

# Silicon sensor study for ILD ECAL

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# Topics

- Comparison between different guard ring structures
  - leakage current and capacitance
  - response to an infrared laser
- Comparison between new prototype and old one
  - leakage current
  - capacitance ( & full depletion voltage)
- Summary and Prospects

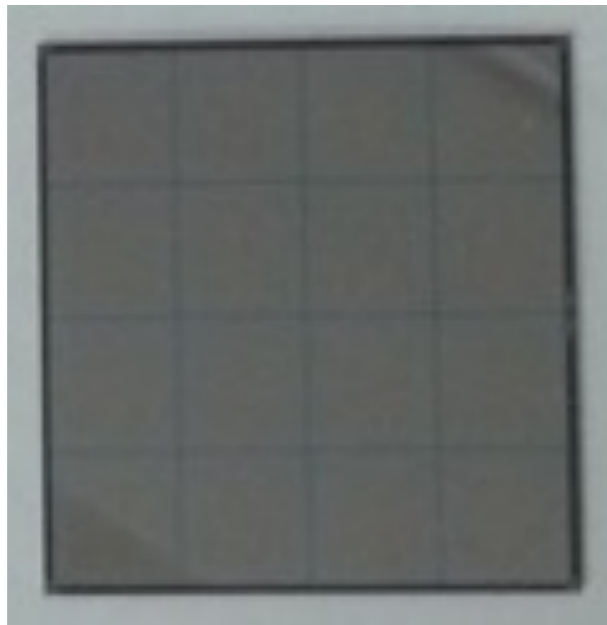
# Current situation of guard ring comparison

- We have four types of sensor (currently only in small chips).

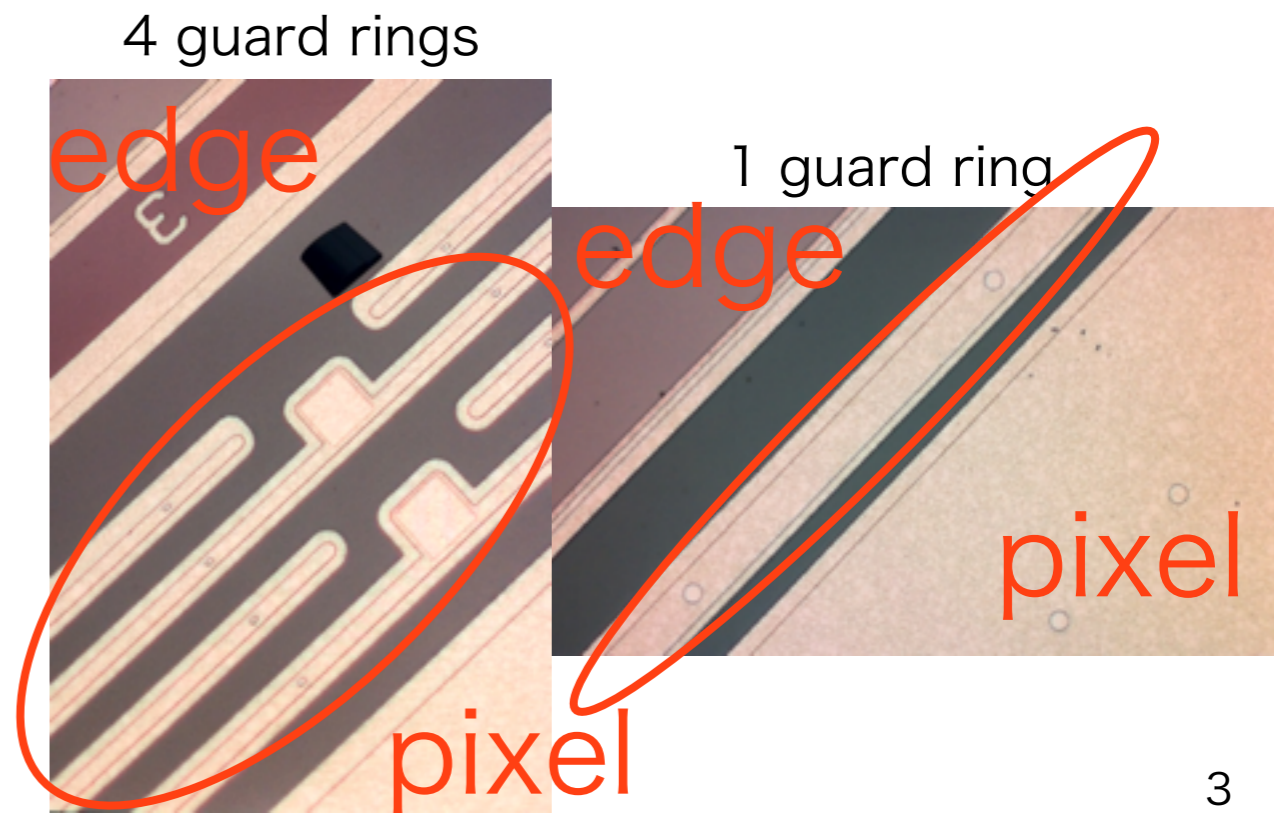
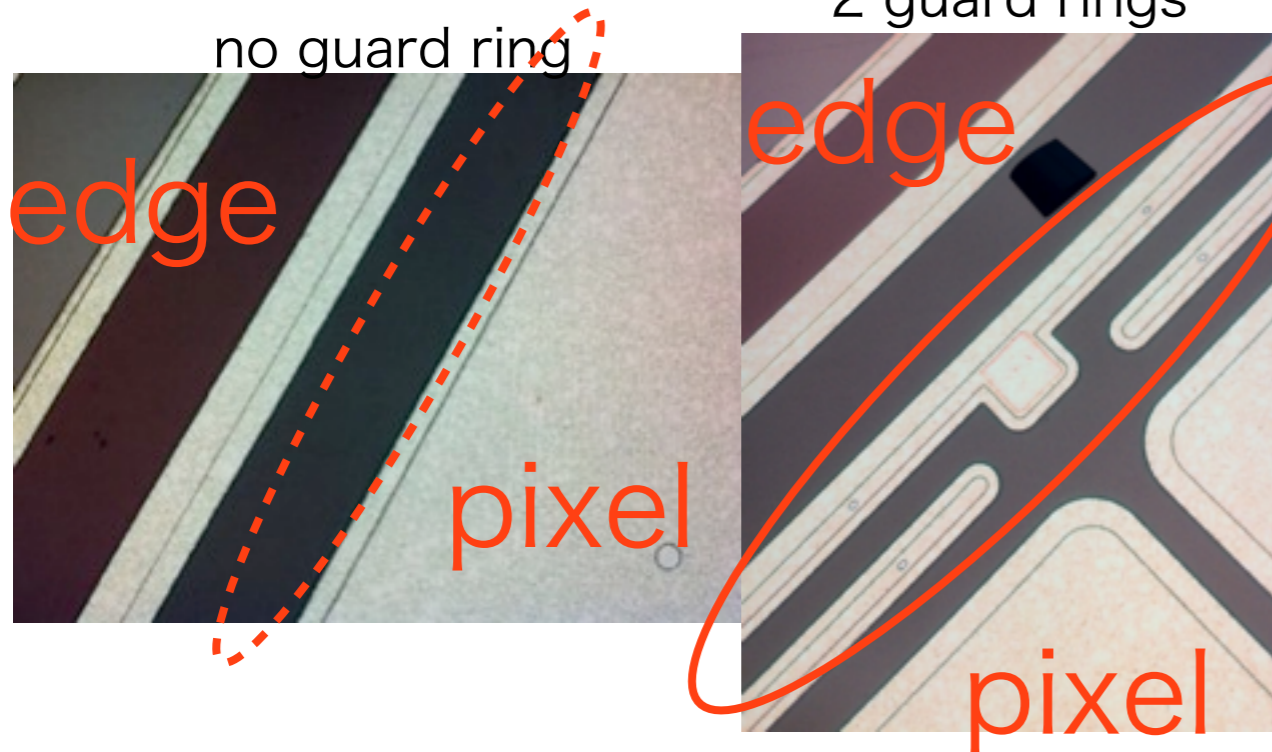
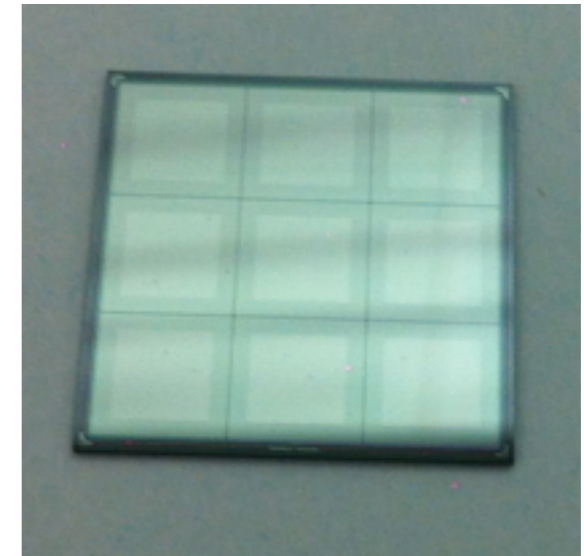
Their guard ring structures are slightly different from each other.

