A study of silicon sensor for the ILD ECAL

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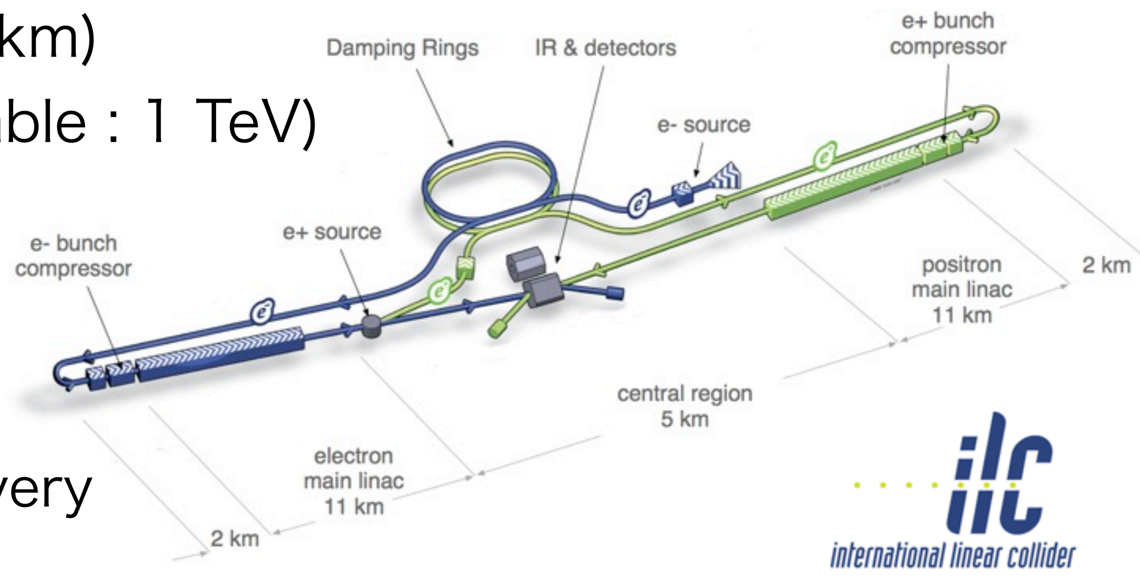
1. Introduction

International Linear Collider (ILC)

Length : 31 km (upgradable : 50 km)
Energy : 250 - 500 GeV (upgradable : 1 TeV)
Beam : Electron & Positron

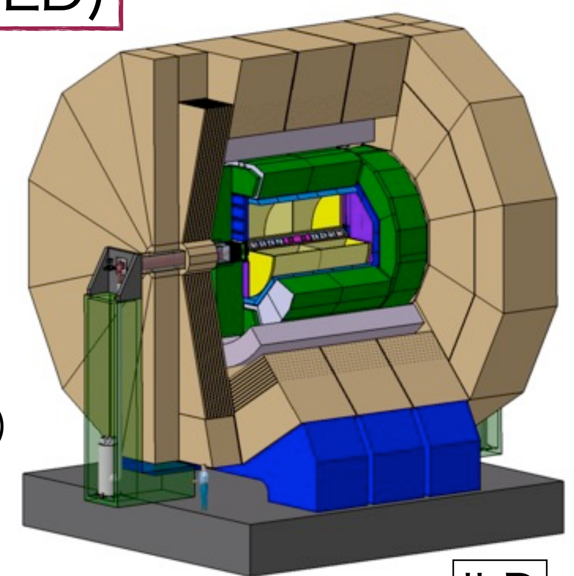
Physics motivation
- Precise measurement of Higgs
- Study for new physics
- Use the Higgs as a tool for discovery



International Large Detector (ILD)

