Characteristic study of silicon sensor for ILD ECAL

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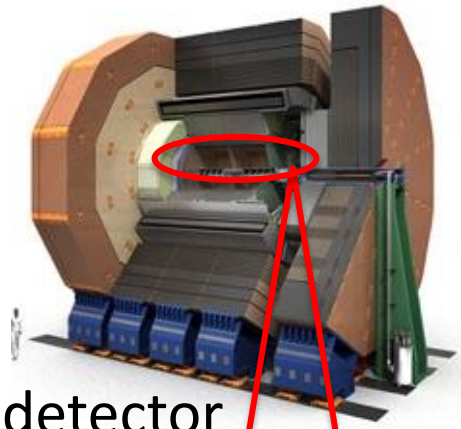
1. Introduction

Electromagnetic Calorimeter（ECAL）

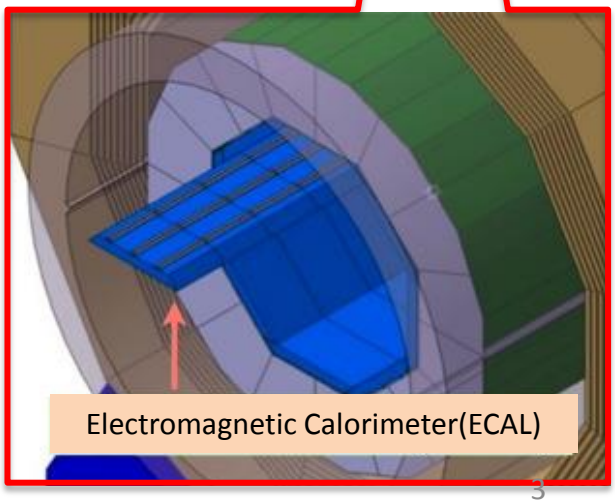
- Sampling Calorimeter

  Absorber : Tungsten

  Detector ： Silicon detector and/or Scintillation detector



- pixelization -> good particle separation
- Pixel size ： 5 mm x 5 mm

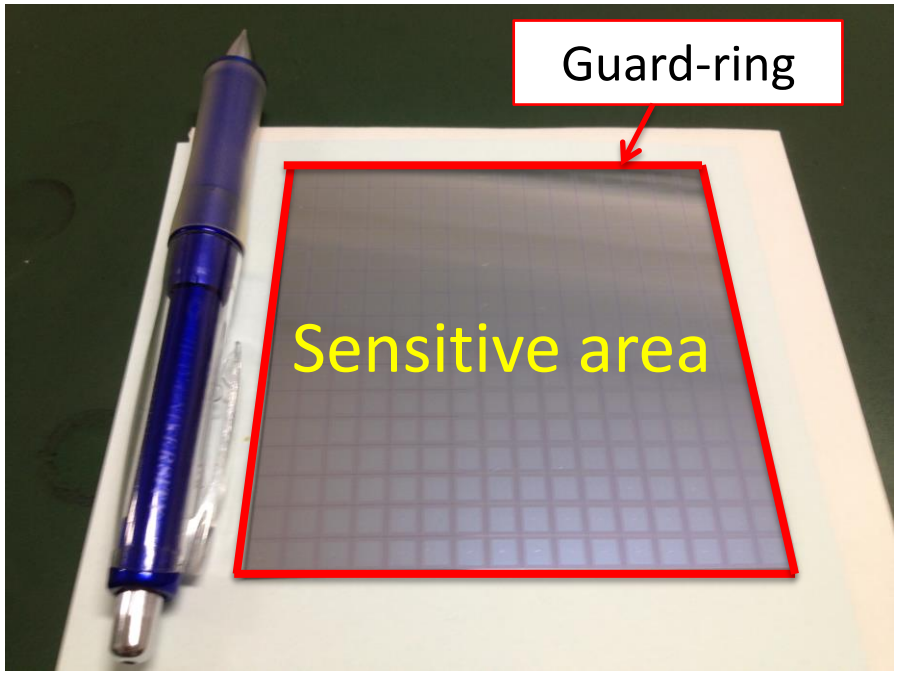


Today, I will talk about characteristic study of this silicon detector.

2. Pixelized silicon detector

Pixelized silicon detector(Si-pad)

- Produced by Hamamatsu Photonics.
- Pixel size : 5.5 mm x 5.5 mm
- Thickness : 320 μm
- 16 x 16 pixels



※Some chips have guard-ring.

Advantage : Collect surface current, prevent an electric discharge, etc.
Disadvantage: Decrease sensitive area, arise crosstalk, etc.

Motivation

Studying characteristics of silicon sensors for optimization

-Measuring crosstalk caused by guard-rings

-Measuring crosstalk between pixels

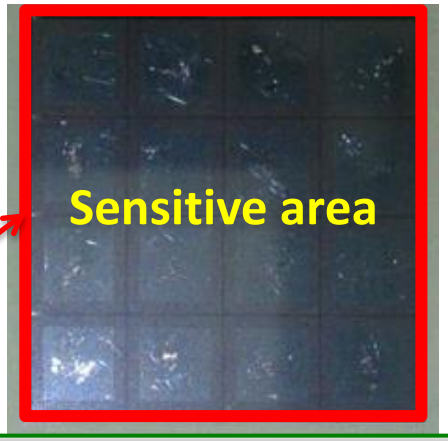
2. Pixelized silicon detector

baby chip(to compare guard-rings)

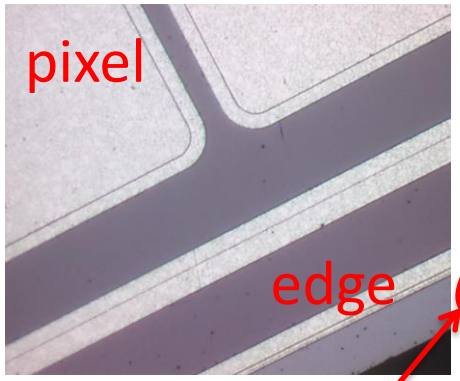
These chips can compare the effect of guard ring.

Pixel size : 5.5 mm x 5.5 mm Thickness: 320μm

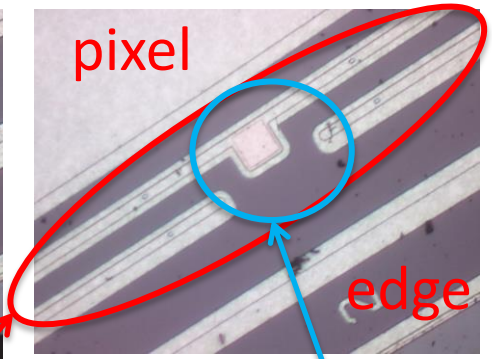
4 x 4 pixels



no guard-ring



2 guard-rings

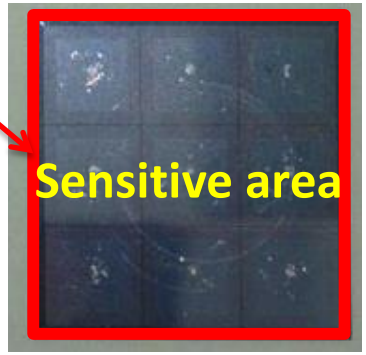


Guard-ring

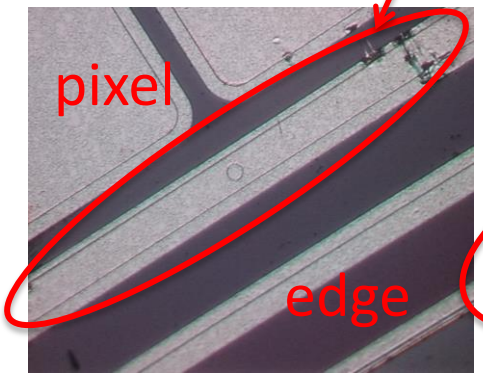
Guard-ring

Split(alternately)

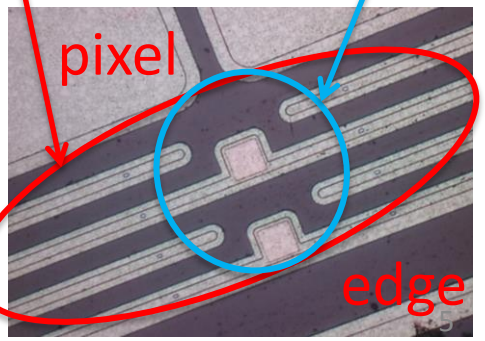
3 x 3 pixels



1 guard-ring

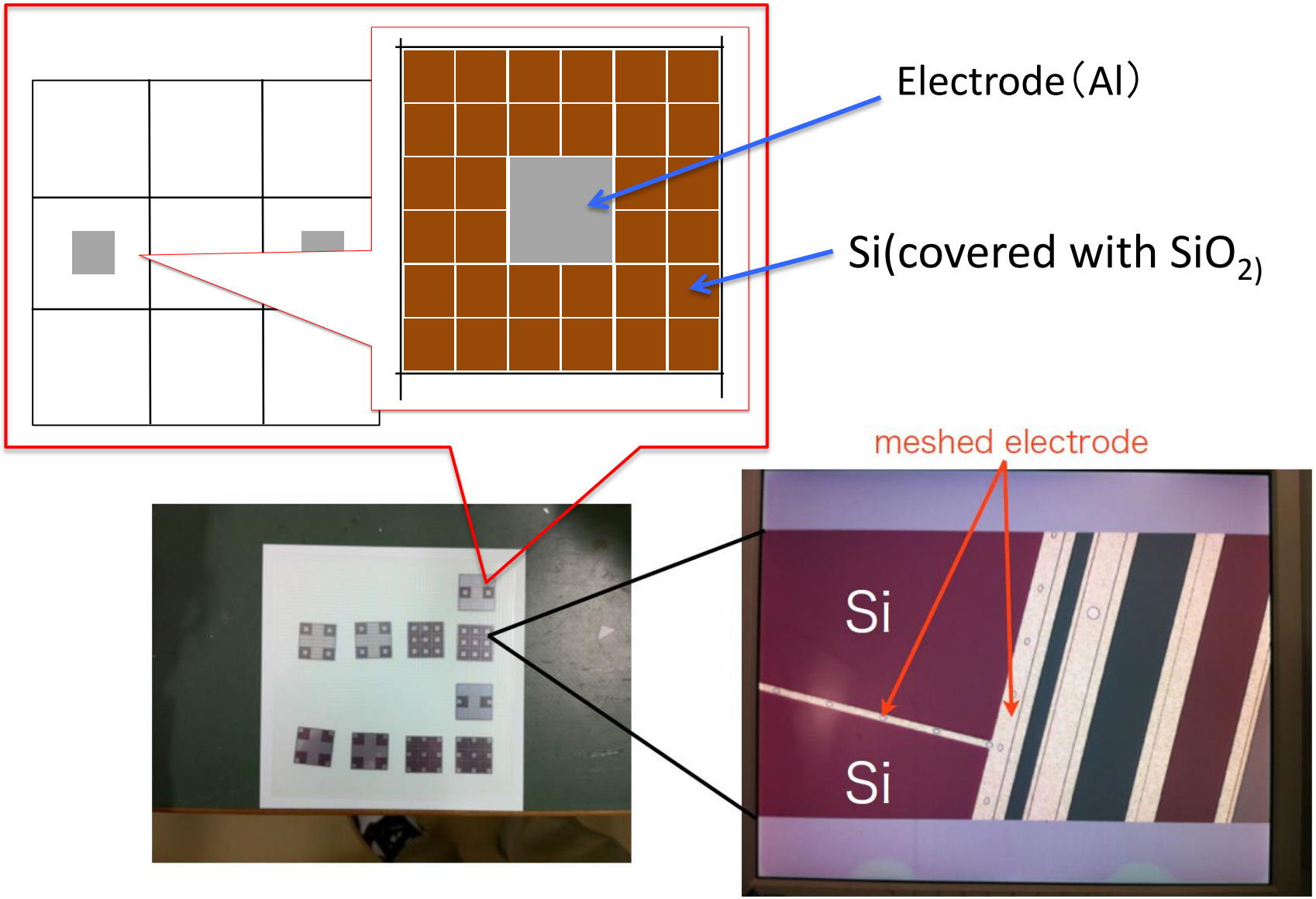


4 guard-rings



2. Pixelized silicon detector

baby chip with meshed pixels for laser injection inside pixels



3. Measurement

We performed two kinds of measurements.
(Guard-ring is not grounded.)

