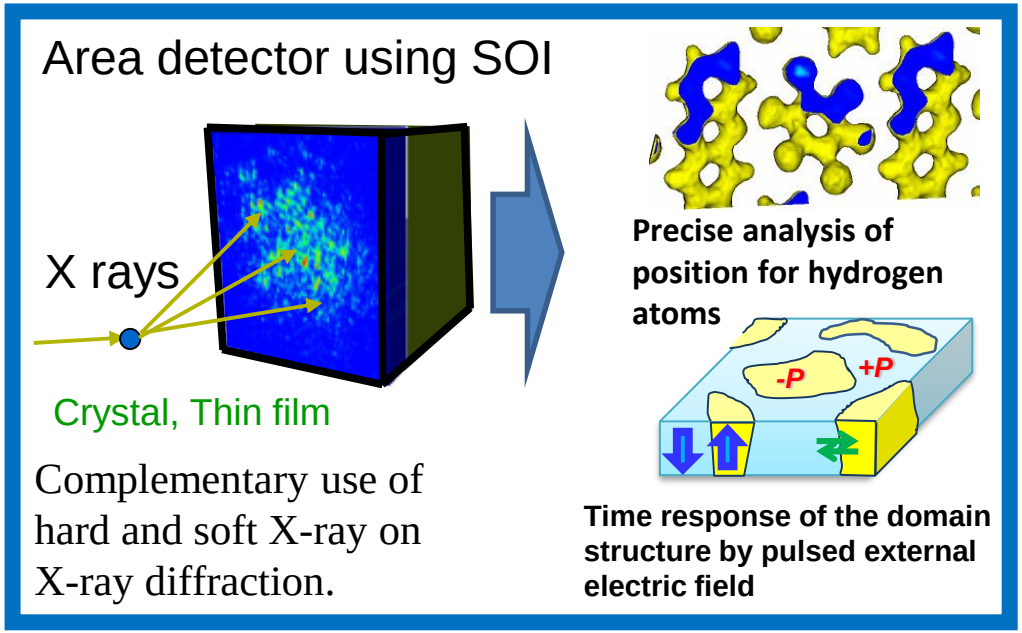
SOKENDAI R. Nishimura

Introduction

Development of the SOI pixel detector for the X-ray structural analysis.

- Small angle X-ray scattering experiment for functional thin films.
- X-ray diffraction experiment for functional materials such as ferroelectrics.

etc…

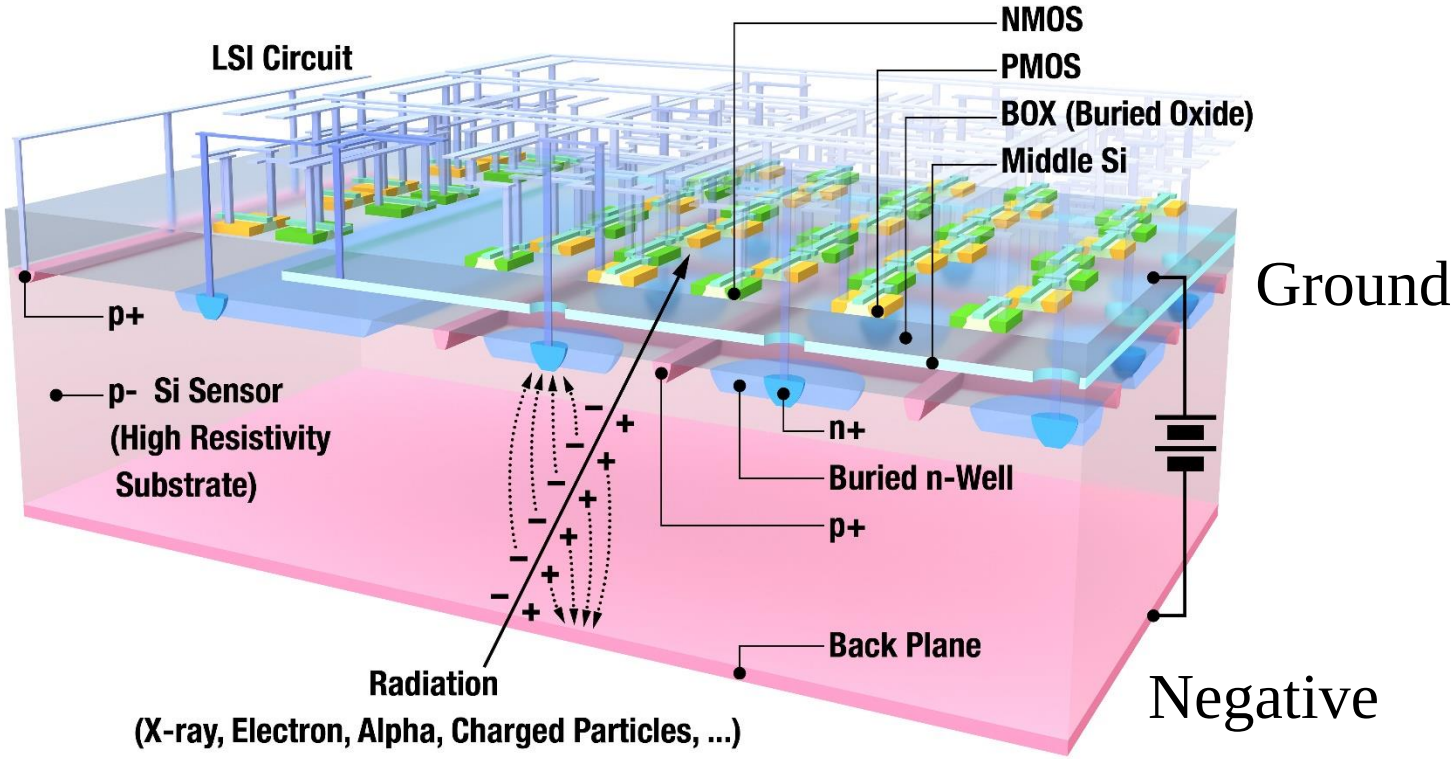


Current status

- Conducting the structural analysis experiment by use of a fine pixelated detector, SOPHIAS.
- Development of the pulse-counting type pixel detector.

Introduction

SOI detector

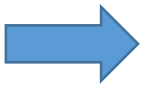


Double-SOI wafer (p-type substrate)
Back plane : negative bias
Another Si layer (middle Si) is in BOX layer

Introduction

Requests for detectors from experiments

- high spatial resolution
  → pixel size is less than 50 μm square
- high sensitivity
  → detecting low energy X-ray ～2 keV
- high frame rate
  → more than 1 kHz

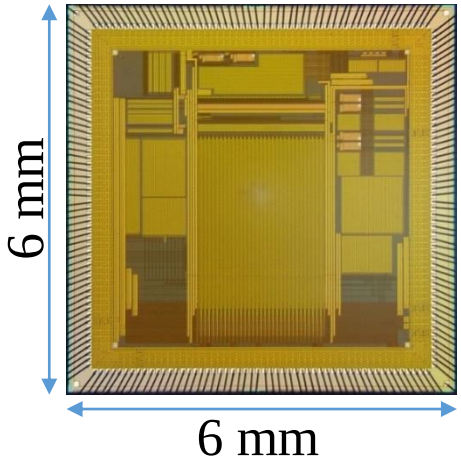


X-ray test for Test-Element-Group (TEG) chip including pulse-counting type pixel TEG.

In this talk, the experimental results of the evaluation for the counting type pixel TEG will be shown.