Optimized for PFA

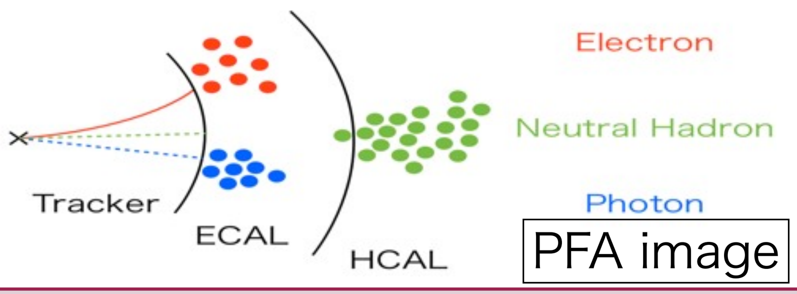
Components
- Vertex Detector (Silicon pixels)
- Tracker (Silicon strips + TPC)
- Electromagnetic Calorimeter (Si-W or Sc-W)
- Hadron Calorimeter
- Muon Tracker



ILD

Particle Flow Algorithm (PFA)

Reconstruct each particle in a jet using track information and shower shapes in calorimetry.



PFA image

Charged particles / Neutral particles → Track Information: Momentum resolution < 0.01 % @ pT 100 GeV → Calorimeters Information: Single particle resolution ~15%/√E (GeV) (ECAL), ~55%/√E (GeV) (HCAL) → Jet energy resolution **3-4 %** @ 100 GeV, twice as good as LEP

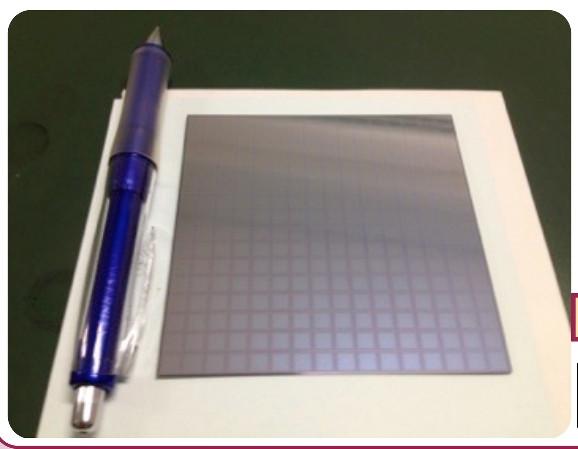
2. Motivation

We need high granular sensor for PFA. → Silicon sensor can realize high granularity at ease. → Need to know about Si sensor.

Guard rings

advantage	disadvantage
reduce leakage current	limit sensitive area make fake signals

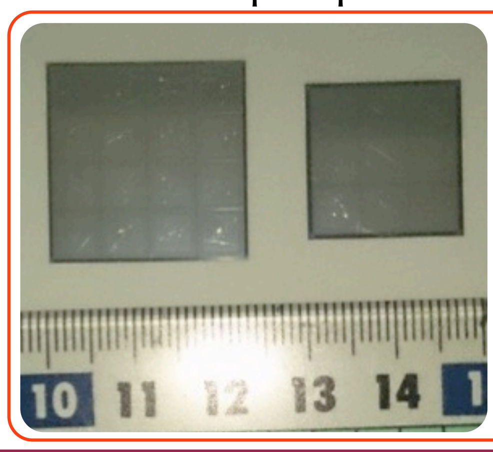
We should finalize the sensor design through comparison of basic properties.