3-1 Temperature and humidity dependence

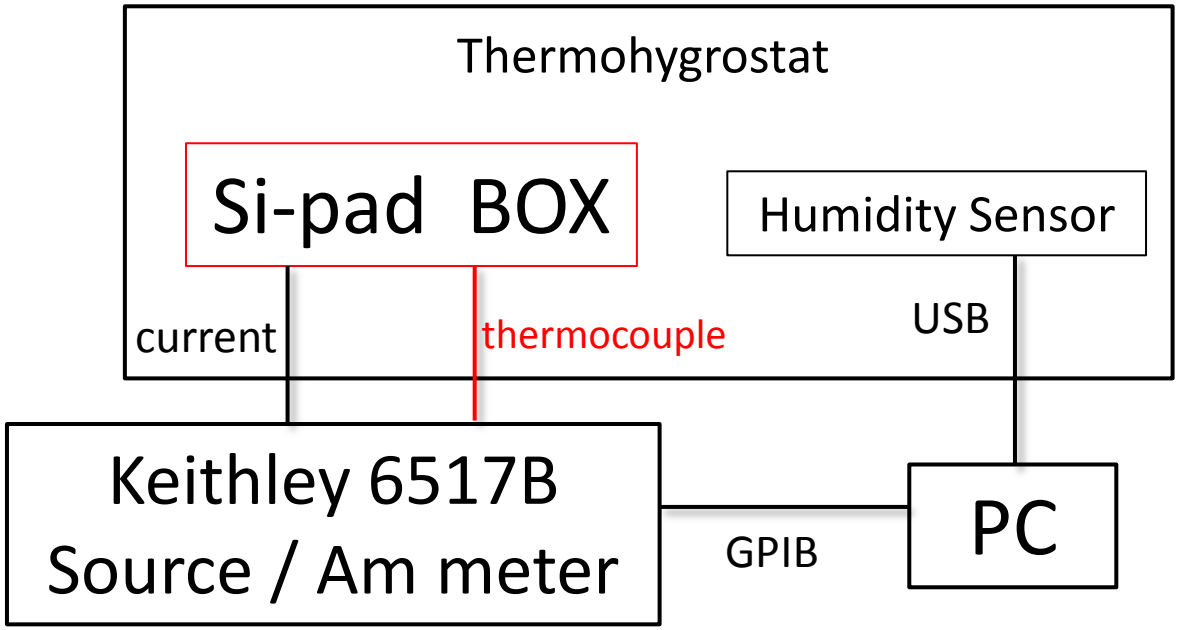
Measurement of temperature and humidity dependence on dark current of Si-pad.

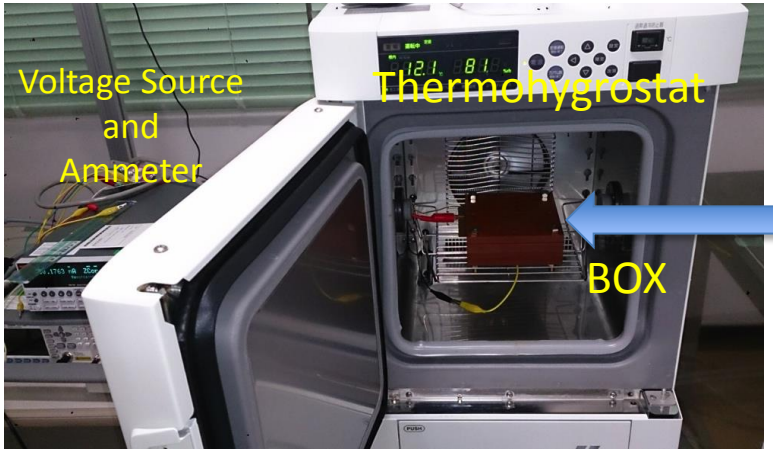
3-2 Laser injection

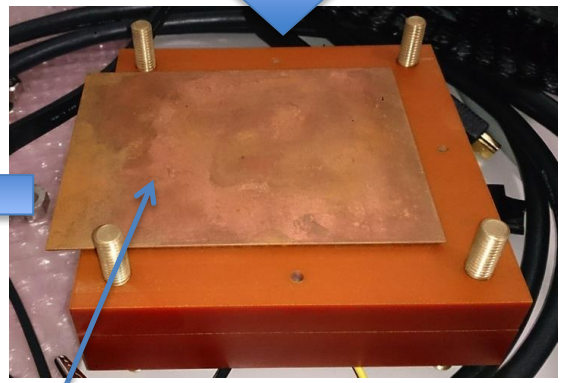
Measurement of laser injection for Si-pad.

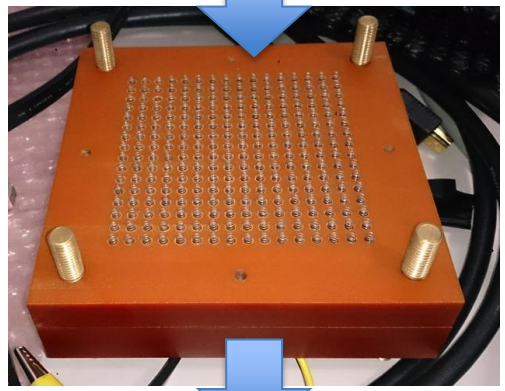
- To the edge of the sensors (to see guard-ring effect)
- Inside pixels (to see inter-pixel crosstalk)