Evaluation of counting type pixel in KEK

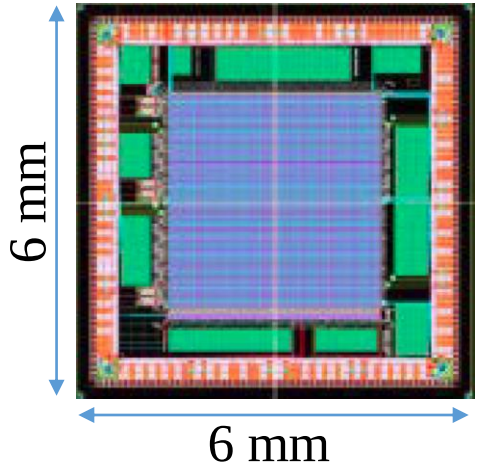
CPIXPTEG1



- 64 μm square pixel
- 32 × 32 array consists of 3 types of pixel + TEGs

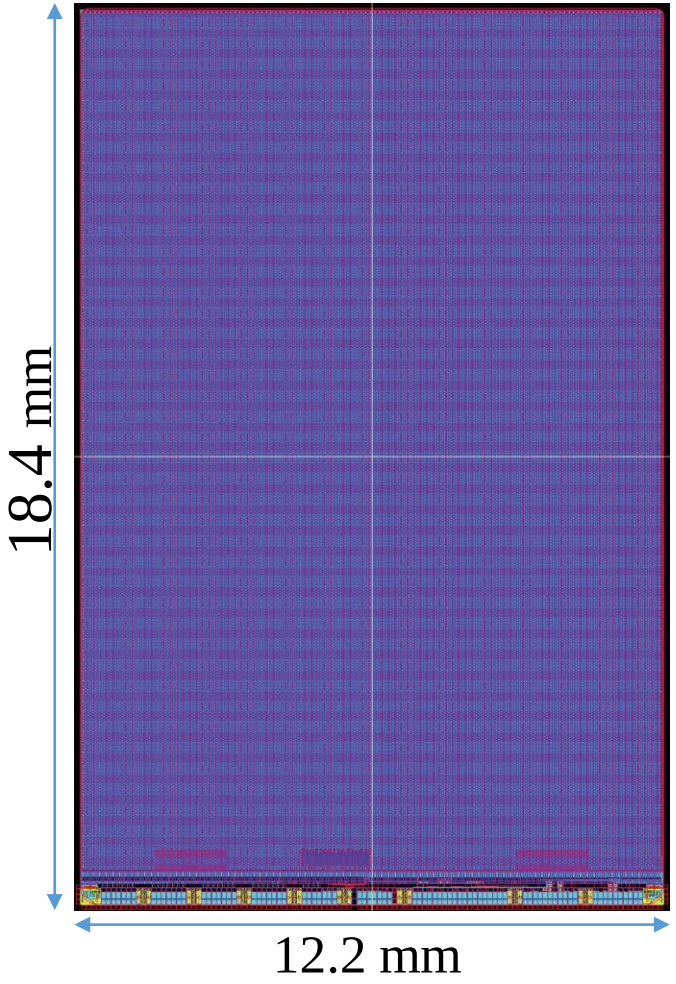
CPIXTEG3b

(collaborated work with IHEP)



- 50 μm square pixel
- 64 × 64 array

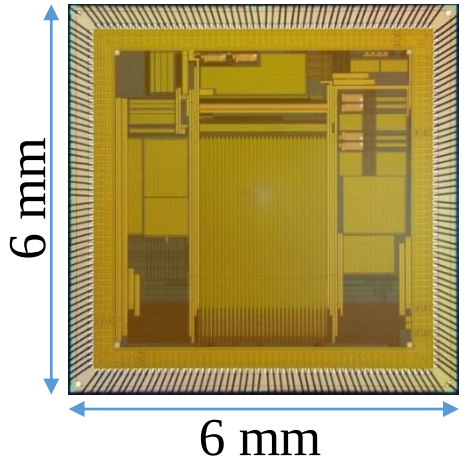
CNPIX1



- 52 μm pitch hexagonal pixel
- 256 ×320 array + TEGs

Evaluation of counting type pixel in KEK

CPIXPTEG1 → CPIXPTEG2

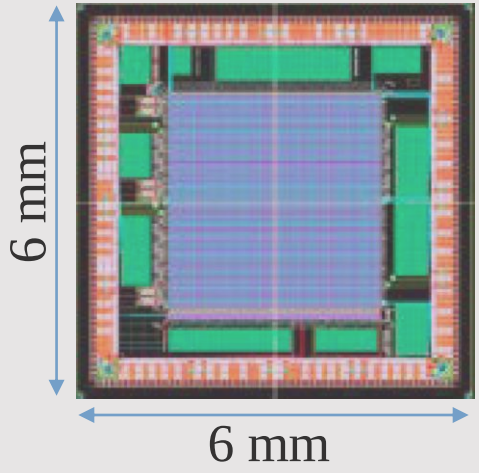


study of low energy X-ray detection

- 64 μm square pixel
- 32 × 32 array consists of 3 types of pixel + TEGs

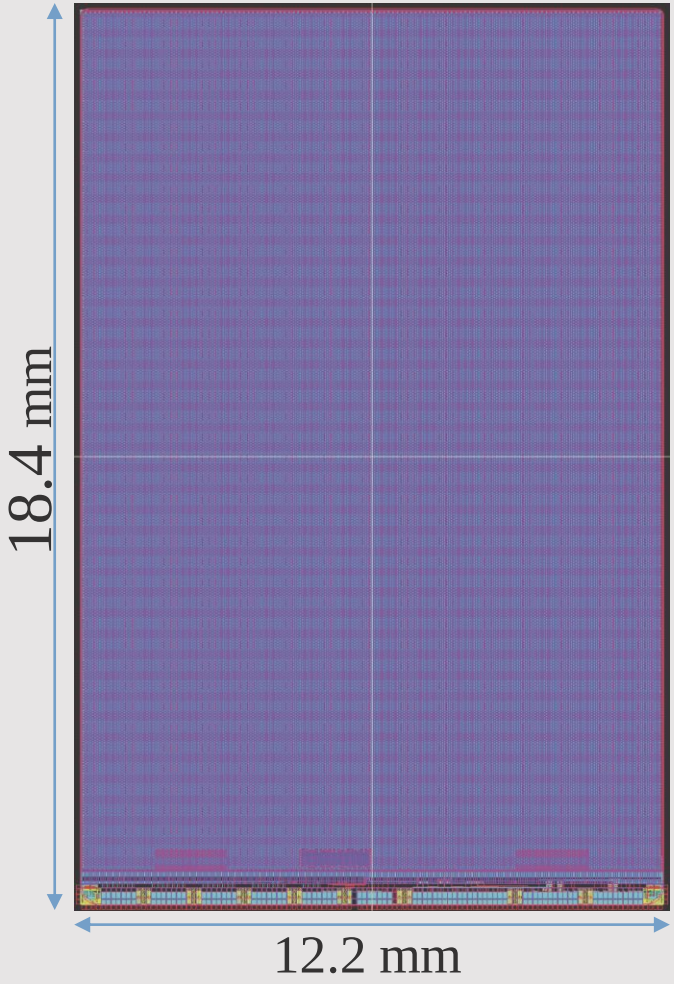
CPIXTEG3b

(collaborated work with IHEP)