Pixel size : 5.5 mm × 5.5 mm
No. of pix. : 256 pixels
Thickness : 320 μm

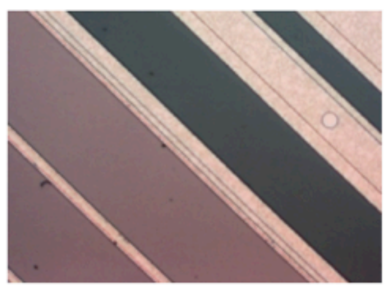
Prototype

Test chip

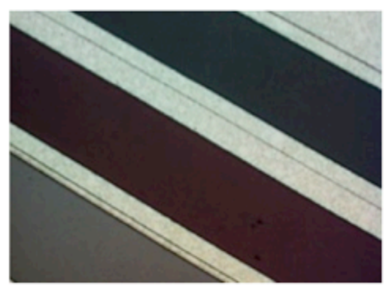


Pixel size and Thickness are the same as those of prototype

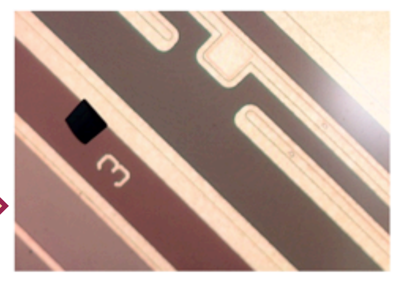
4 types of guard rings