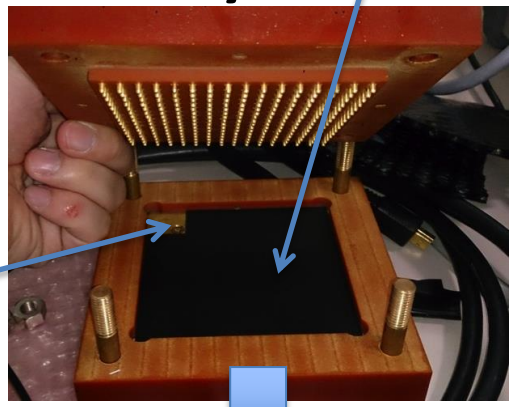
3-1 Temperature and Humidity dependence





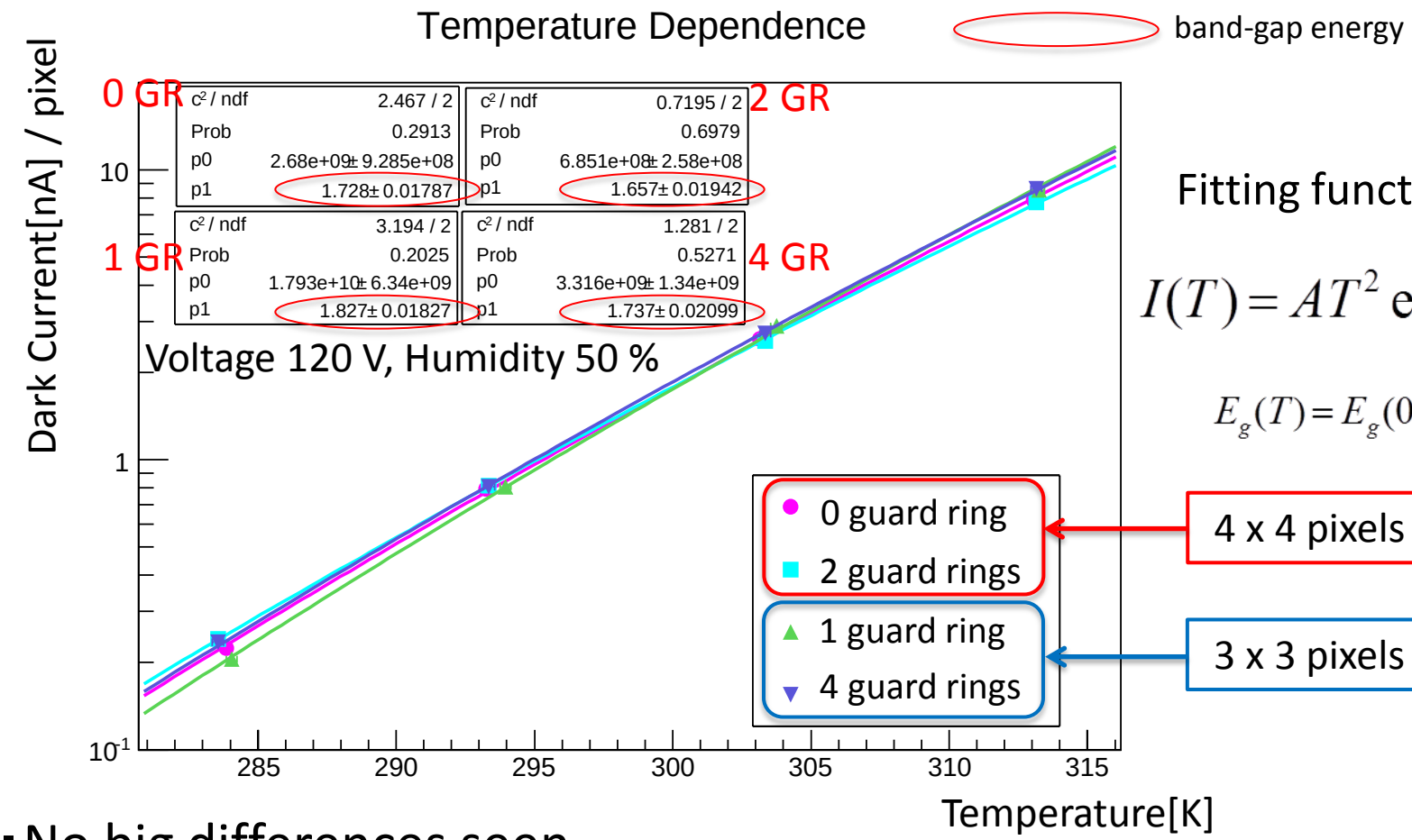






Copper sheet

Result of Temperature dependence



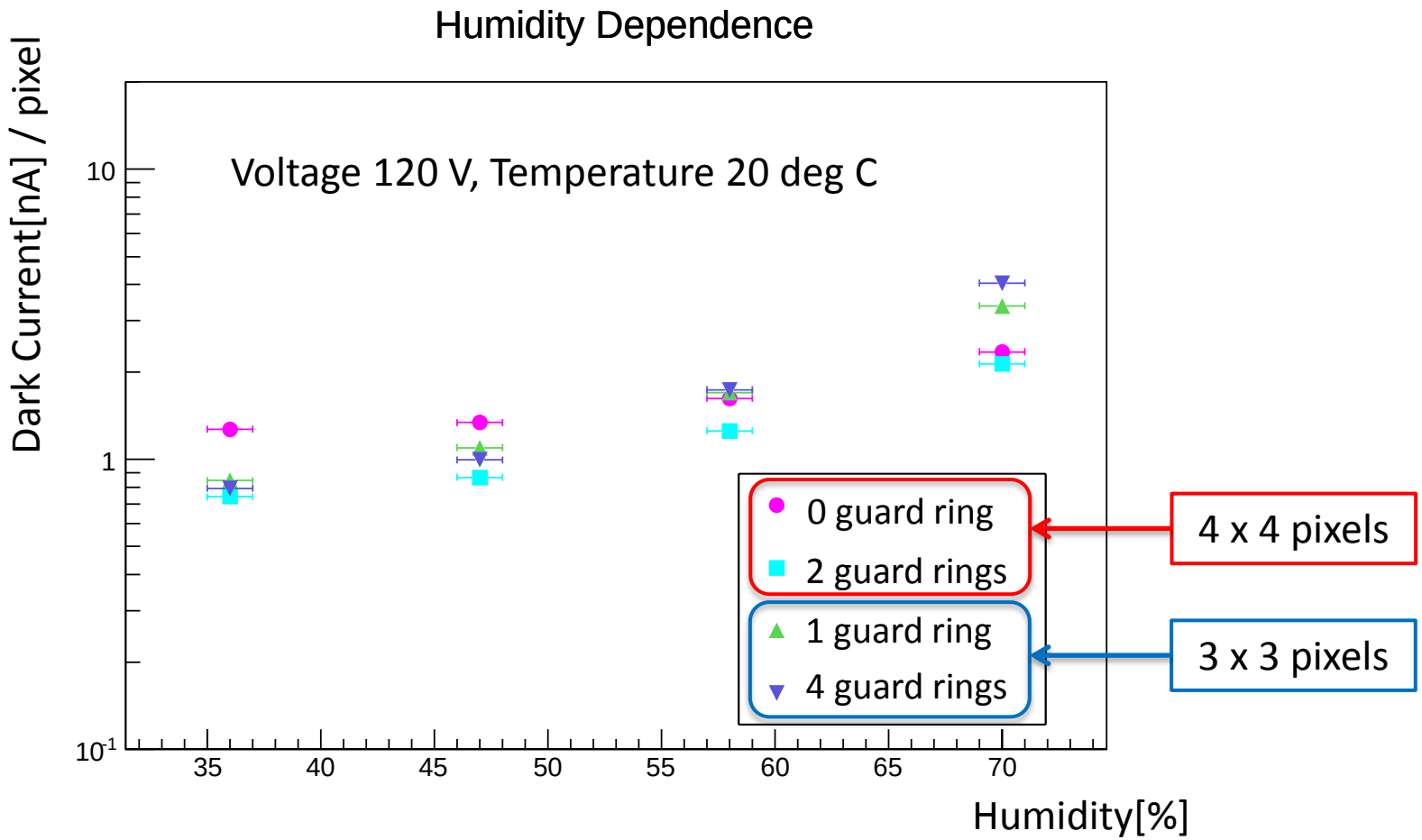
Fitting function

$$I(T) = AT^2 \exp\left(-\frac{E_g(T)}{2k_B T}\right)$$

$$E_g(T) = E_g(0) - \frac{\alpha T^2}{\beta + T}$$

- No big differences seen
- Silicon's band-gap energy $E_g(0)$ is 1.166 eV, but this result doesn't consistent. (For all type of guard ring, fitting parameter $p1 \approx 1.7$.)
  - Perhaps this is caused by effect of current from edge.

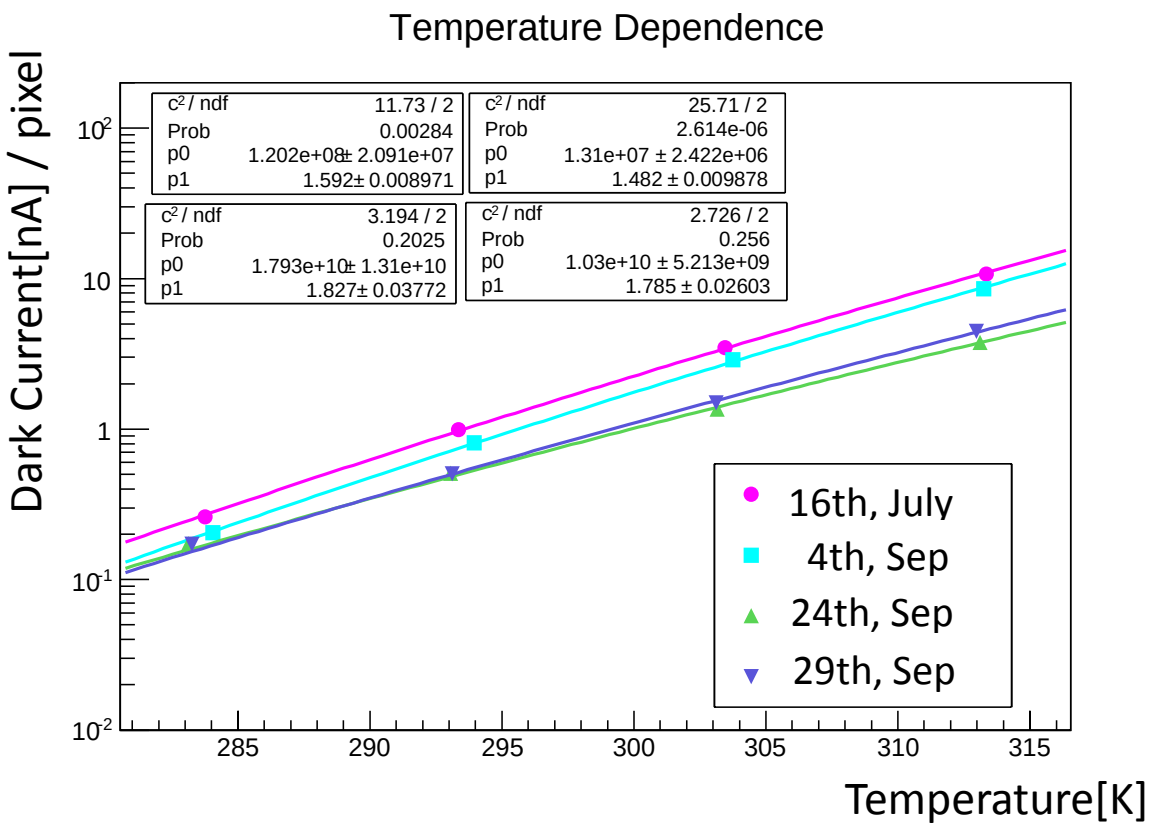
Result of Humidity dependence



- No big difference seen
- As humidity increase, dark current tend to increase. (unknown reason)

Problem

Example : result of 1 guard ring
(Temperature dependence)



・Poor reproducibility seen by taking out and in the sensor from the measurement box. (should be fixed)

・This shift may be occurred by surface resistance of copper sheet. (condition is not good)

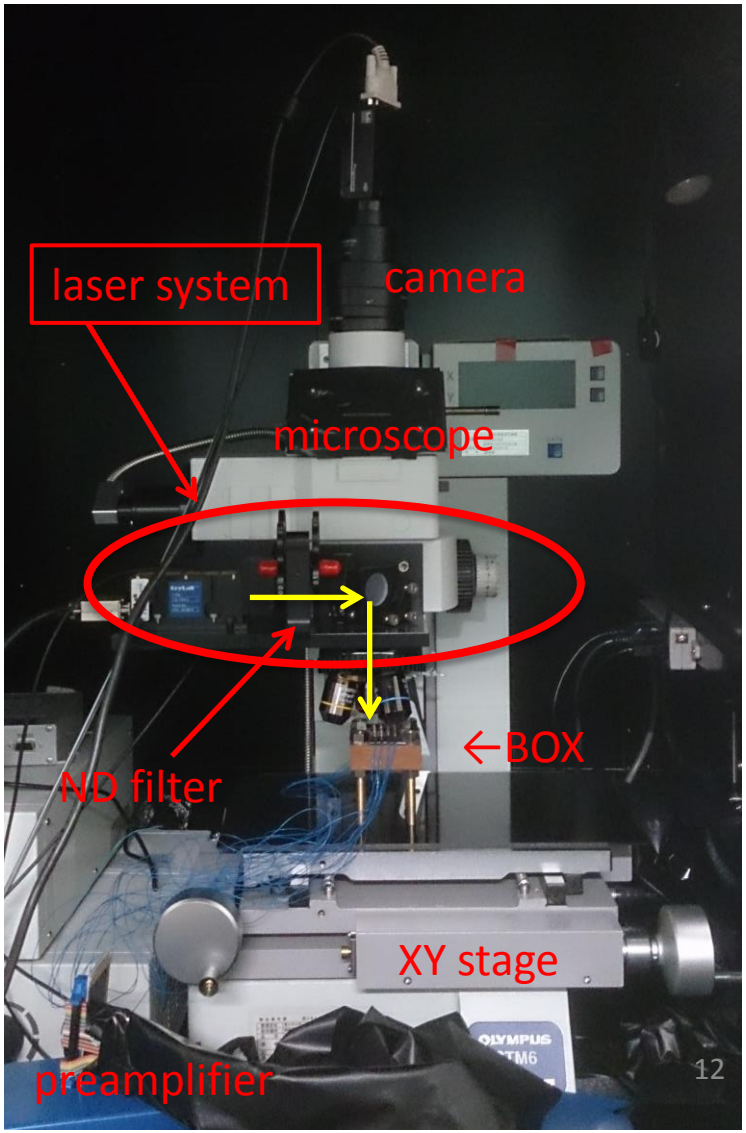
3-2 Laser injection Setup

Specification of laser

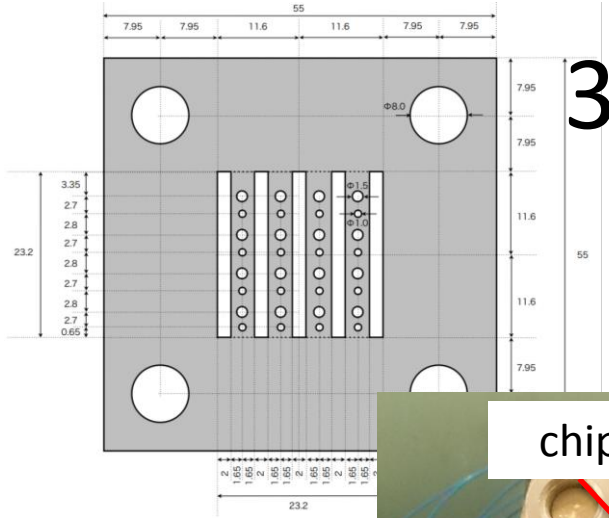
CRYLAS GmbH
DSS1064-Q2 (Class 3B)
Wave length : 1064 nm
Pulse width : ~ 1.5 ns
Pulse energy : > 20μJ/pulse
~ 10^{14} photons/pulse
Peak power : > 13kW -> use ND filter
Reputation rate : 1 kHz
Laser spot size : < 20 μm