The guard rings can collect surface current and moderate electric field distribution of edge, but it also limits sensitive region and make non-uniformity in gap area.

4x4 sensor



3x3 sensor

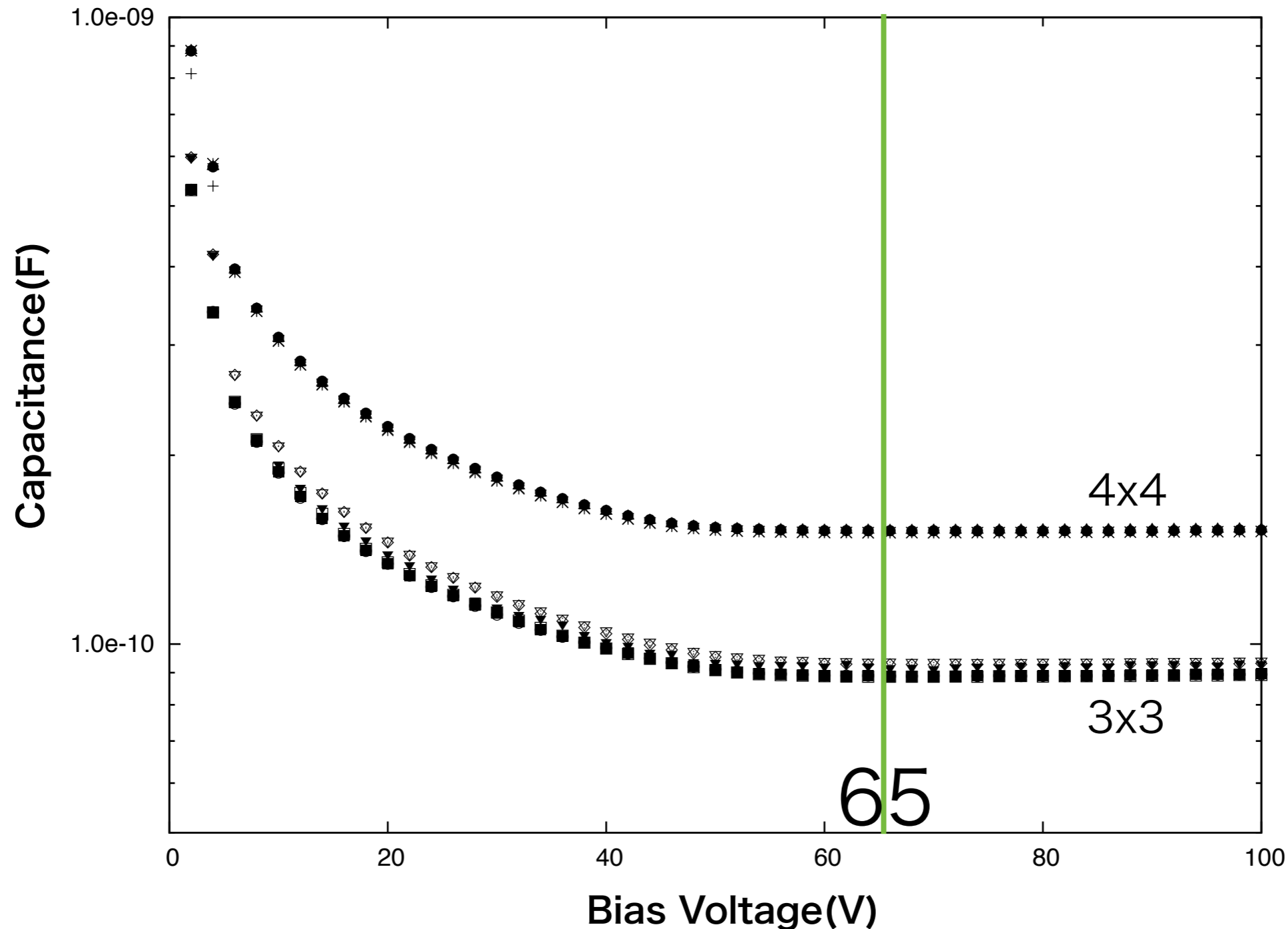


# Capacitance comparison

Since chip area is different between 3x3 and 4x4, capacitance value is slightly different.