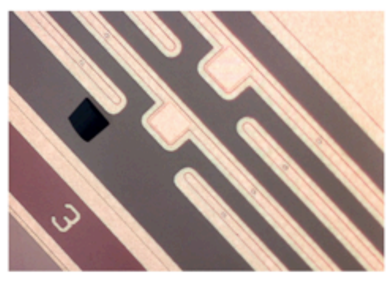
1 guard ring



no guard ring



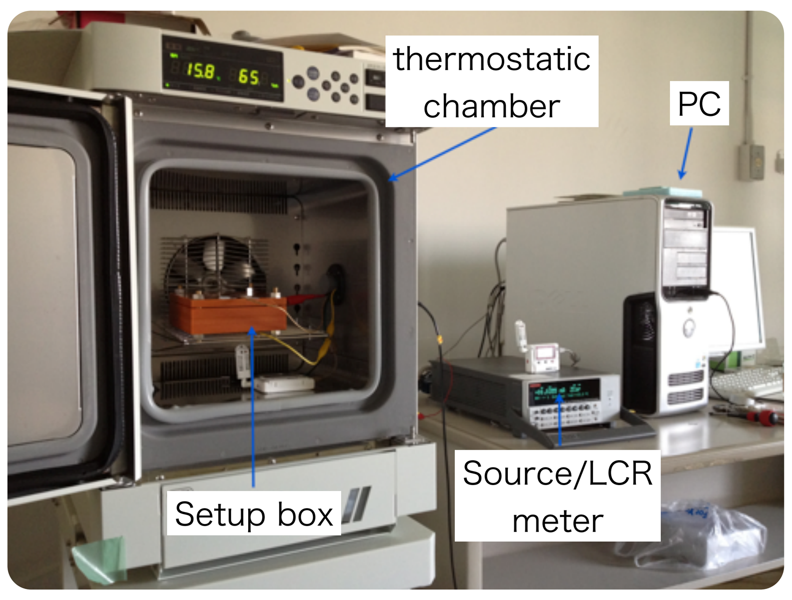
2 guard rings



4 guard rings

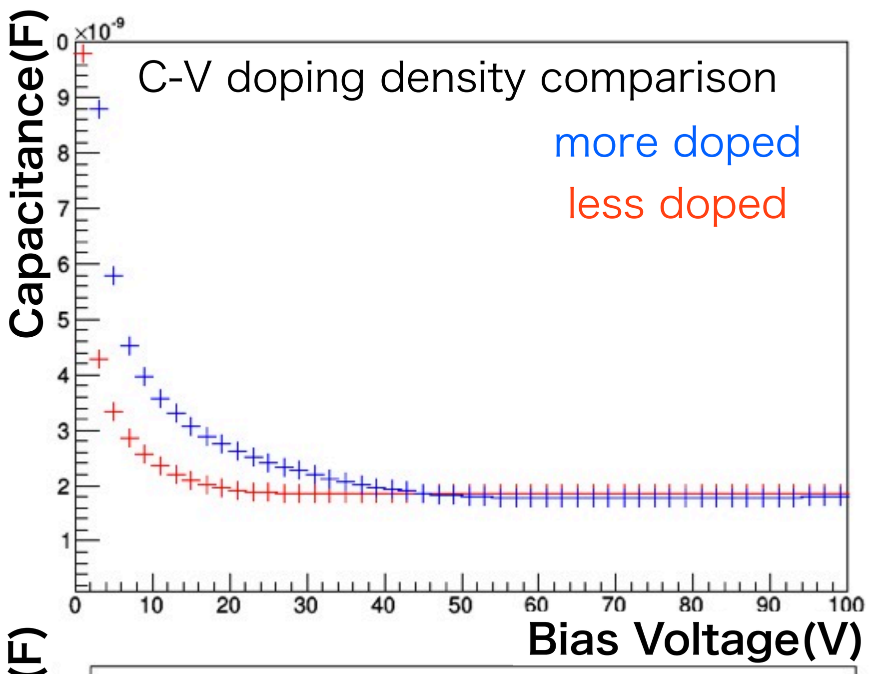
3. I-V, C-V measurements

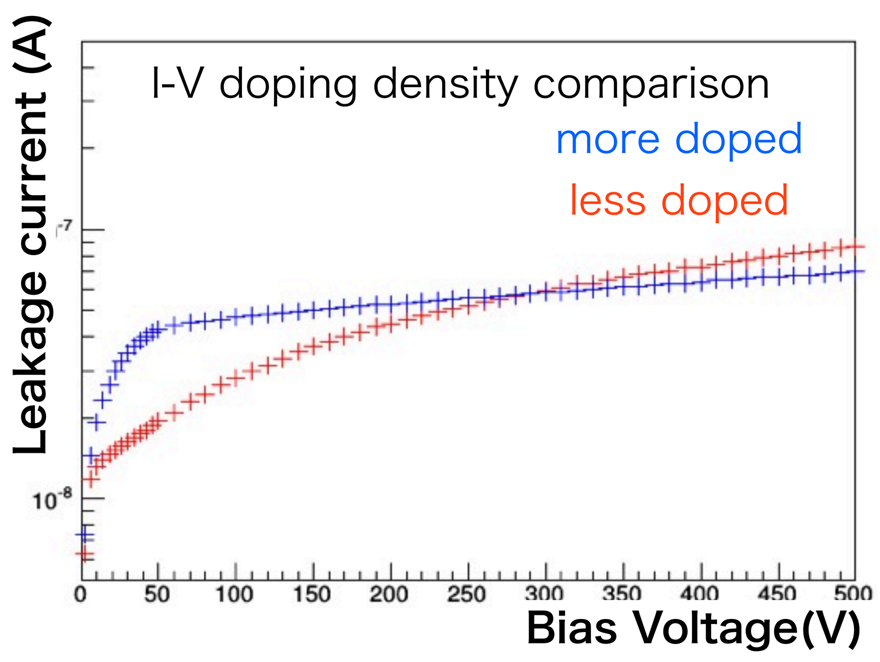
Leakage current <-> sensor noise
Capacitance <-> operation voltage