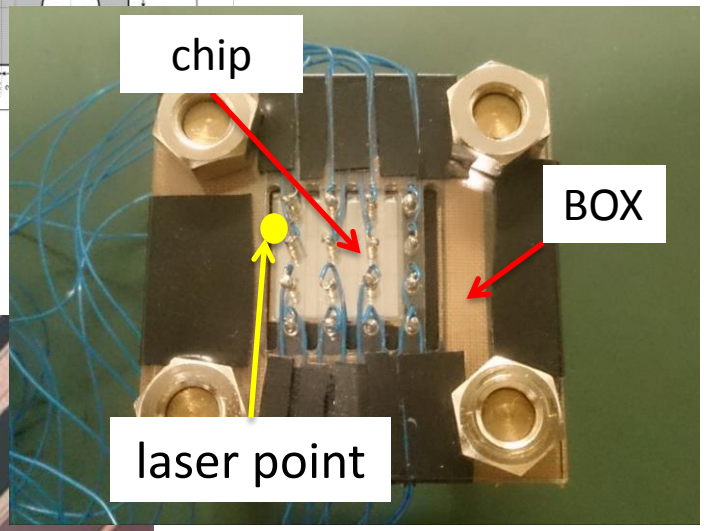
1064nm = 1.16 eV
（※Silicon ‘s band-gap energy is 1.12 eV）

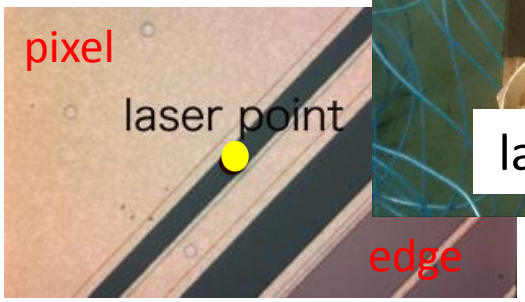
A photon can product an electron-hole pair.

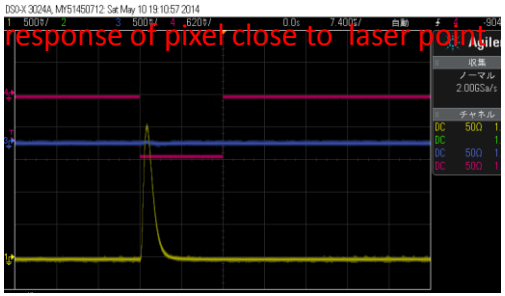


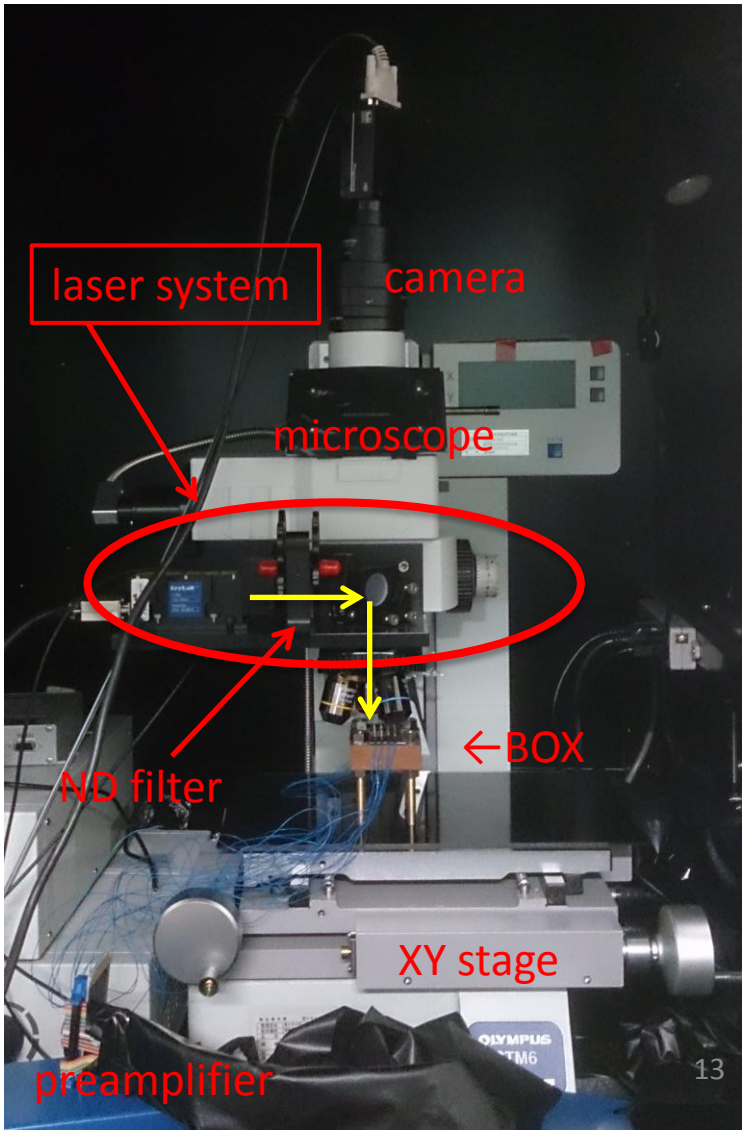
3-2 Laser injection Setup



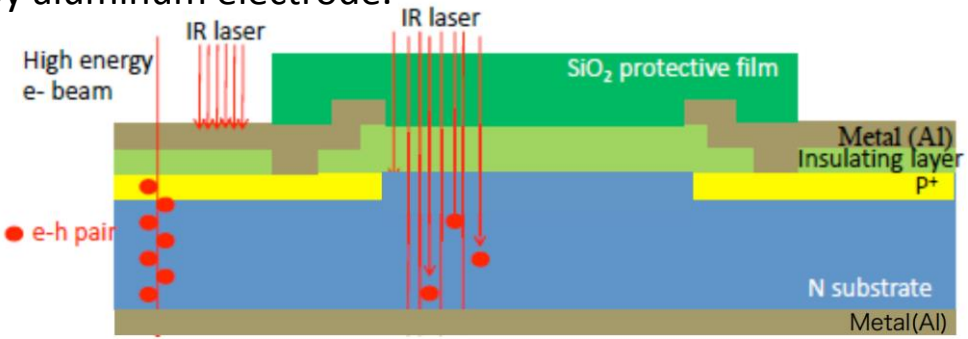








・The Laser is irradiated to gap because pixels are covered by aluminum electrode.

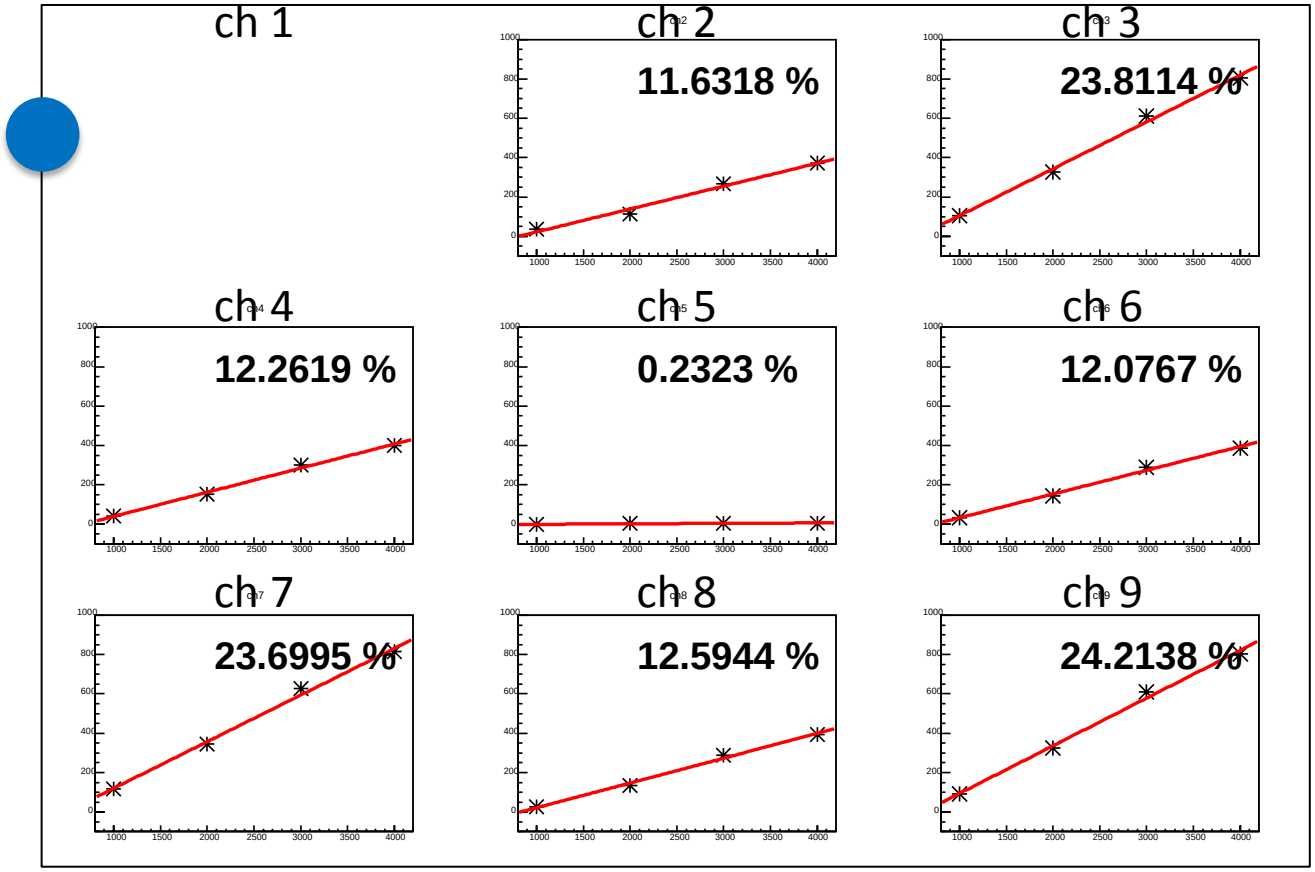


3-2-1 Injection to the edge

Results of 1 GR

1 guard ring

Horizontal axis : Response of ch 1 [mV] (~Laser Power)
Vertical axis : Response of each pixel[mV]

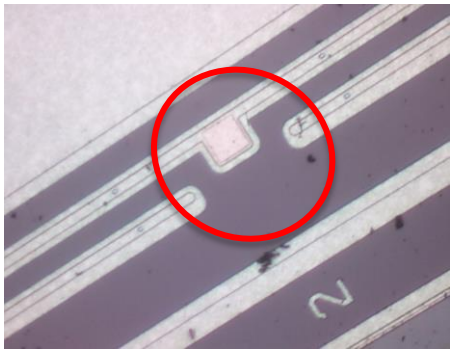


Laser point

- Crosstalk was seen because current flows along the guard ring.
- We are able to get reproducible results.