- 50 μm square pixel
- 64 × 64 array

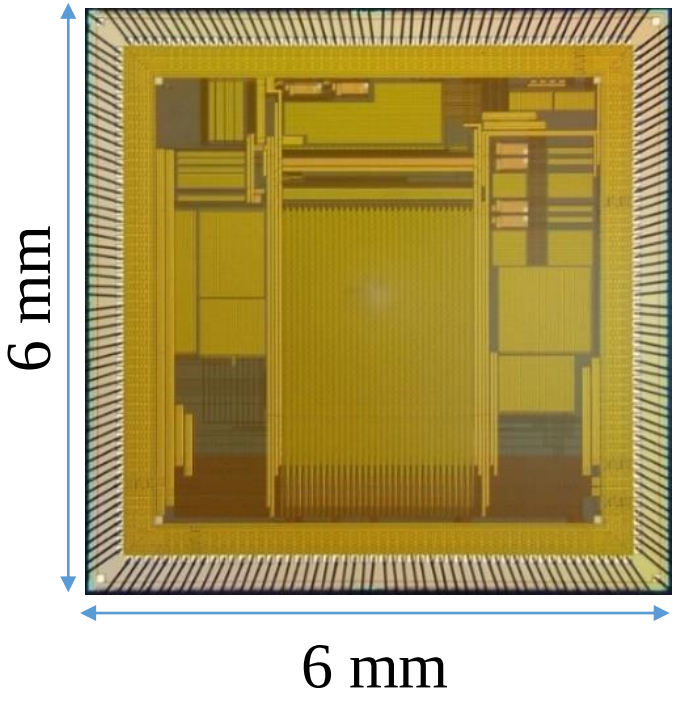
CNPIX1



- 52 μm pitch hexagonal pixel
- 256 ×320 array + TEGs

Chip overview

CPIXPTEG2



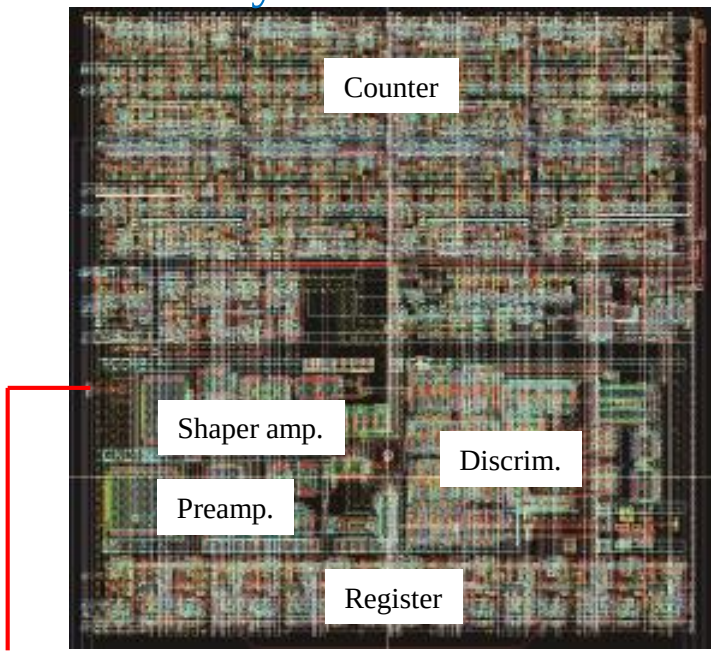
- 64 μm square pixel
- 32 × 32 array consists of 3 types of pixel + TEGs
- 16-bit counter
- Double-SOI wafer

Chip overview

CPIXPTEG1 → CPIXPTEG2

- Increasing contact via of the middle-SOI layer

Pixel layout of CPIXPTEG1



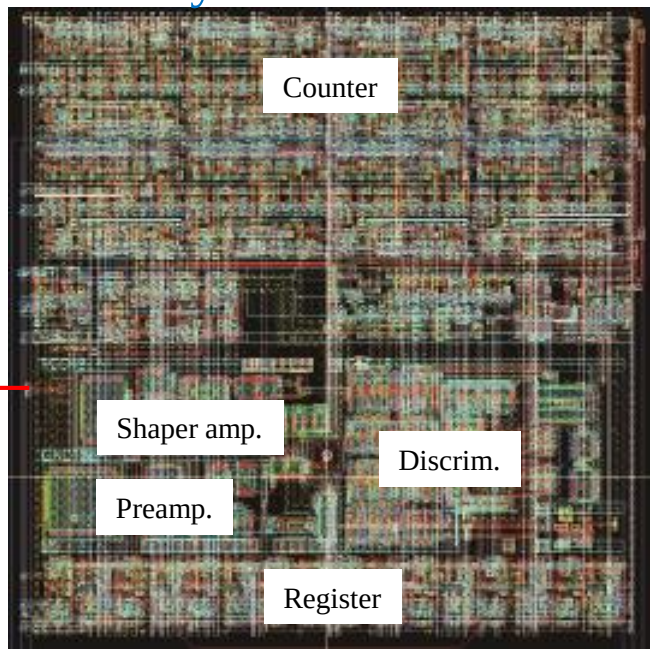
Only 1 Middle-SOI contact

Chip overview

CPIXPTEG1 → CPIXPTEG2

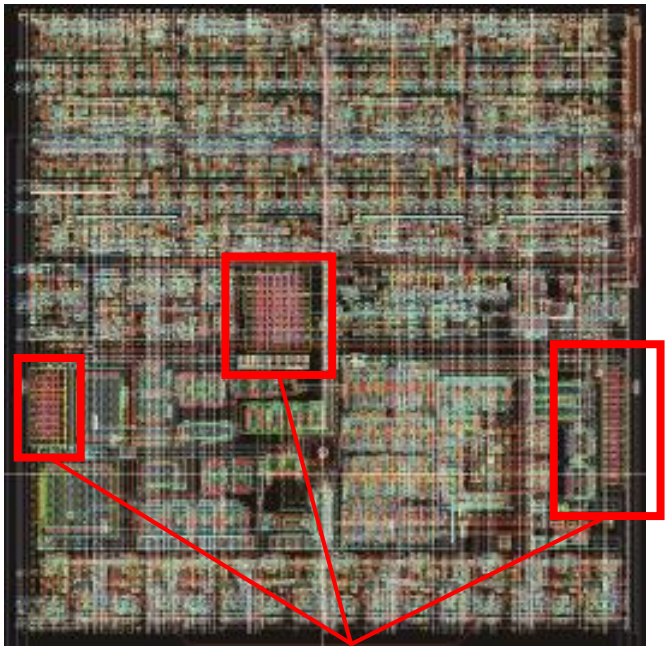
- Increasing contact via of the middle-SOI layer