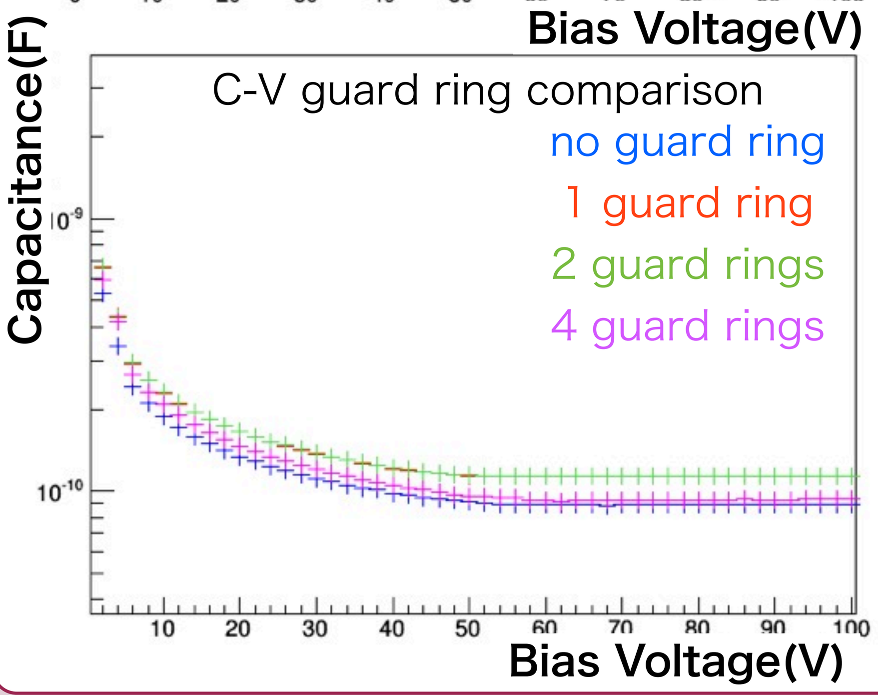


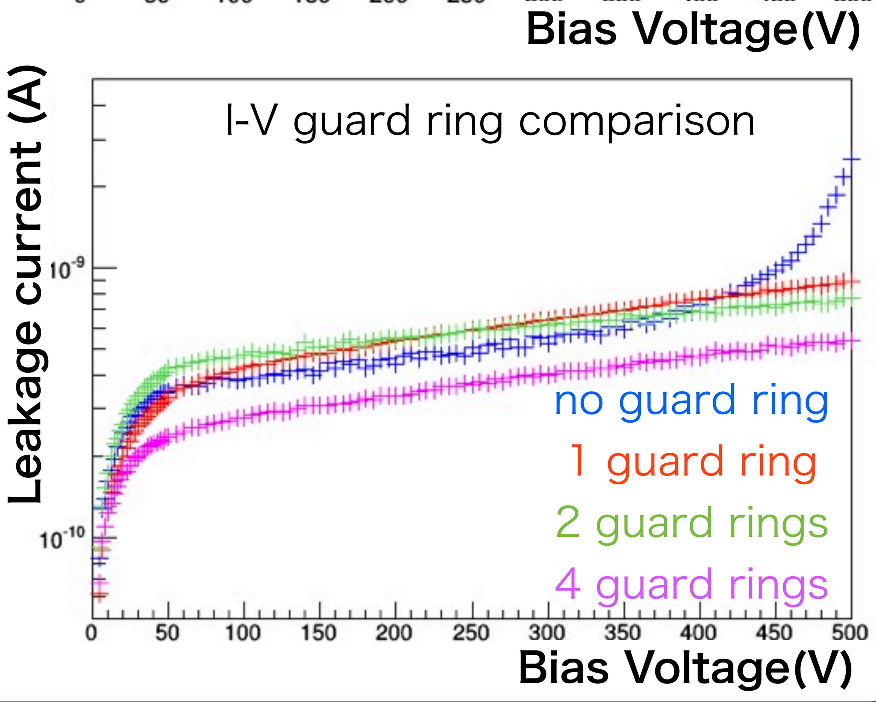
setup
- Automated measurement system
- Temperature and humidity control box (20℃, 50%)
- Source/LCR meter