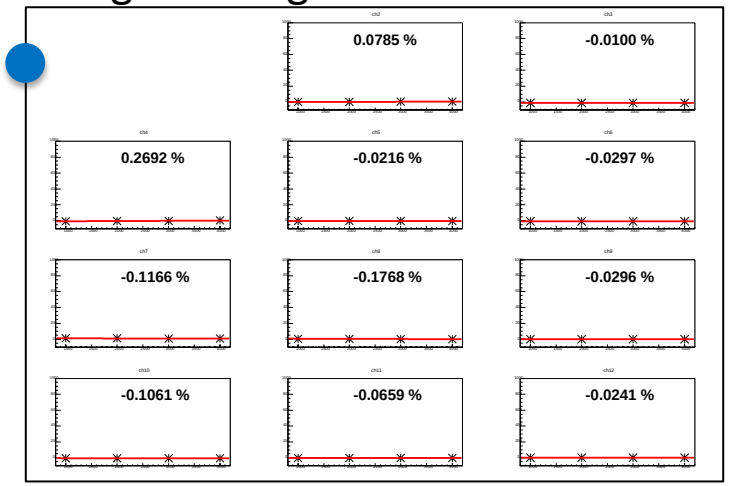
3-2-1 Injection to the edge

Results of Others

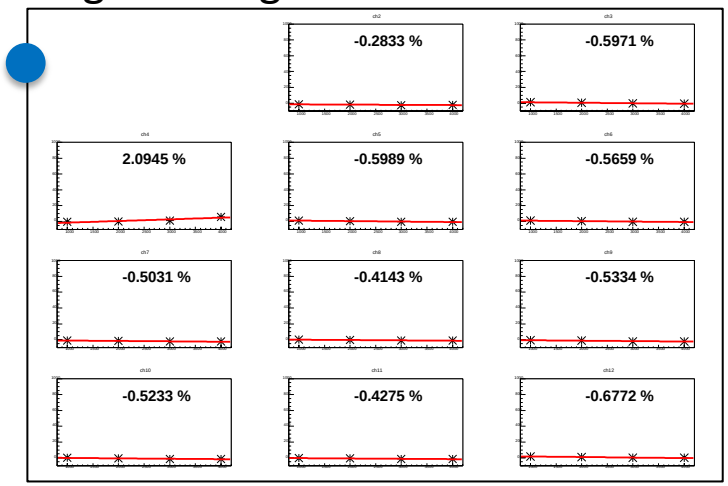


Horizontal axis : Response of ch 1 [mV] (~Laser Power)
Vertical axis : Response of each pixel[mV]

no guard ring

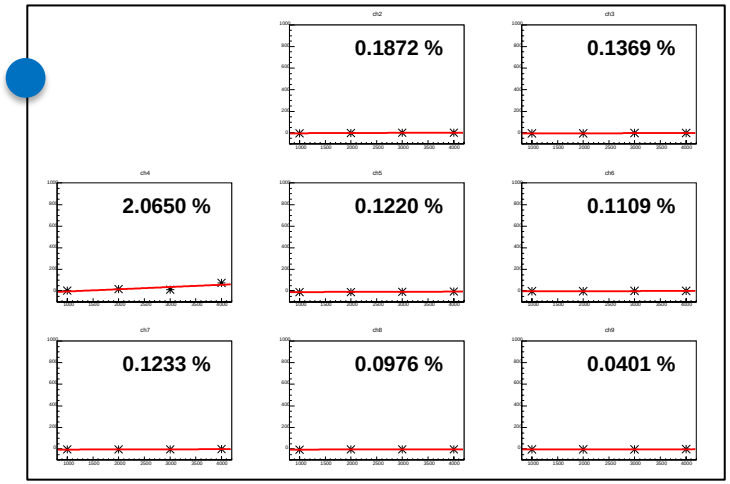


2 guard rings



Laser point

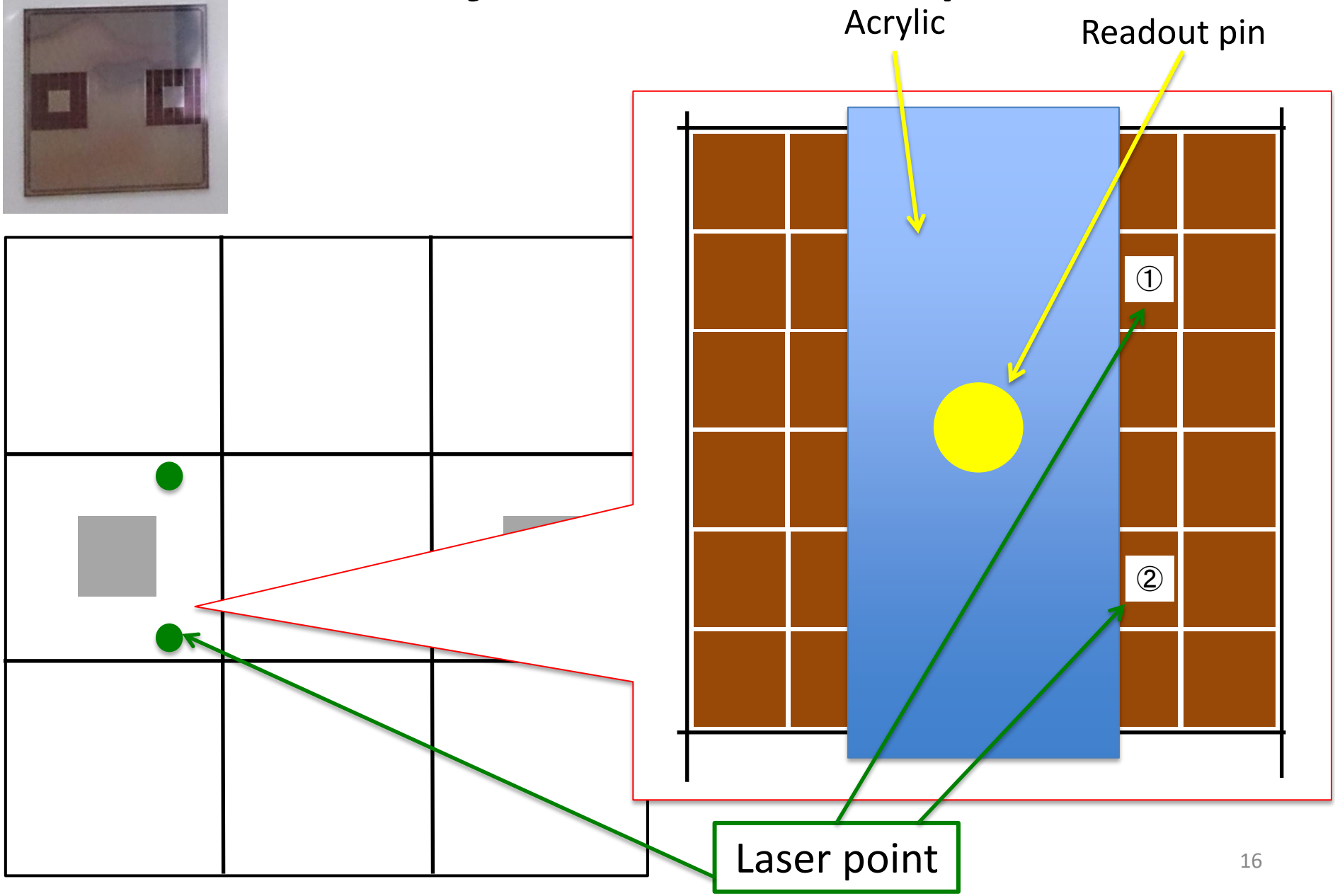
4 guard rings



- There are no significant crosstalk because
  - Si-pad doesn't have guard ring.(no GR)
  - Guard rings are separated.(2,4 GR)

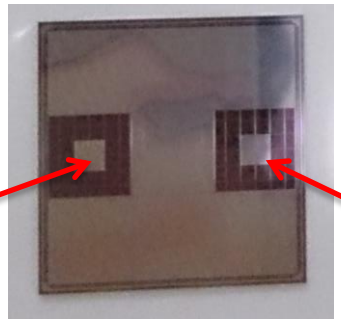
So current cannot flow to other channels.

3-2-2 Injection inside pixels



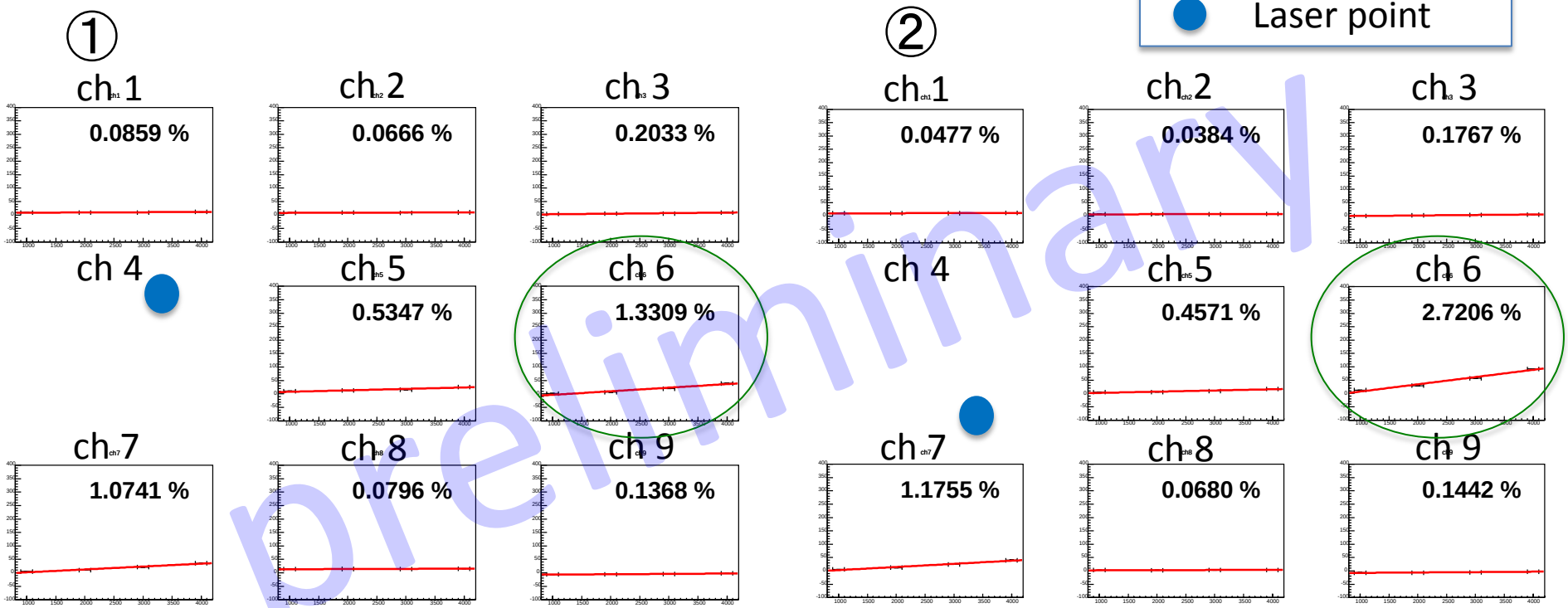
3-2-2 Injection inside pixels

Results



Horizontal axis : Response of ch 4 [mV] (~Laser Power)
Vertical axis : Response of each pixel [mV]

Laser point



preliminary

- Almost all channels, crosstalk < about 1%
- Optical crosstalk seen at ch 6 -> to be fixed

4. Summary & Conclusion

Temperature and Humidity dependence

- No significant difference is seen among guard-ring types.
- Reproducibility have to be improved.