Pixel layout of CPIXPTEG1



Only 1 Middle-SOI contact

CPIXPTEG2



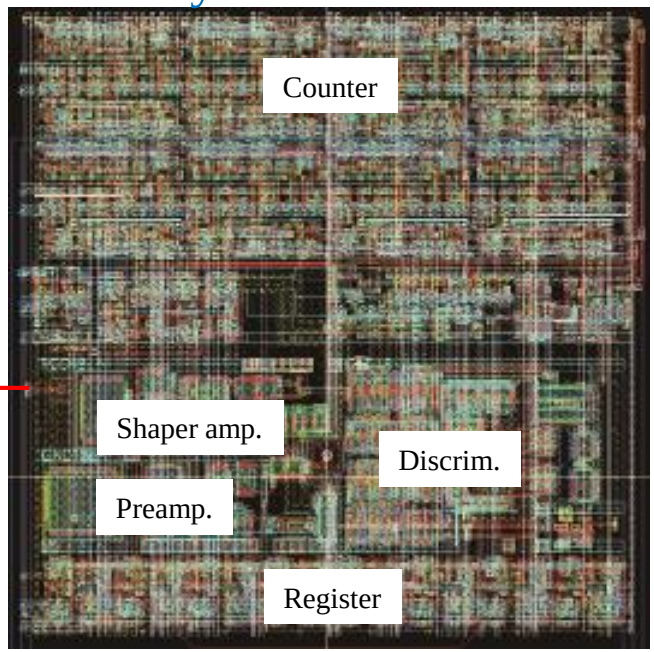
Increasing contacts

Chip overview

CPIXPTEG1 → CPIXPTEG2

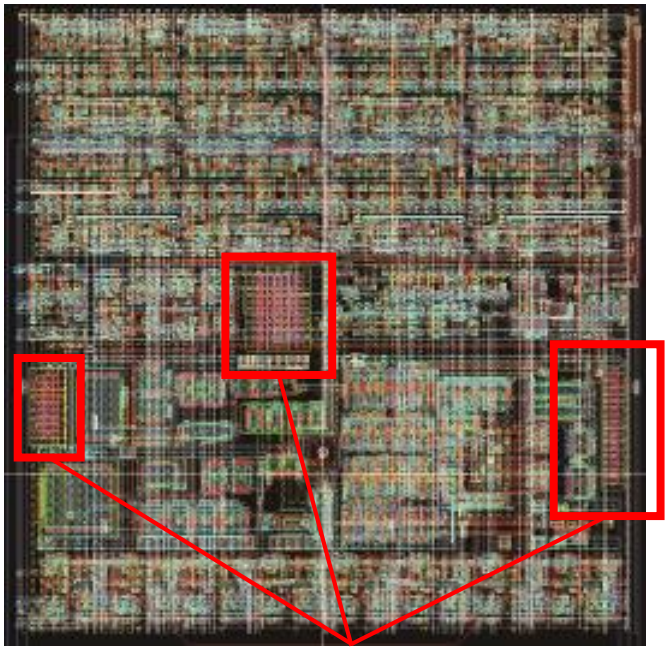
- Increasing contact via of the middle-SOI layer

Pixel layout of CPIXPTEG1



Only 1 Middle-SOI contact

CPIXPTEG2



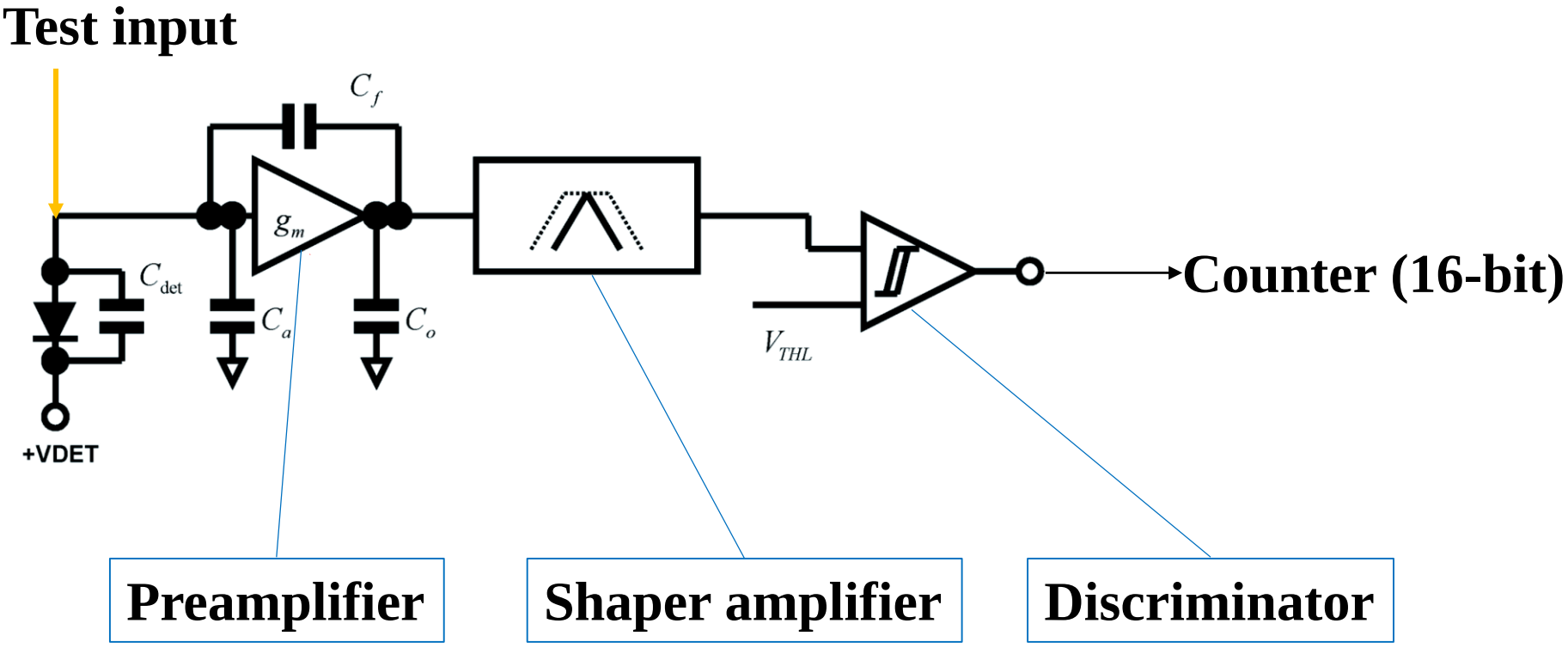
Increasing contacts

- Study of the backside process for the soft X-ray detection

  ⇒ Wafer thinning process

  Total thickness 75 μm

Schematic of the pixel circuit



Gain : 45 μV/e$^-$
@designed value.

Gain : twice
@designed value.

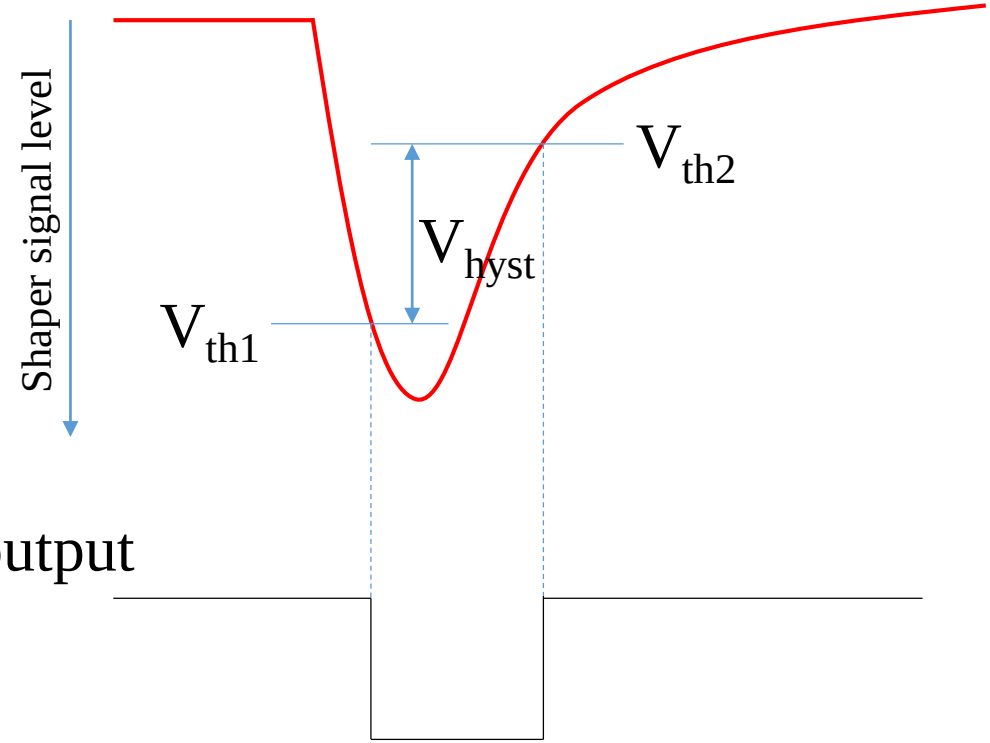
- 4-bit DAC for adjusting threshold level.
- Hysteresis comparator.