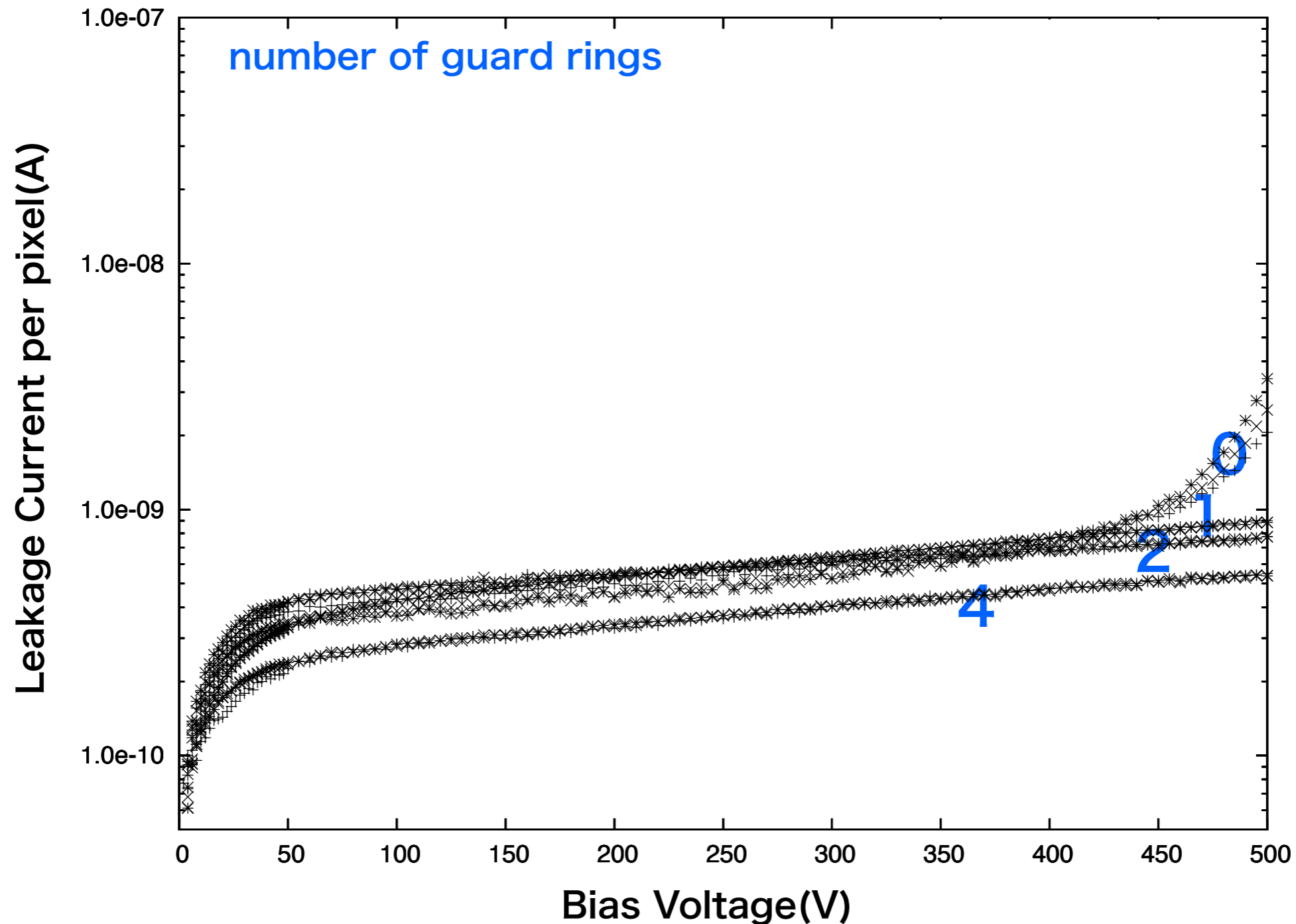
Full depletion voltage is about 65 V,

and this value is consistent with specification from Hamamatsu.



# Leakage current of small chip

- Chip leakage current is shown below.  
The shape of leakage current is almost the same in all type.  
Break down voltage is higher than current operation voltage. (120 V)



# Infrared laser system

CRYLAS GmbH

DSS1064-Q2 (Class 3B)