Laser injection at the edge

- Crosstalk is seen at the 1 guard-ring type (floating).
- Crosstalk is not seen at 0/2/4 guard-rings.

4. Summary & Conclusion

Laser injection inside the pixels

- Crosstalk between pixels is at 1 percent level.
- Optical separation must be improved.

Conclusion

- Currently we do not see any disadvantages in no guard-ring sensors.
- Crosstalk from the guard-ring should be avoided.

5. Plan

Measurement of

- Meshed electrode chip (continue)
- Grounded guard ring
- Thicker chip

backup

Band-gap energy is also depend on temperature.

$$E_g(T) = E_g(0) - \frac{aT^2}{T+b}$$

$$I(T) = AT^2 \exp(-\frac{E_g}{2k_B T})$$

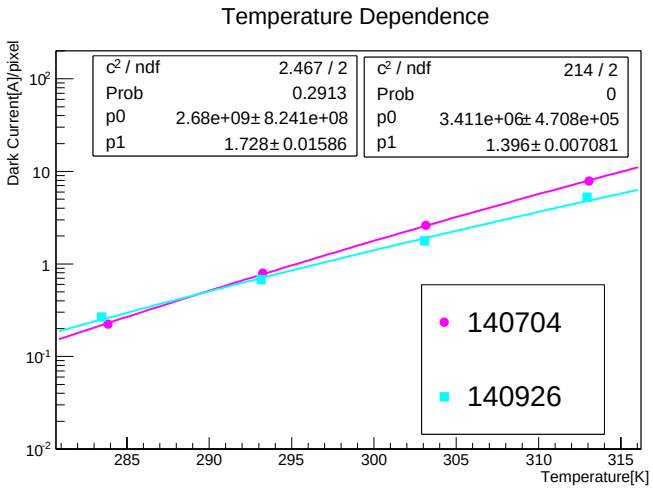
Silicon

$E_g(0)$	1.166 eV
a	4.73 × 10^{-4} eV/K
b	636 K

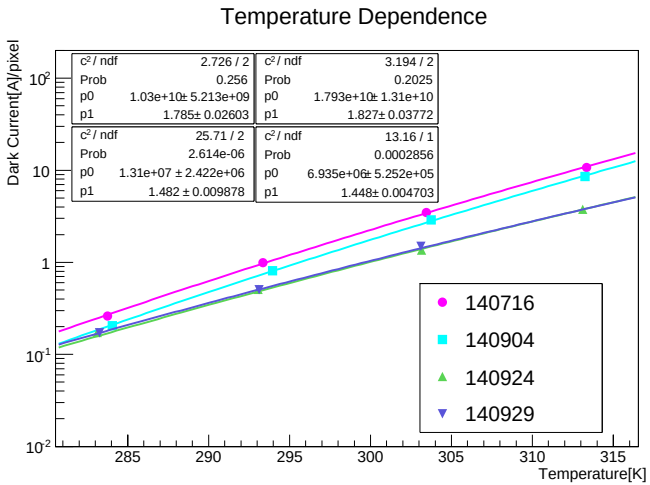
※If T=293.15 K（20℃), Eg(T) is 1.122252312….

backup

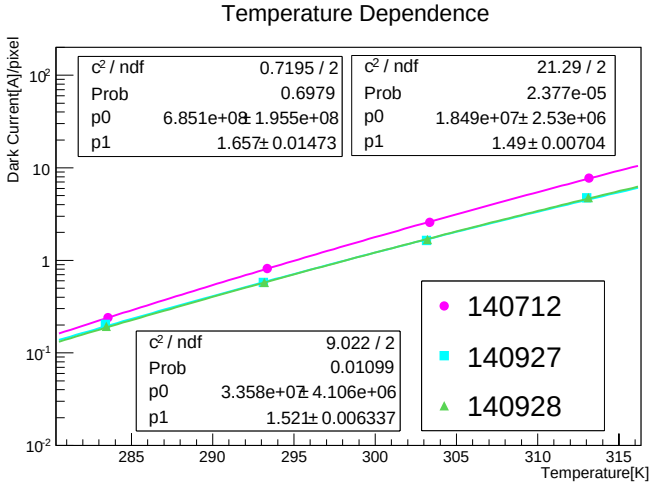
0 guard



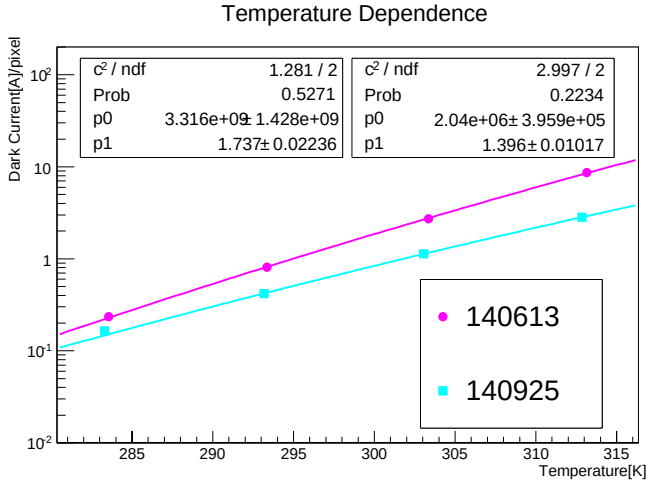
1 guard



2 guard

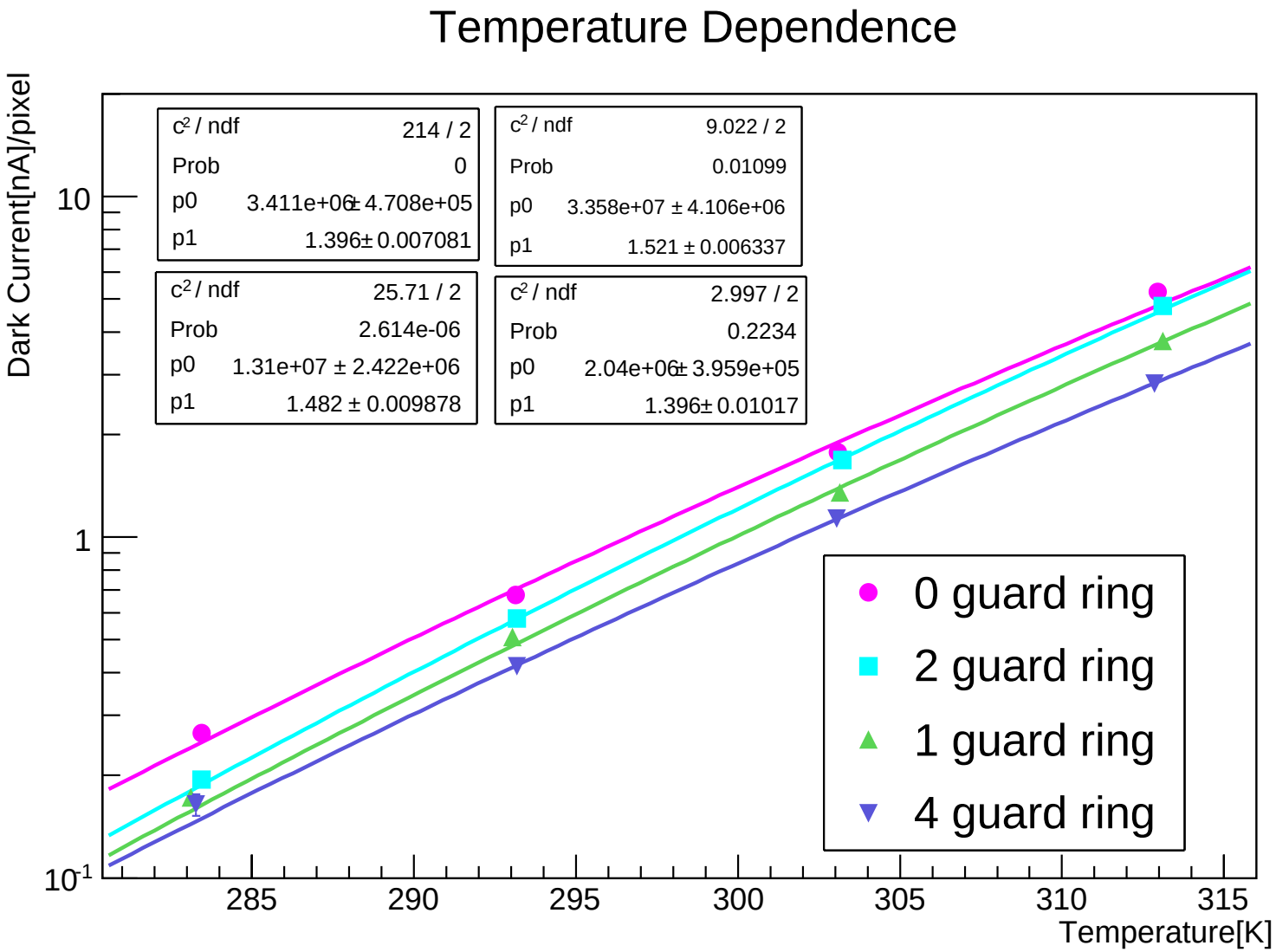


4 guard



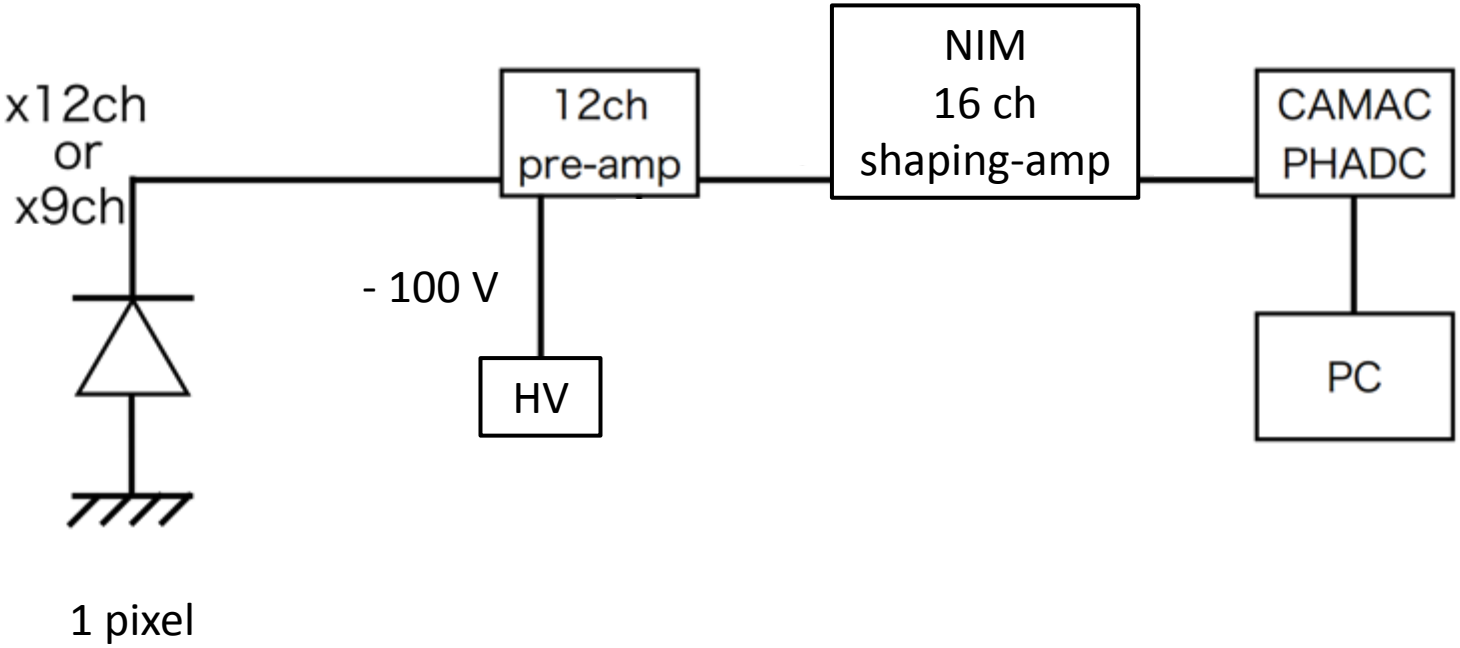
Latest version(temperature dependence)

backup



backup

Circuit(Measurement of laser irradiation)