Total gain of preamp. and shaper amp. : 90 μV/e$^-$
→ CPIXPTEG1 evaluation result 33.5 μV/e$^-$

Hysteresis width of discriminator

Discriminator behavior

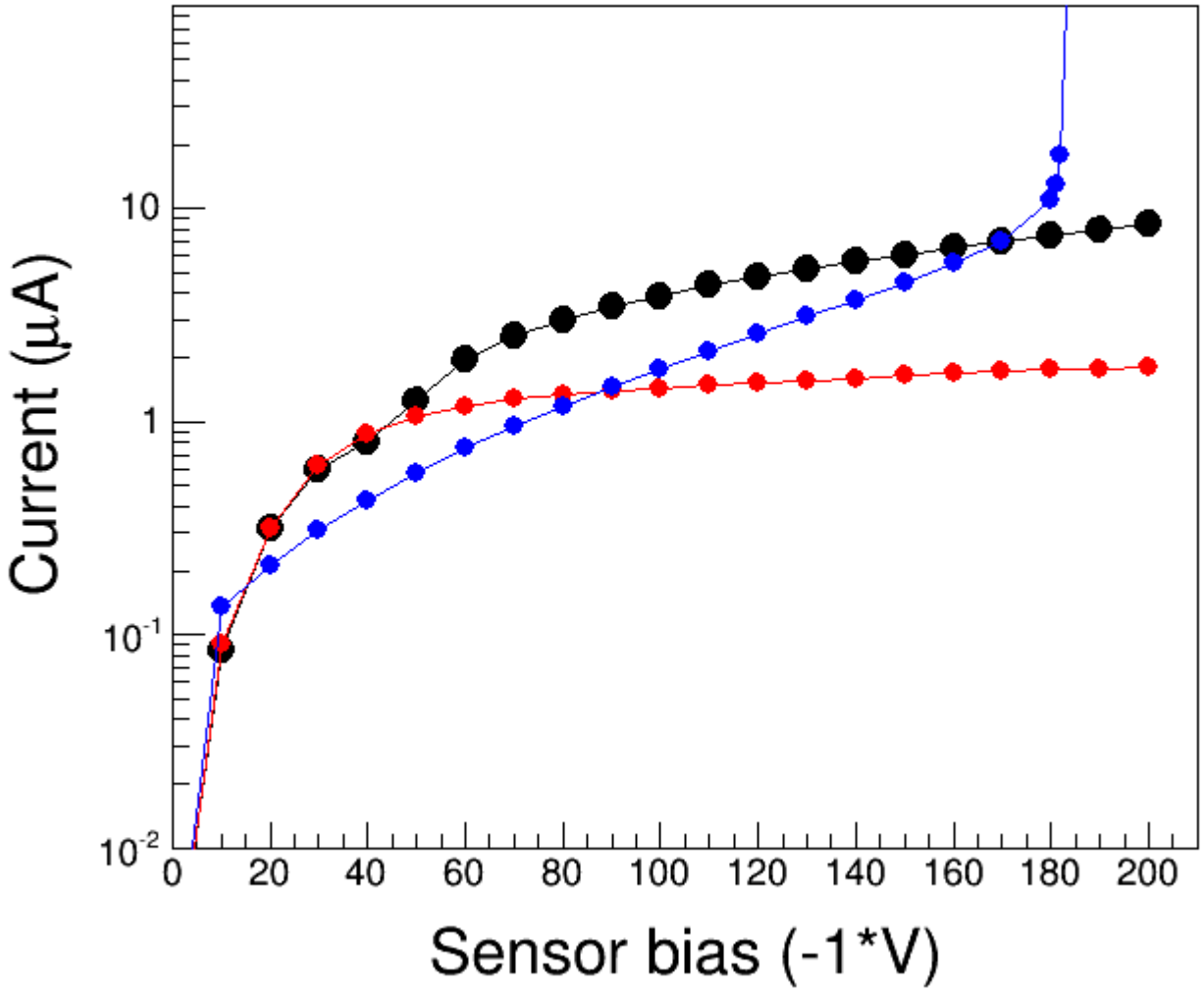
Signal from shaper amplifier



Discriminator output

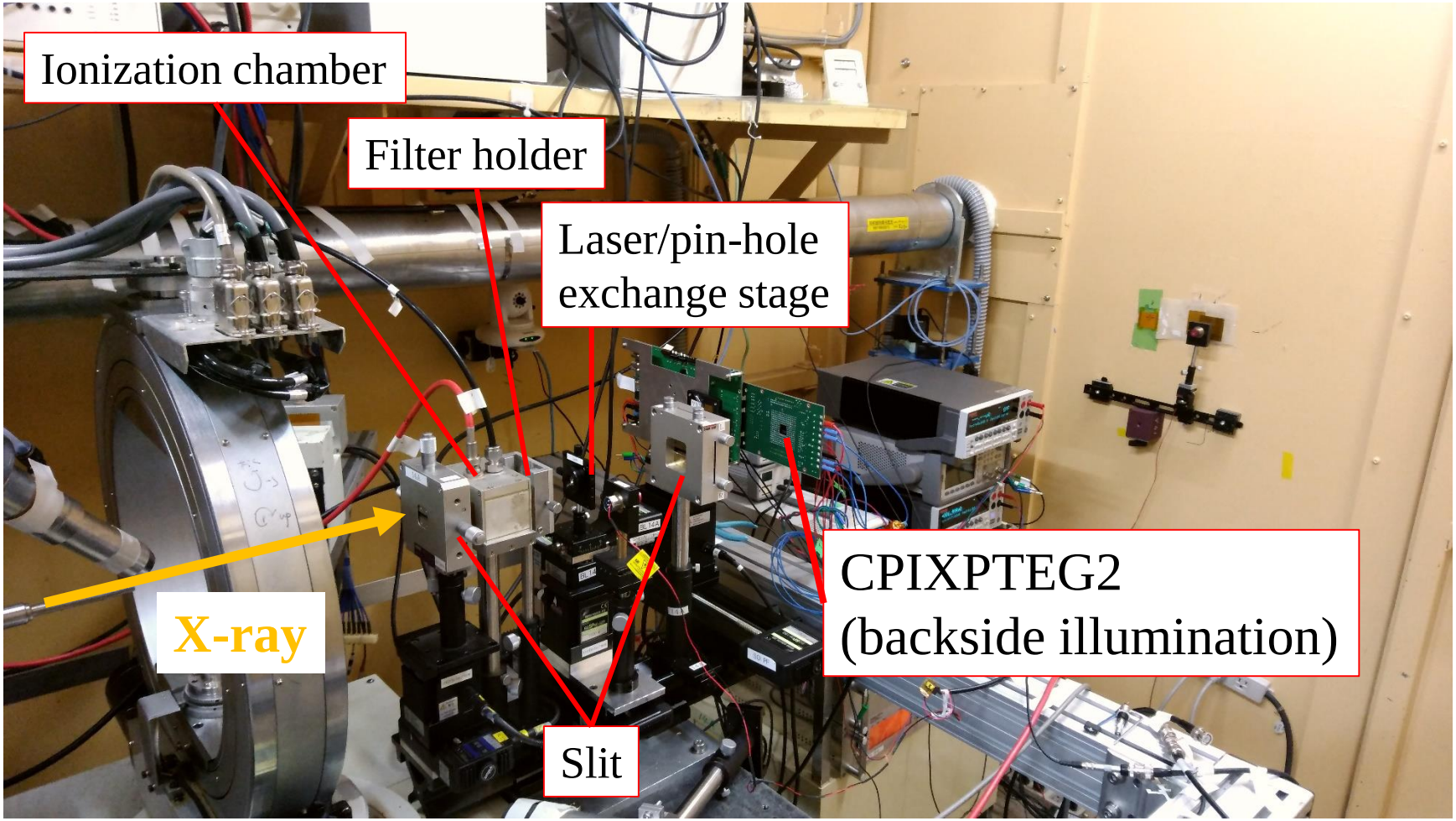
Against malfunction due to the noise signal.
Designed value of V_{hyst} = 80 mV.
→ Cannot measure the lower level signal than V_{hyst}.