Wave length : 1064 nm → 1.16eV

Pulse width : ~ 1.5 ns

Pulse energy : > 20  $\mu$ J/pulse  
~  $10^{14}$  photons/pulse

Peak power : > 13kW

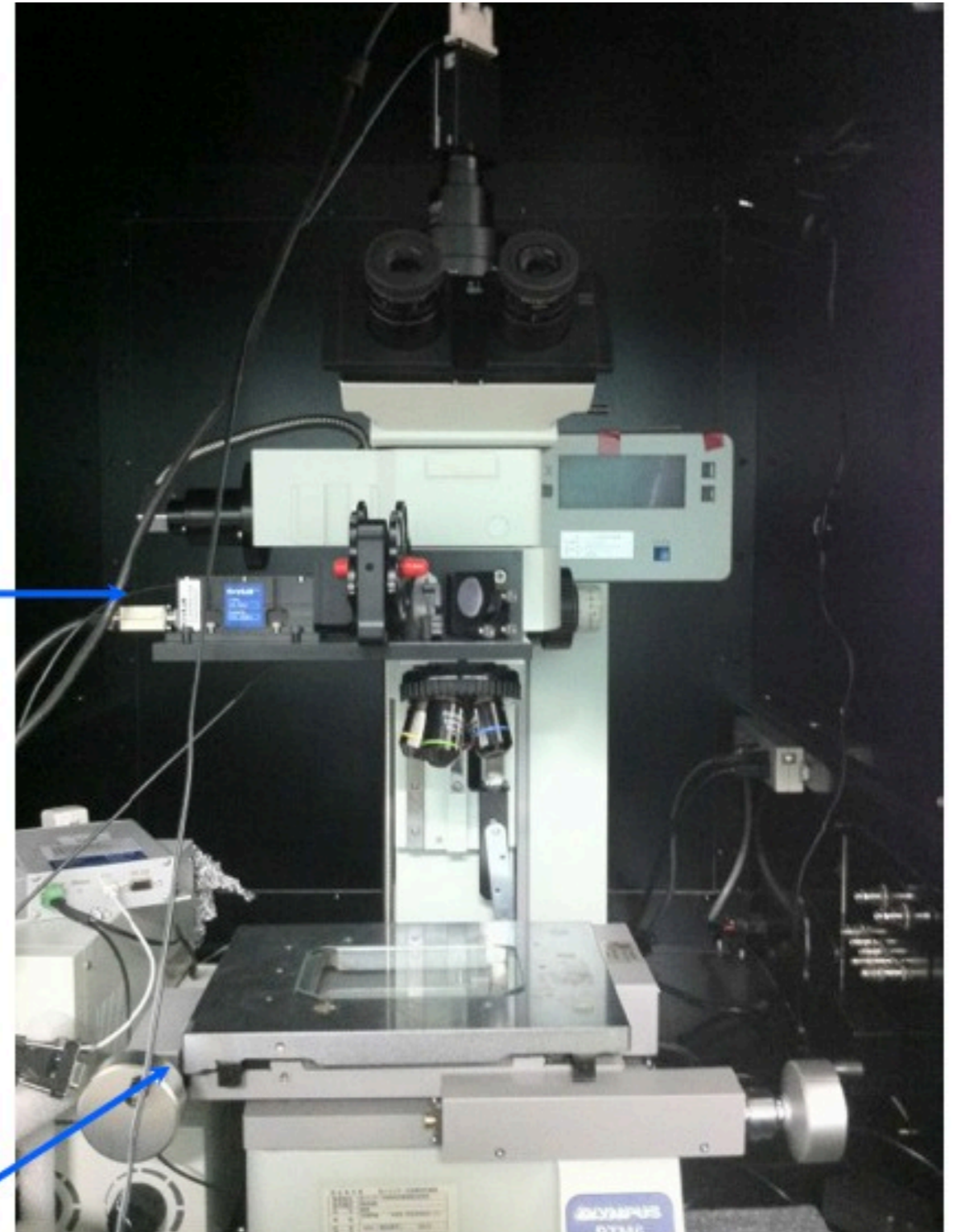
Repetition rate : 1 ~ 10kHz

Interface of the control software



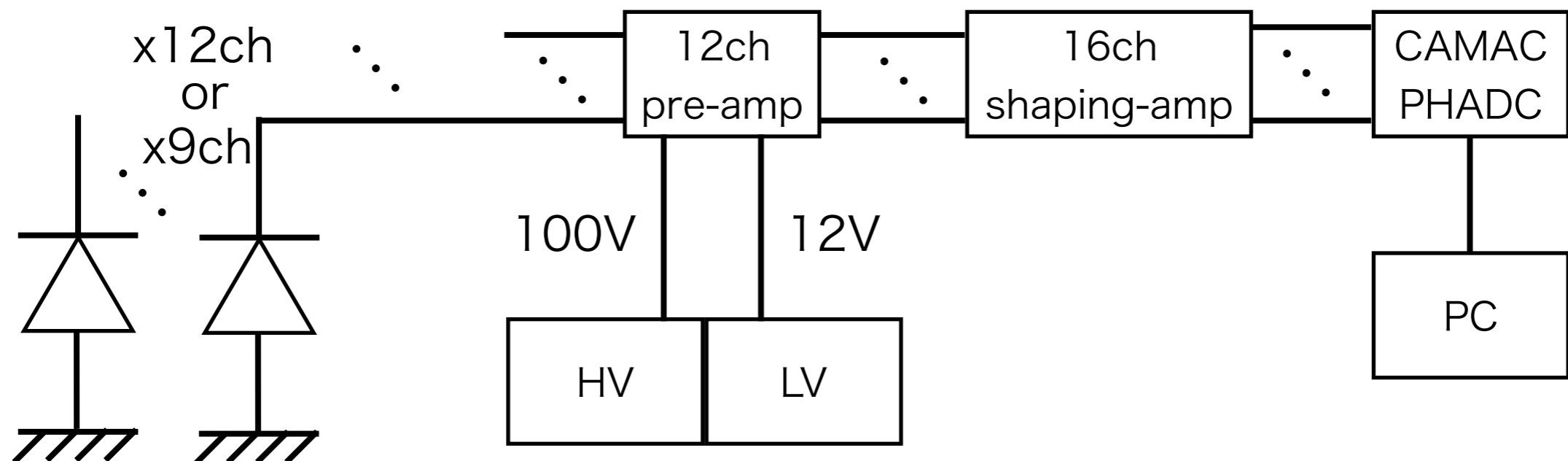
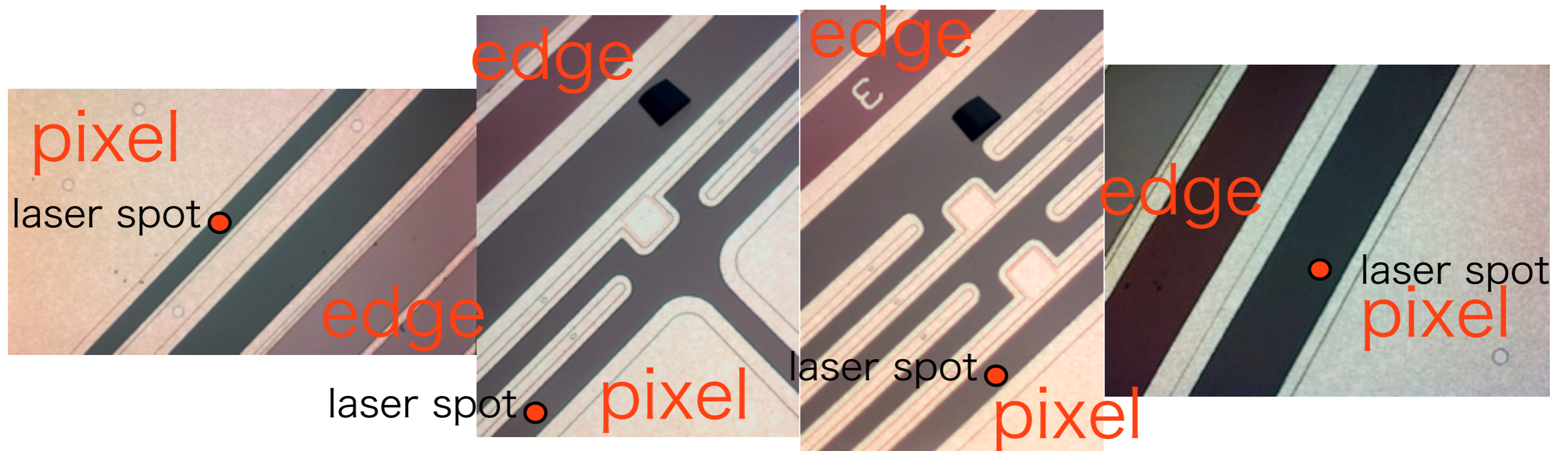
Laser  
Trigger  
ND-filters  
mirror