Laser point

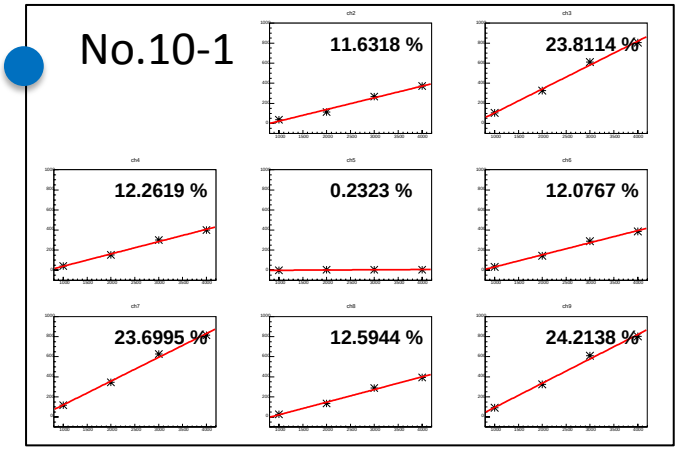
Horizontal line : Response of pixel close to laser point[mV]
Vertical line : Response of each pixel[mV]

backup

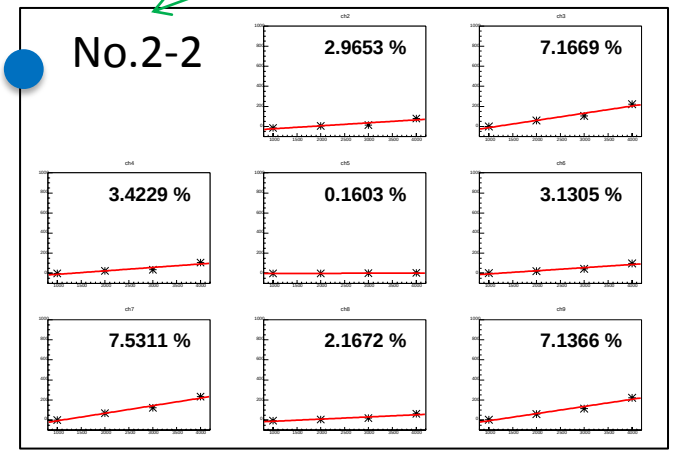
All 1 guard ring

Serial Number of Si-pad

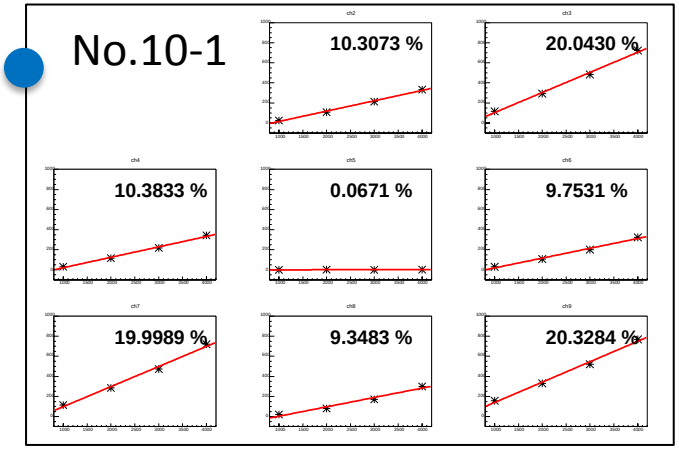
No.10-1



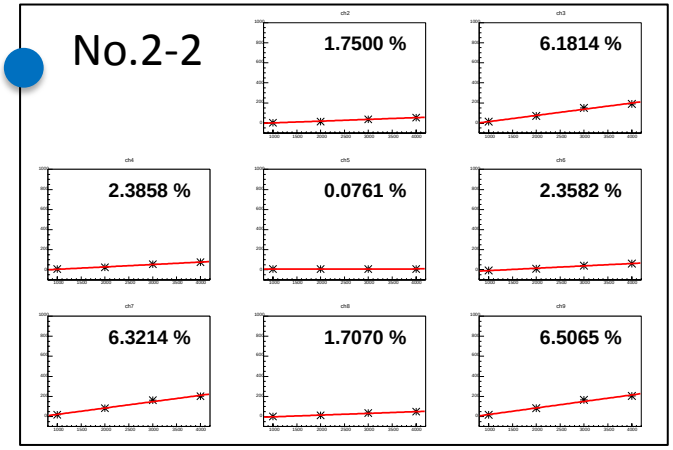
No.2-2



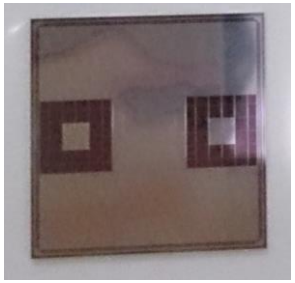
No.10-1

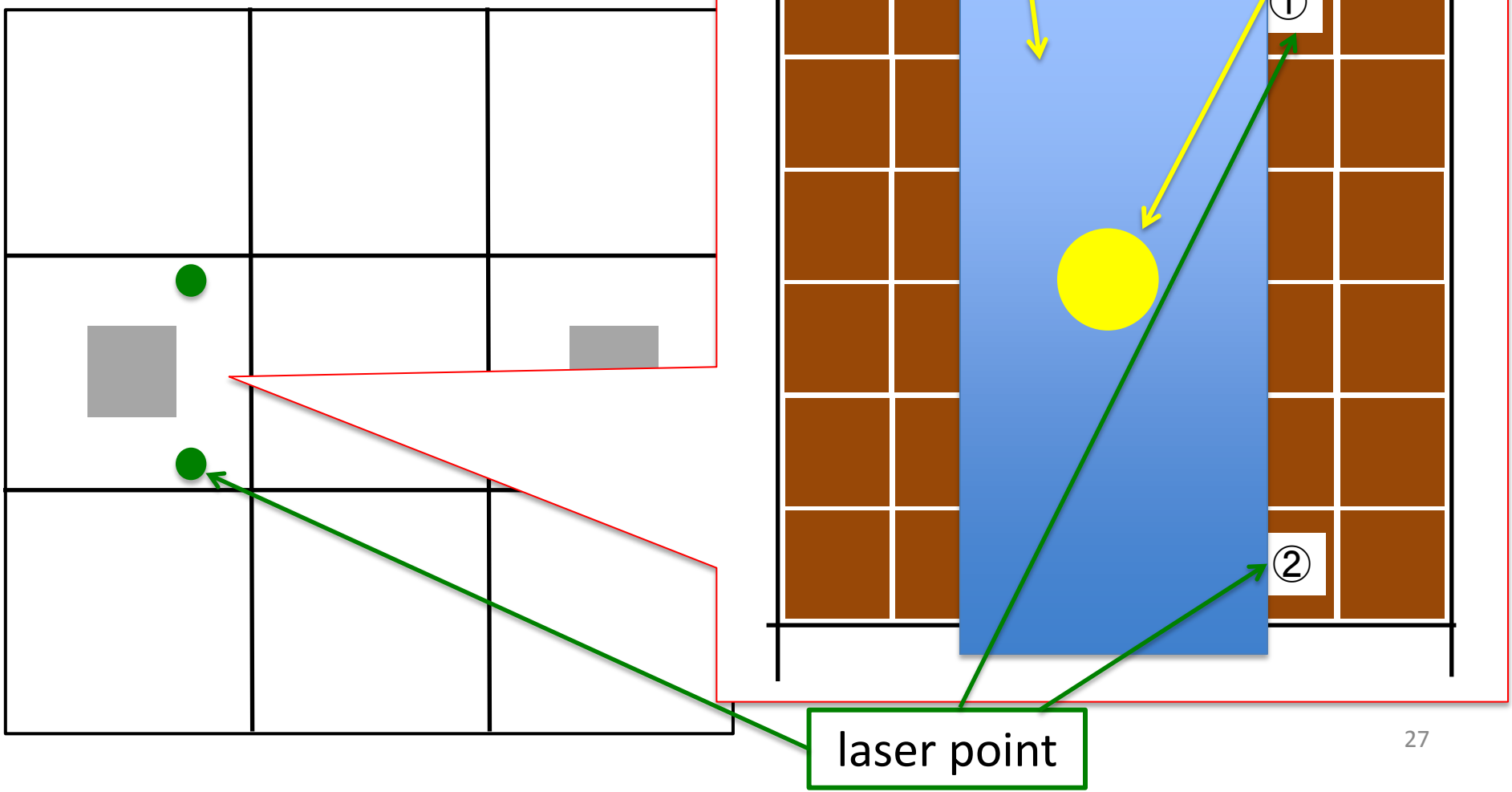


No.2-2



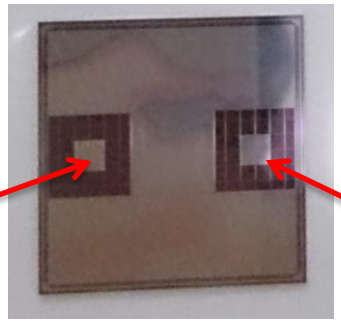
backup





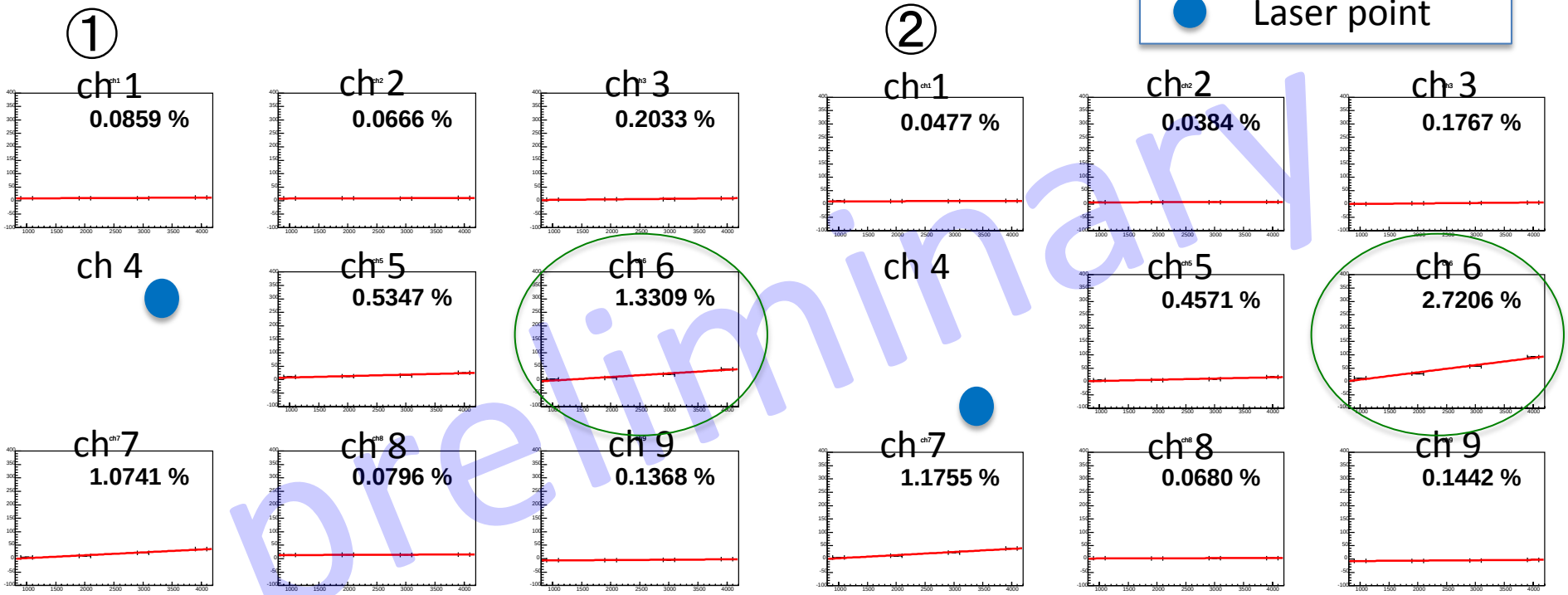
3-2-2 Inject to center of pixel

Results



Horizontal axis : Response of ch 4 [mV] (~Laser Power)