I-V curve measurement



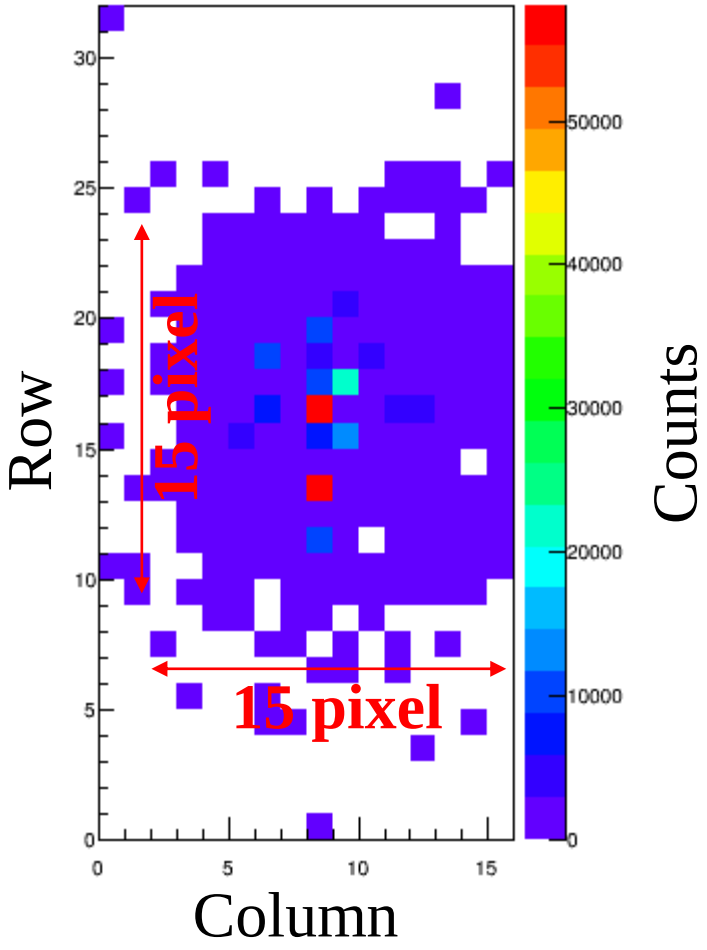
CPIXPTEG2 (thinning)
CPIXPTEG2 (normal)
CPIXPTEG1 (normal)

Experimental setup @KEK/PF BL-14A

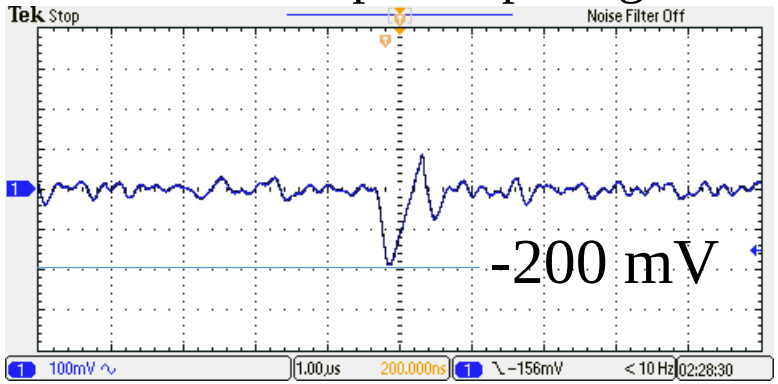


Measurement of X-ray profile

Exposing 6 keV X-rays with 0.8 mmφ in diameter with V_{det} = -10 V.



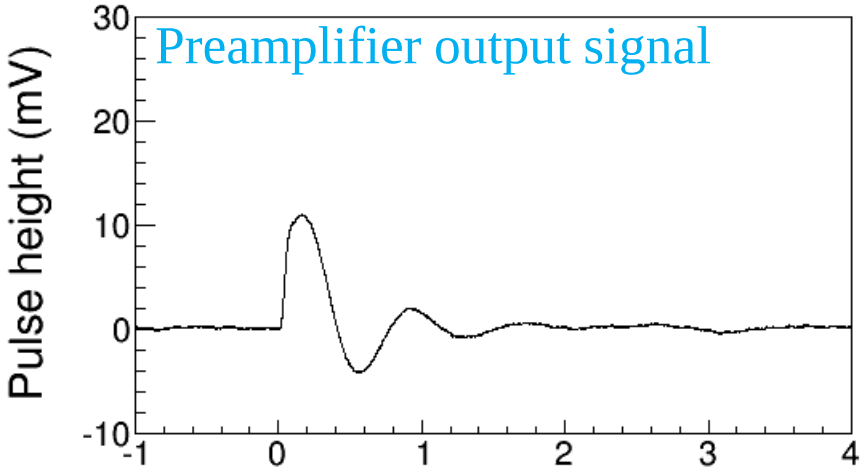
Obtained shaper output signal

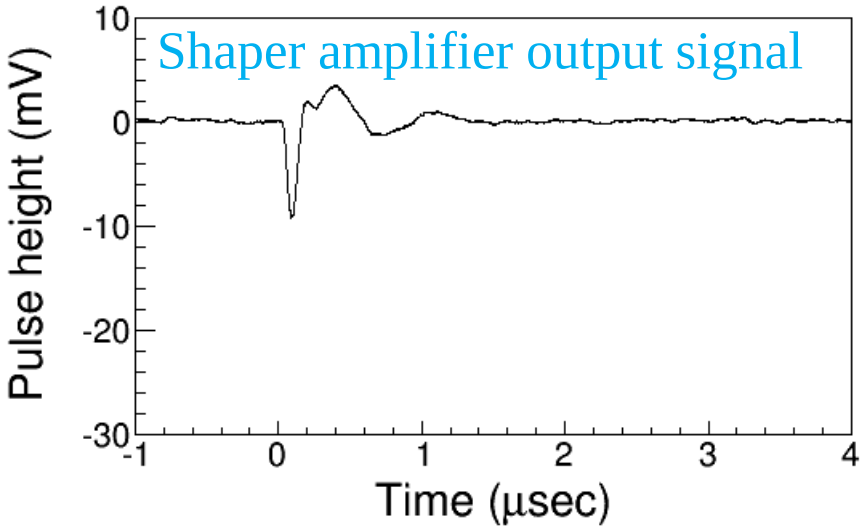


In measurement using X-ray micro beam, we missed the position of X-ray.