x-y stage

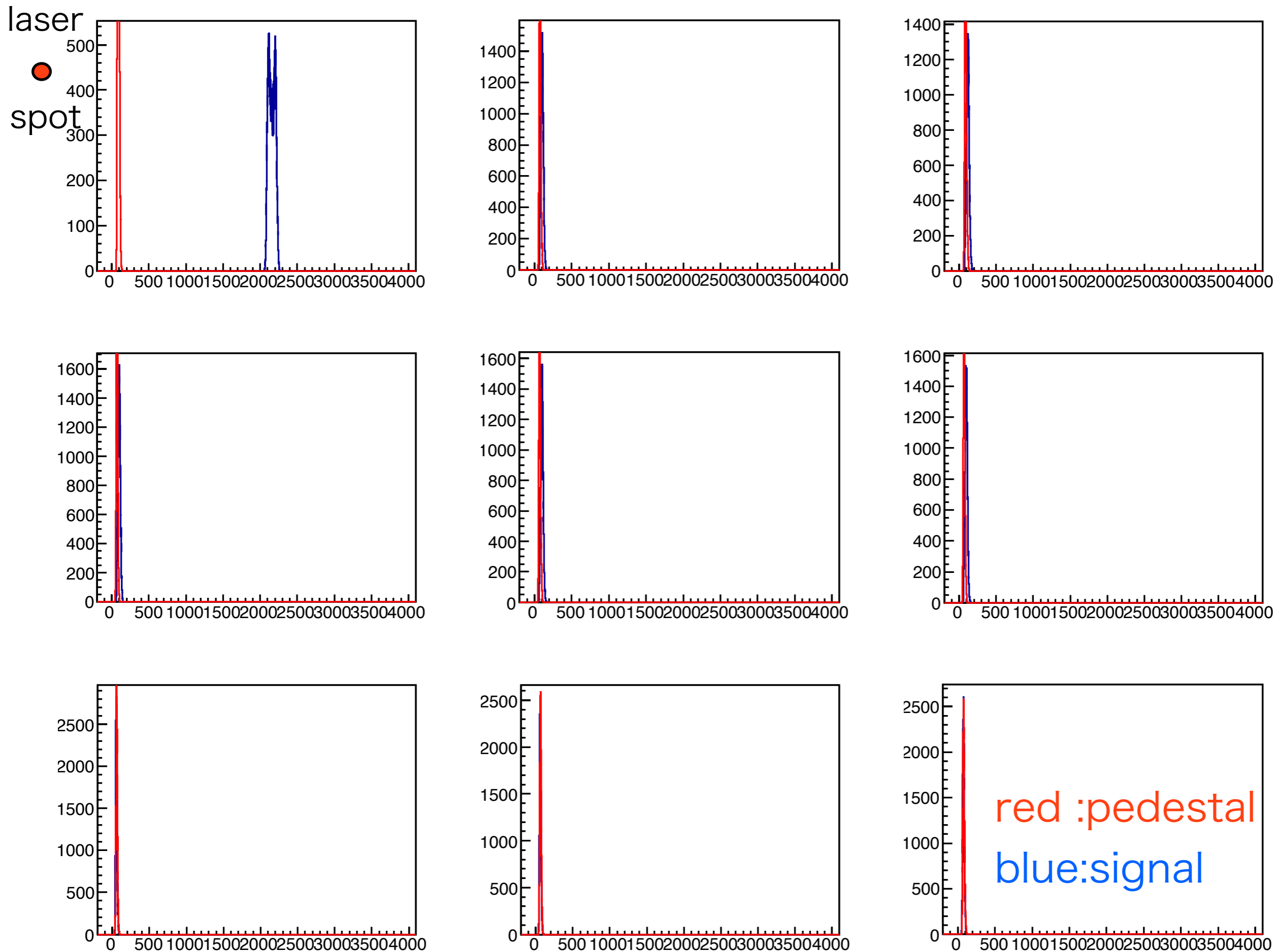


# Method

- We shoot the infrared laser between guard ring and a pixel.