Vertical axis : Response of each pixel [mV]

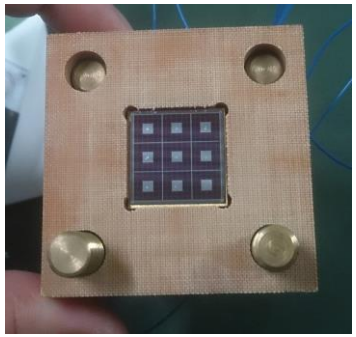
Laser point



preliminary

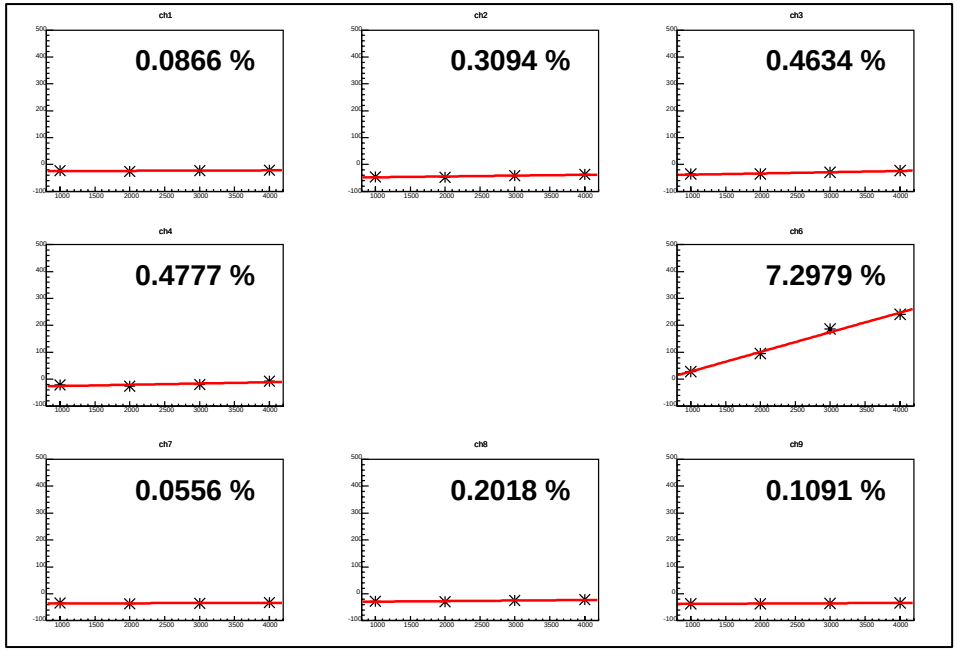
- Almost all channels, crosstalk < about 1%
- optical crosstalk seen at ch 6 -> to be fixed

backup

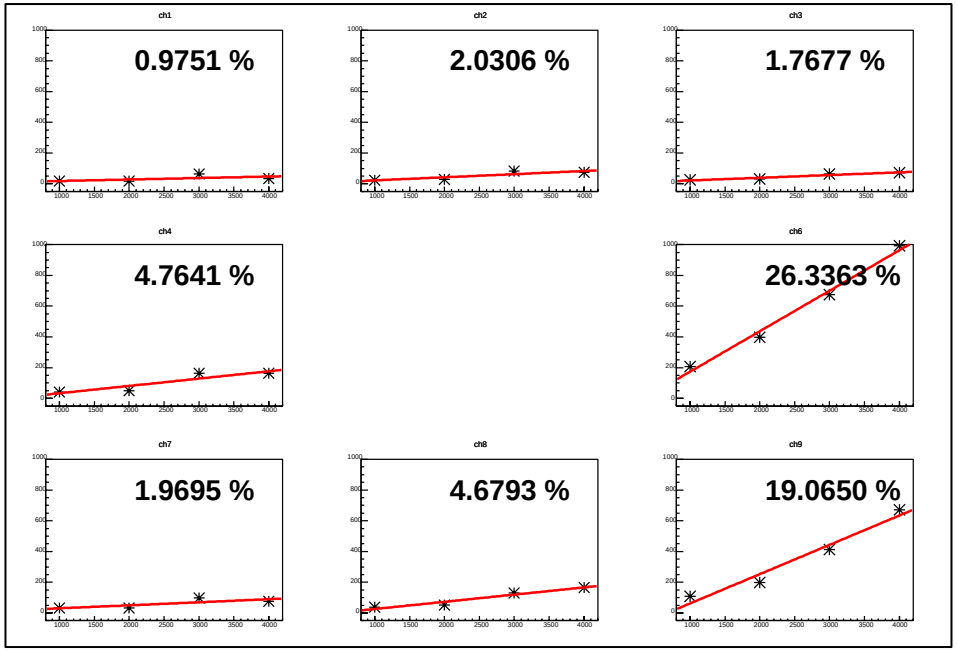


1 guard

2014/9/23

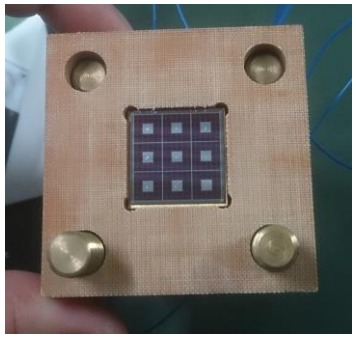


2014/9/25



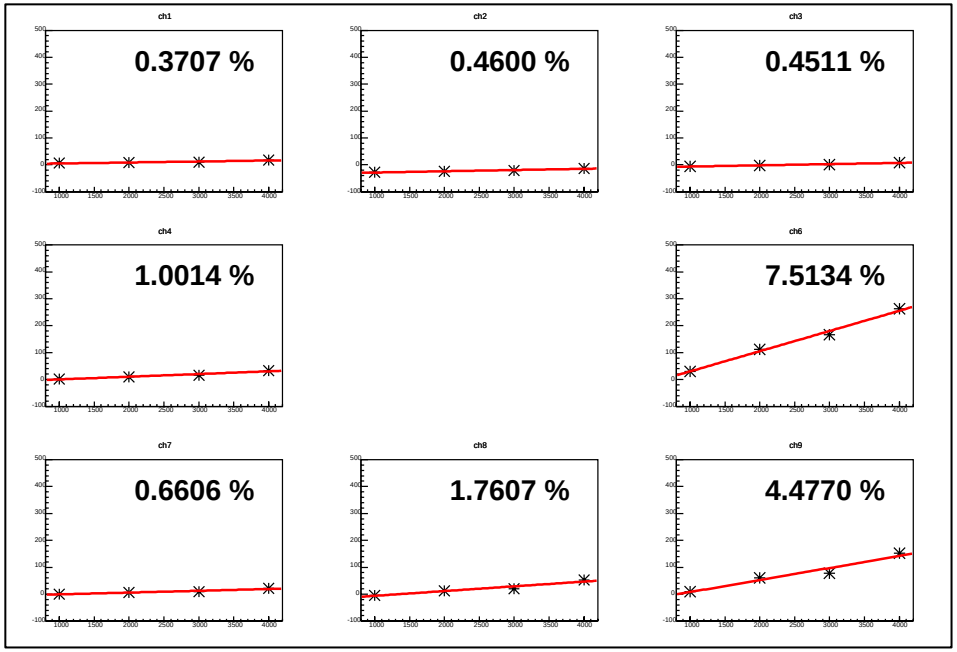
Reproducibility was not seen.
Laser is reflected by Si-pad.

backup

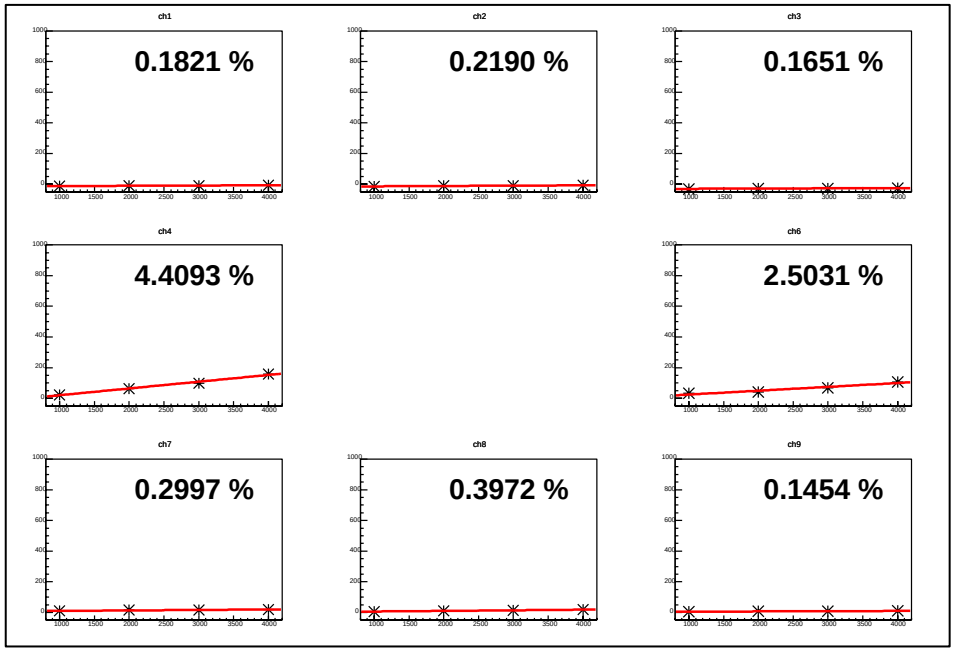


0 guard

2014/9/23



2014/9/25



Reproducibility was not seen.
Laser is reflected by Si-pad.