Study in test bench

Low gain problem





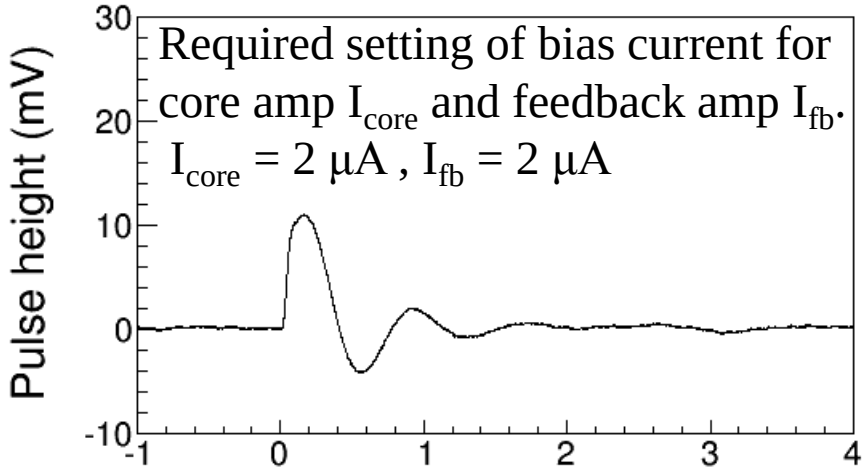
Test input capacity : 4.2 fF
Input signal : 62 mV
Output : 10 mV
→ Corresponding gain is 6 μV/e^-

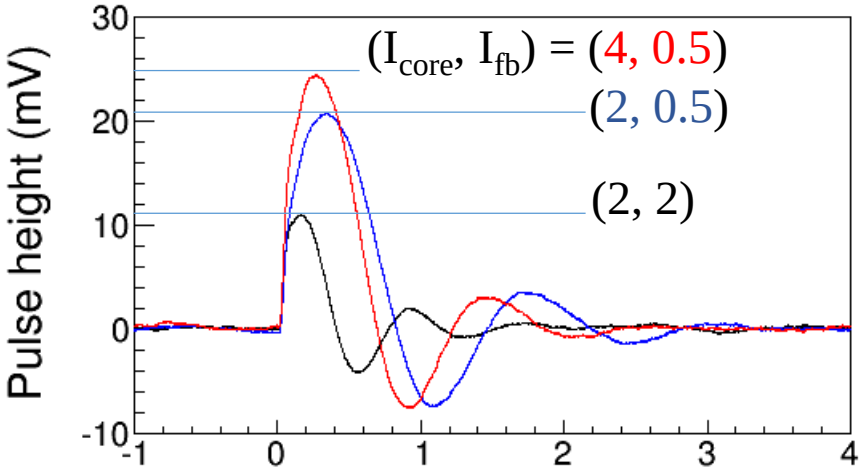
Gain was half of designed value.

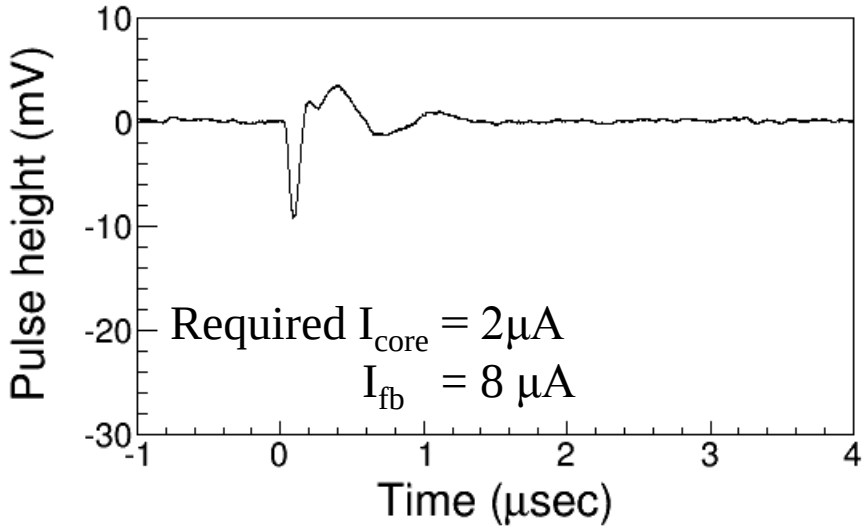
Total gain is 5 times lower
than 33.5 6 μV/e^- of CPIXPTEG1.

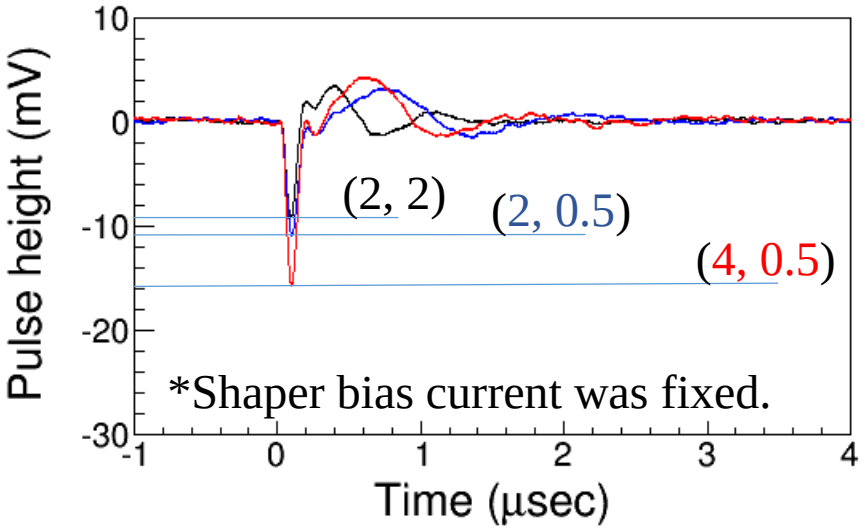
Study in test bench

Increasing the gain by adjusting bias current of Preamplifier.