# Response (4 guard rings)



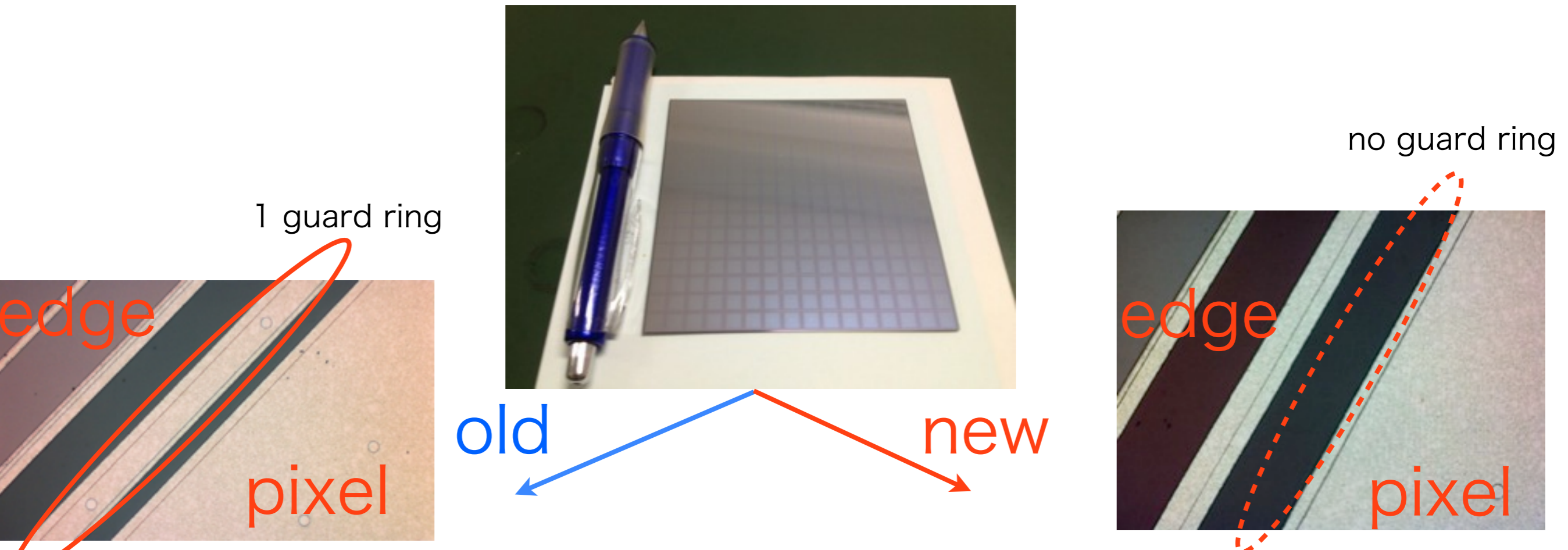


# Laser study status

- We have started the study about guard ring effect using basic properties: leakage current, capacitance and response to infrared laser.
- We will investigate the difference among guard ring structures.
- We can also investigate the response between pixels using same method.

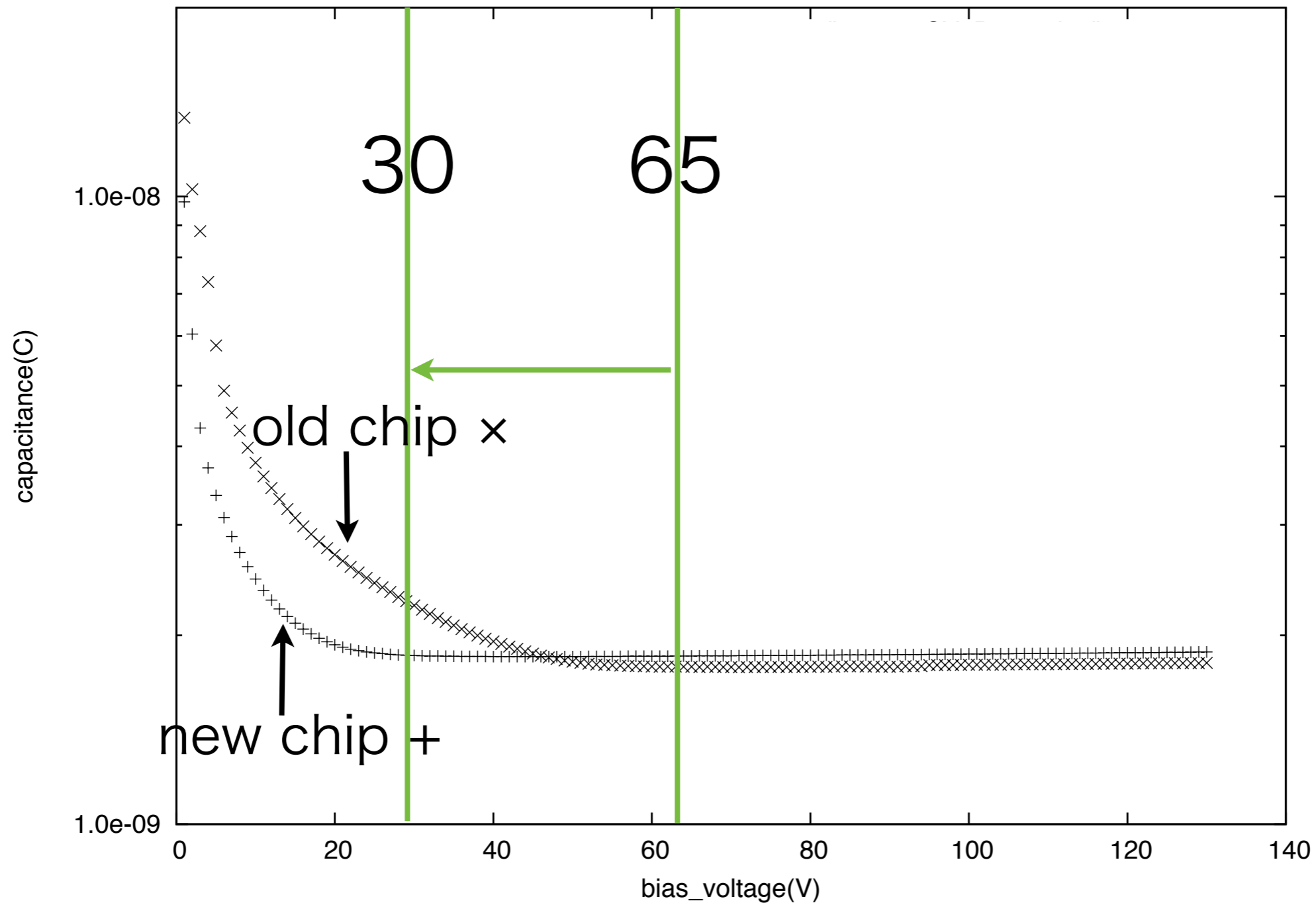
# Comparison between old and new prototype

- Hamamatsu made new prototype with no guard ring structure.



pixel size : 5.5 x 5.5 mm	same	pixel size : 5.5 x 5.5 mm
thickness : 320 $\mu\text{m}$	same	thickness : 320 $\mu\text{m}$
number of pixels : 256	same	number of pixels : 256
guard ring : 1	different	guard ring : 0
resistivity : unknown	higher as Hamamatsu said	resistivity : unknown