- 4 types of guard rings
- 2 types of doping densities





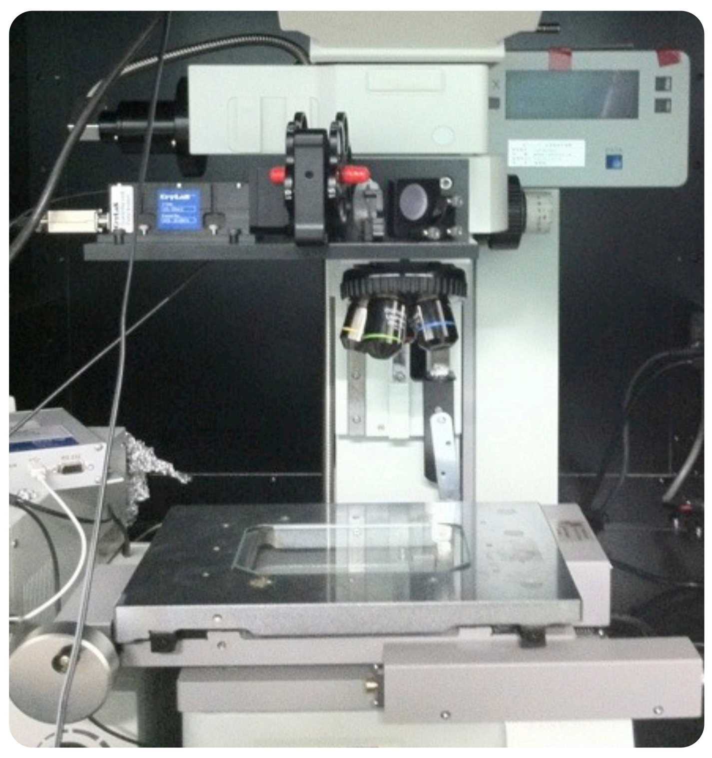


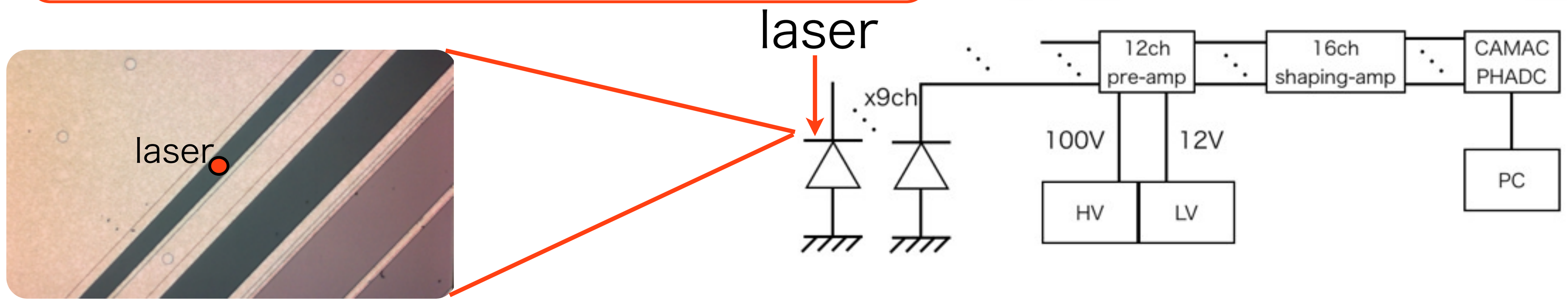


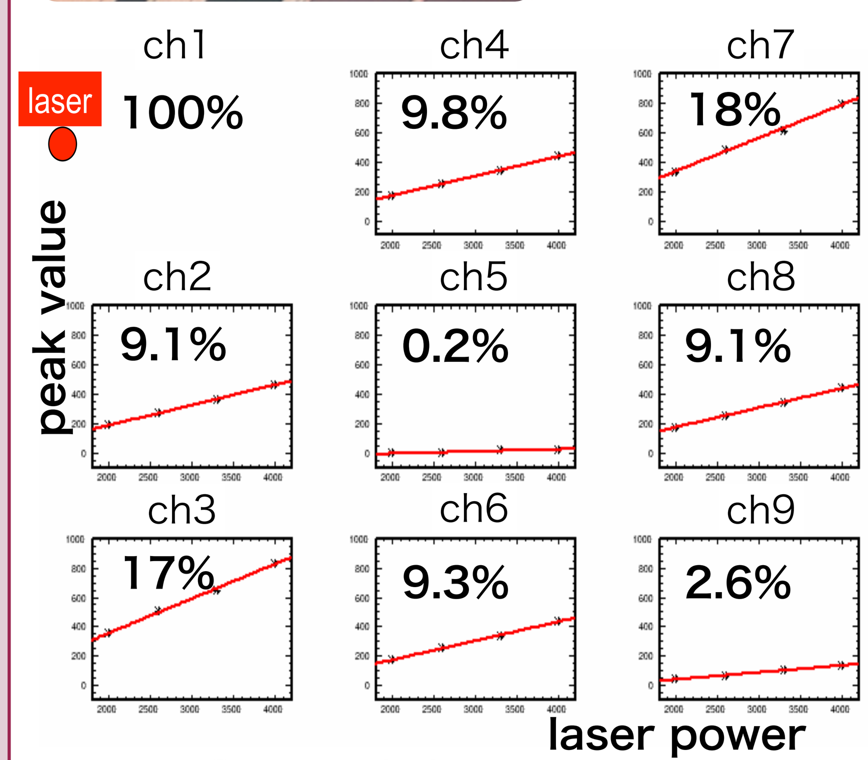
4. Response study using infrared laser

specifications

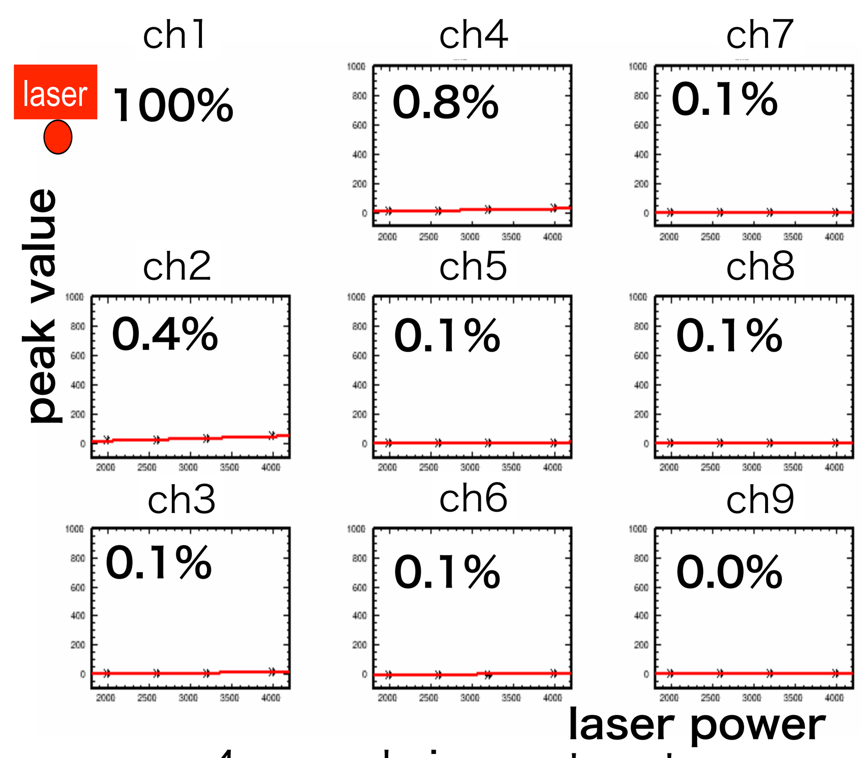
Wave length : 1064 nm
-> 1.16 eV (= a pair of e-h in Si)
Pulse width : 1.5 ns
Repetition rate : 1Hz - 10000 Hz (controlled by a PC)
Laser spot size : < 20 μm
Peak Power : ~13 kW
(with 36 steps of attenuation using ND-filter)







1 guard ring structure



4 guard rings structure

2 guard rings structure and no guard ring structure are the same as the result of 4 guard rings structure.

5. Conclusion & next steps

I-V,C-V measurements
- Guard ring structures don't affect the leakage current and capacitance. -> we can use any structure.
- The doping density changed the capacitance and leakage current. -> we can try high resistivity for baseline design.

laser measurements
- 1 guard ring structure caused fake signals along its guard ring. -> we should try to use "no guard ring" or "split one".
- The measurement system using the infrared laser works well -> we can do other measurement using this system.

Next Steps: noise rate, inject laser between pixels , tolerance to radiation damage, etc.