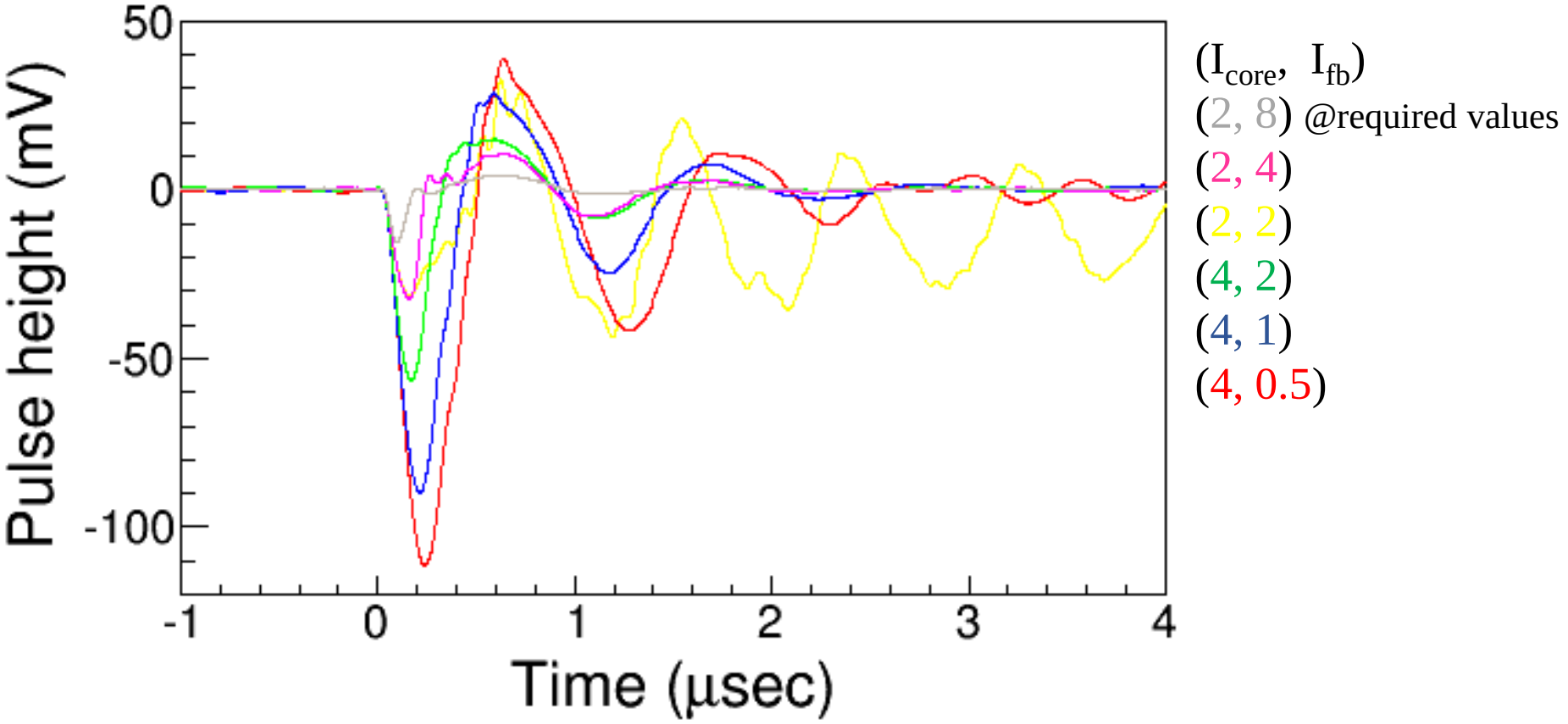




Study in test bench

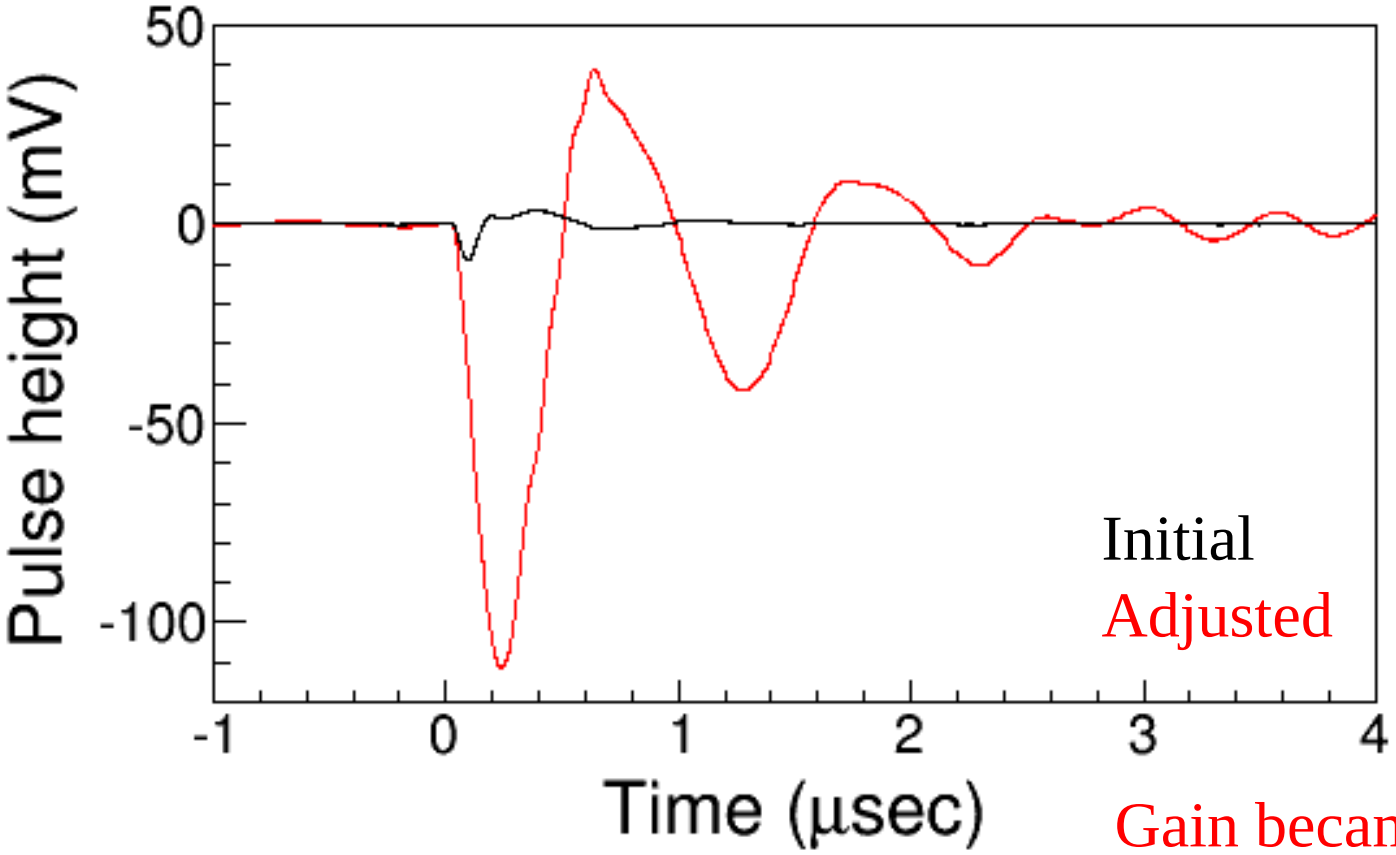
Increasing the gain by adjusting bias current of a Shaper amplifier.

I_{core} and I_{fb} of preamplifier were 4 μA and 0.5 μA, respectively.



Study in test bench

Increasing the gain by adjusting bias current of amps.



Gain became almost 10 times larger than initial setting.

Summary

We have started the study of counting type pixel for soft X-ray.

Back side process aiming the soft X-ray counting was performed.

The evaluation experiment by use of 6 keV X-ray was done but we could not measure.

→ Shortage of the gain was found out so that we recovered that by adjusting the bias current of amps.

After checking the discriminator and counter action and other tools used for measurement, we try again the 6 keV X-ray experiment.

- counting micro spot X-ray beam.
- 1- and 2-dimentinal pixel scan, etc…

Future plan

For the soft X-ray counting

Using SOI-APD for the counting type pixel array.

Avalanche mechanism is helpful for soft X-ray measurements.

Thank you for your attention !