# Comparison of sensor capacitance



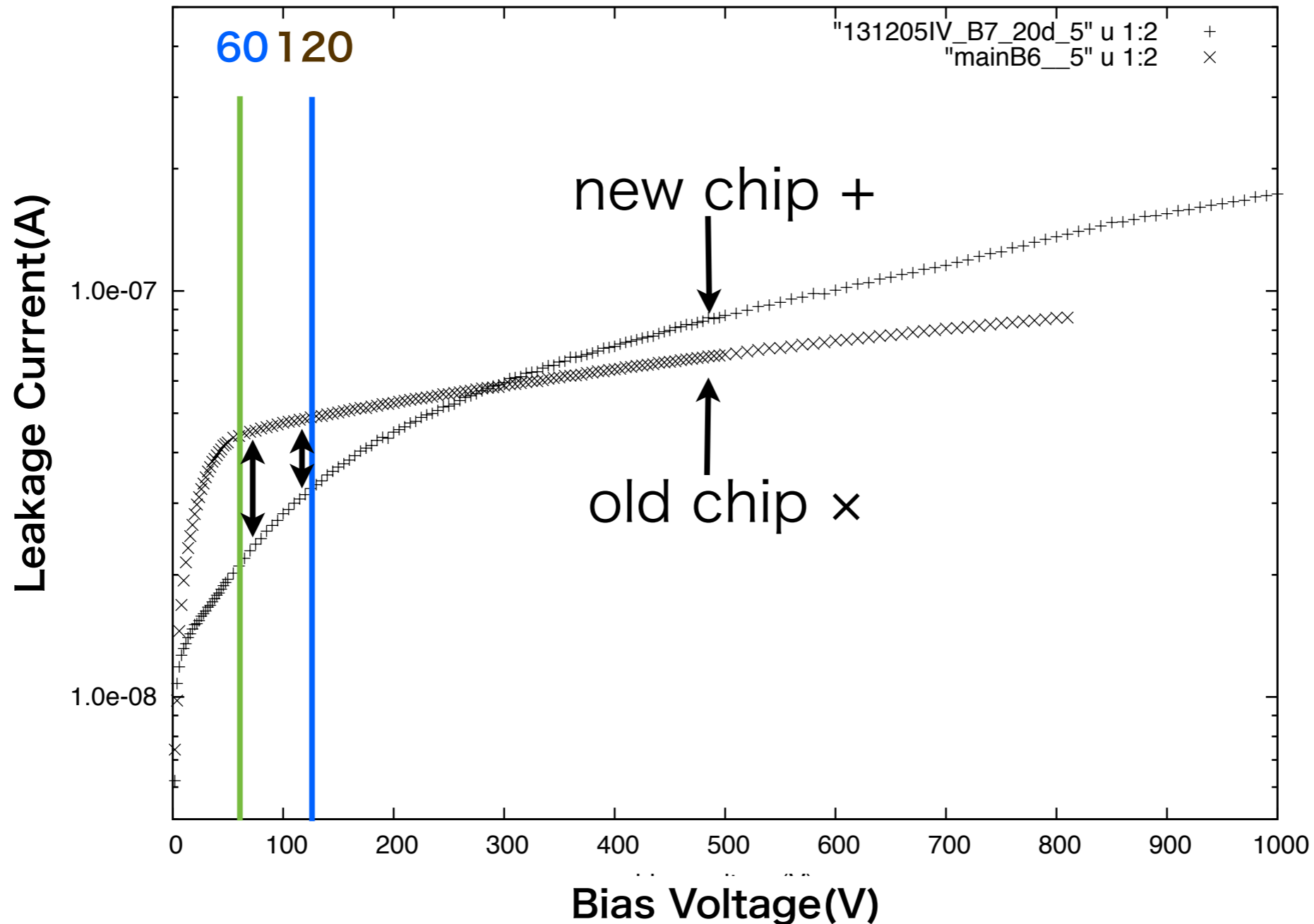
The chip capacitance does not change,  
because new prototypes' thickness is same as old one.  
However, since chip resistivity increased, full depletion voltage went lower.

# Full depletion voltage

- New sensor chips have higher resistivity than the previous one.  
->Hamamatsu said that they can get this high resistivity one easier.  
: Now they are preparing for mass production phase.
- High resistivity means high purity of silicon.  
->Depletion region can expand easily.
- Since full depletion voltage went lower, we can apply less operation voltage on chips. (eg. 60 V)

# Leakage current

- The leakage current at 120 V is **31 nA** (old : 48 nA),  
at 60 V is **21 nA**.

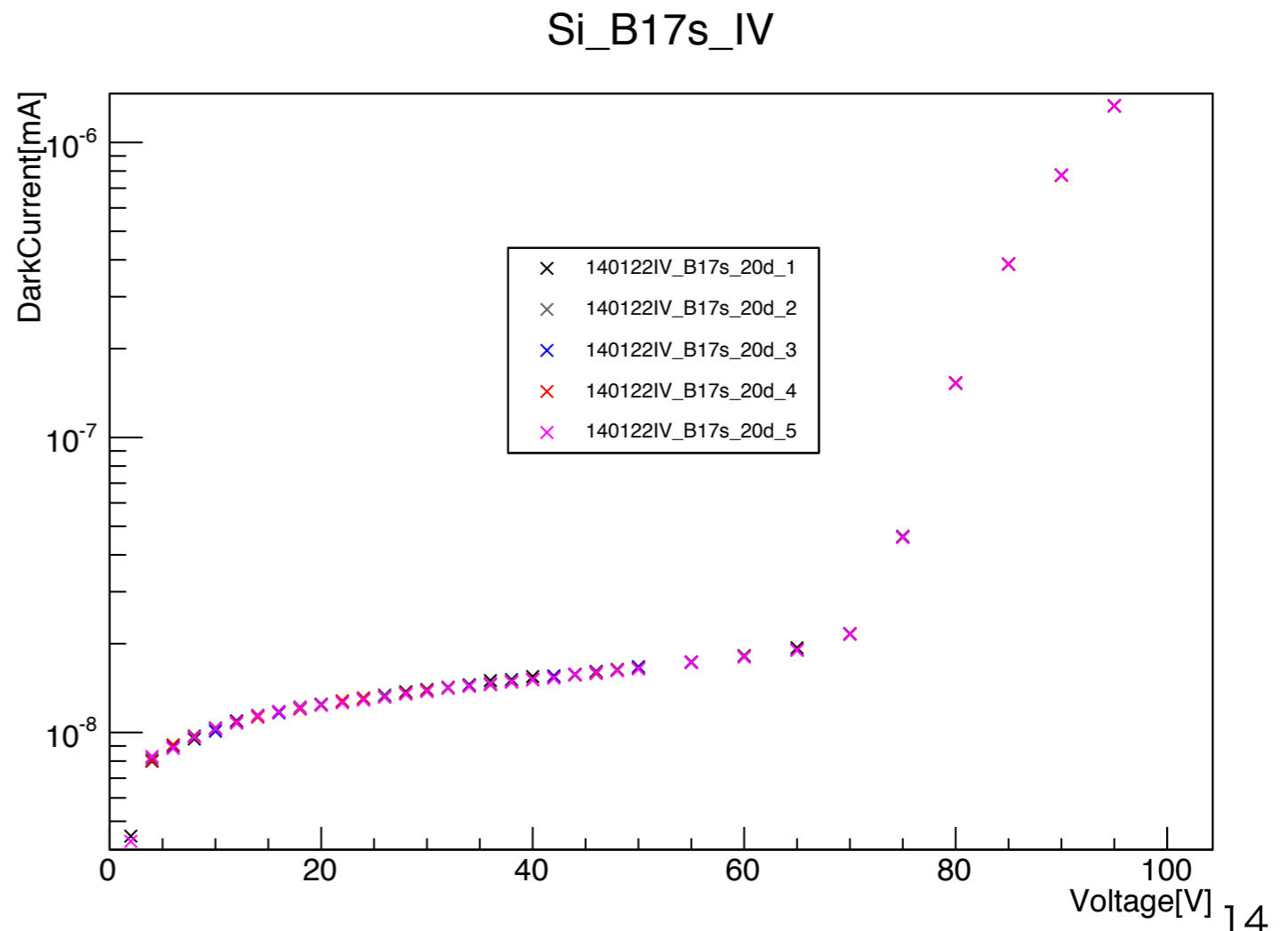


This value is twice lower than old prototype.

# Bad pixels

- We have two samples with “NG channel” in chip. One of them has “over limit” channel. In plot of Si\_B17s, we can see the effect of the bad pixels as the breakdown at lower voltage.
- If we set the operation voltage at 120 V, this chip is no use. However, if we set the operation voltage of 60 V, we can use this chip.

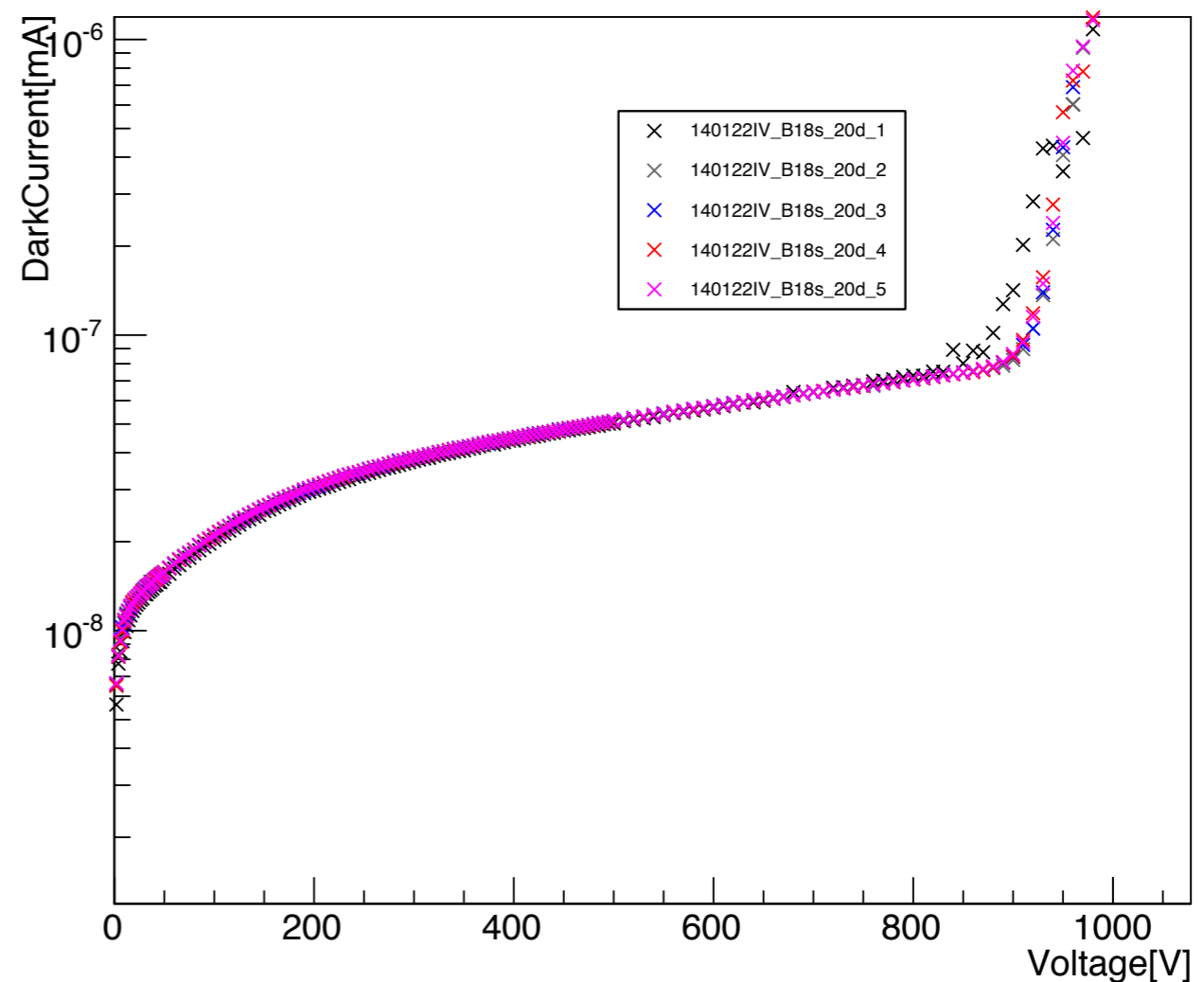
If we masked over limit channel and its surroundings channel, this break down voltage went higher slightly (about 140 V).



# NG channel (Cont.)

- The other NG chip has shorted channel.  
This caused merged channel in chip.
- In this case, chip granularity will decrease in such shorted channel.  
However, from leakage current measurement, chip break down voltage is higher than the operation voltage of 120 or 60 V.

Si\_B18s\_IV



# Summary

- Guard ring structure comparison
  - Leakage current and capacitance have almost same tendency.
  - Now we are preparing to investigate the difference of response using an infrared laser system.
- Comparison between new prototype and old one
  - leakage current went lower with new prototype.
  - capacitance does not changed, but full depletion voltage changed to 30V.  
-> we can try to decrease sensor operation voltage.



# Prospects

- We should decide chip design according to these measurements.
- Radiation test should be done for new prototype (and old one too).
- Investigate pixel response to infrared laser using “meshed chip”

