

Newly Developed Semiconductor Detectors

• Multi-Pixel Photon Counter (MPPC)

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PD07 Kobe June 27th 2007

■ Multi Pixel Photon Counter (MPPC)

What's MPPC?

Solid state photon counter having
Multi pixelated Geiger-mode APDs
with self-quenching resistance



The MPPC (Multi-Pixel Photon Counter) is developed by HAMAMATSU PHOTONICS K. K. and it is one of the products of Si-PM (Silicon Photo multiplier) family which was originally developed in Russia.

HAMAMATSU MPPC is designed as a photon counting device based on structures of a Si APD which was adopted by CERN (CMS).

HAMAMATSU named this product MPPC which is a trademark.

The candidates of name in SiPM family

SiPM (Silicon Photo Multiplier)

SiPM^T (Silicon Photo Multiplier ^Tube)

MRS-APD (Metal Resistive Semiconductor APD)

SPM (Silicon Photo Multiplier)

MPGM APD (Multi Pixel Geiger-mode APD)

AMPD (Avalanche Micro-pixel Photo Diode)

SSPM (Solid State Photo Multiplier)

GM-APD (Geiger Mode APD)

SPAD (Single Photon Avalanche Diode)

MPPC : Multi Pixel Photon Counter

What is the structure of MPPC to improve the performances

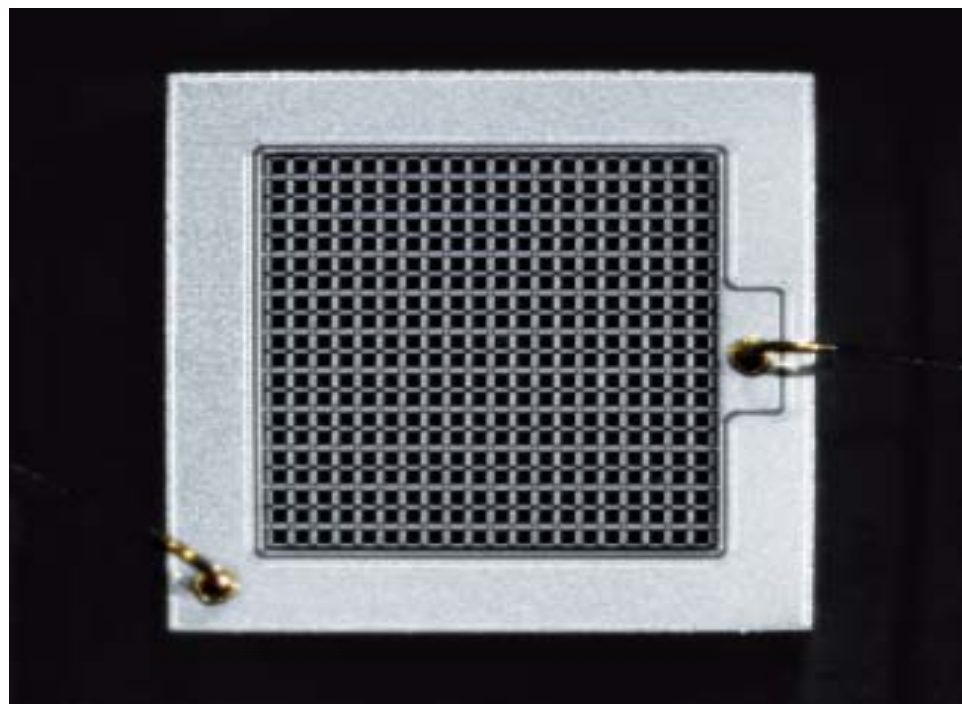
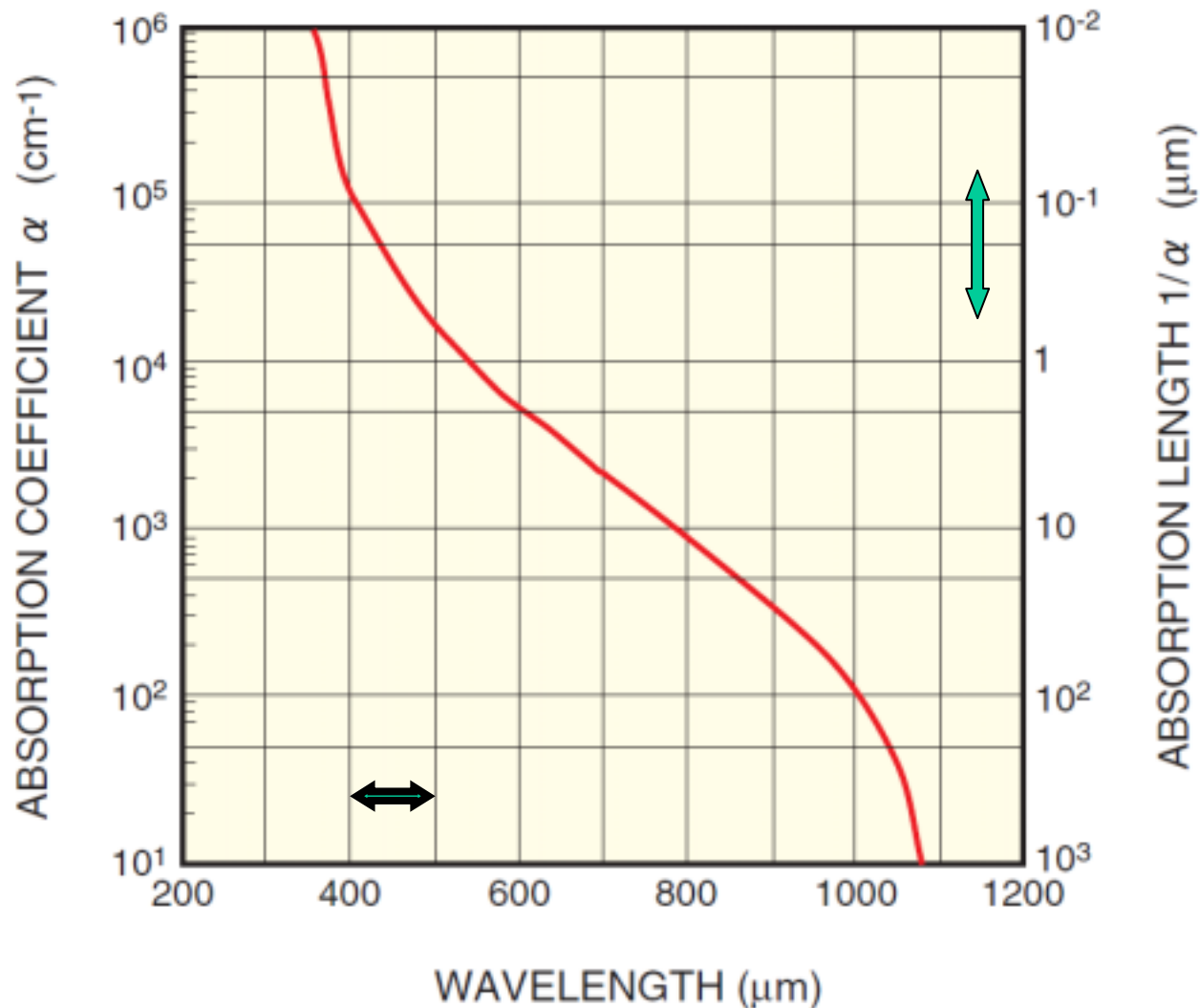
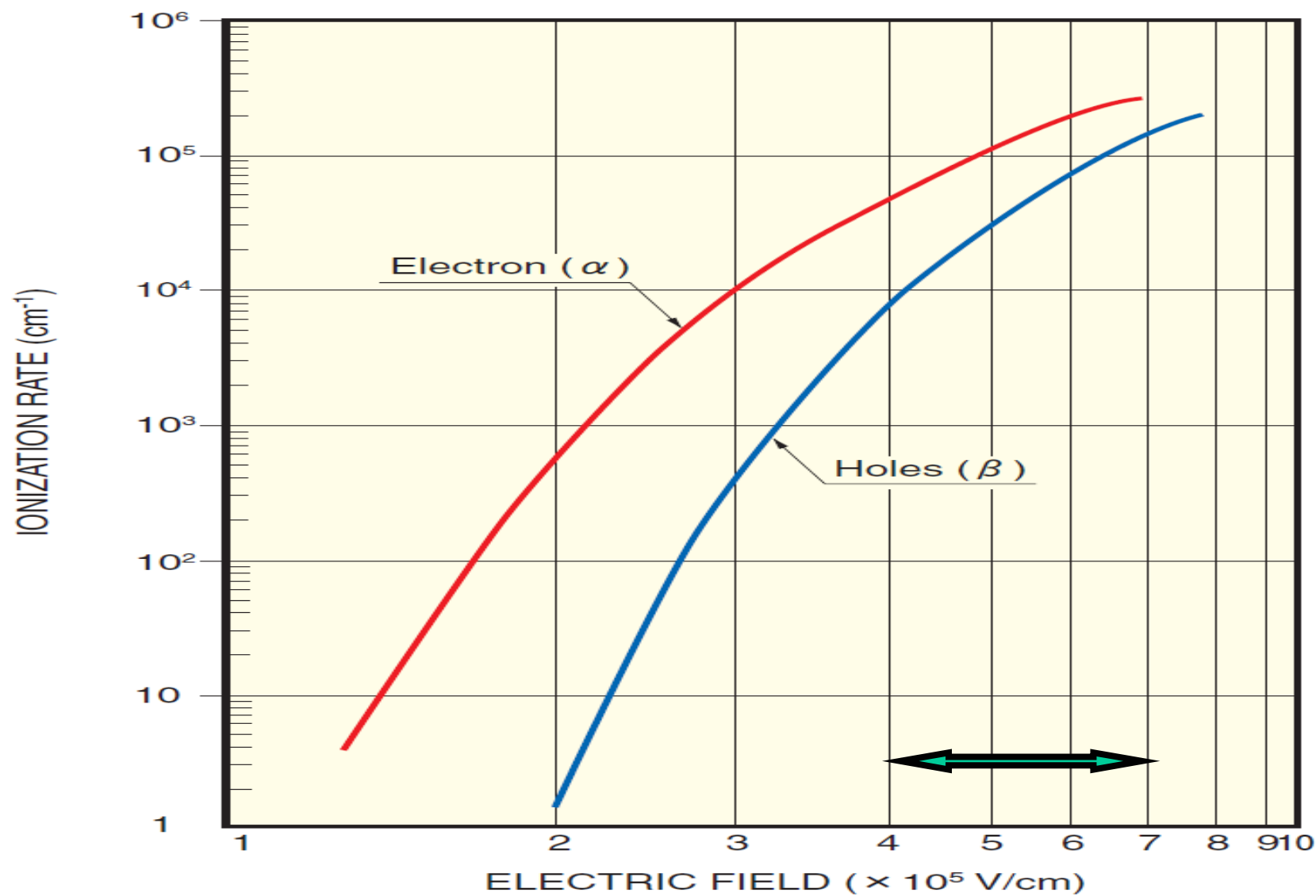
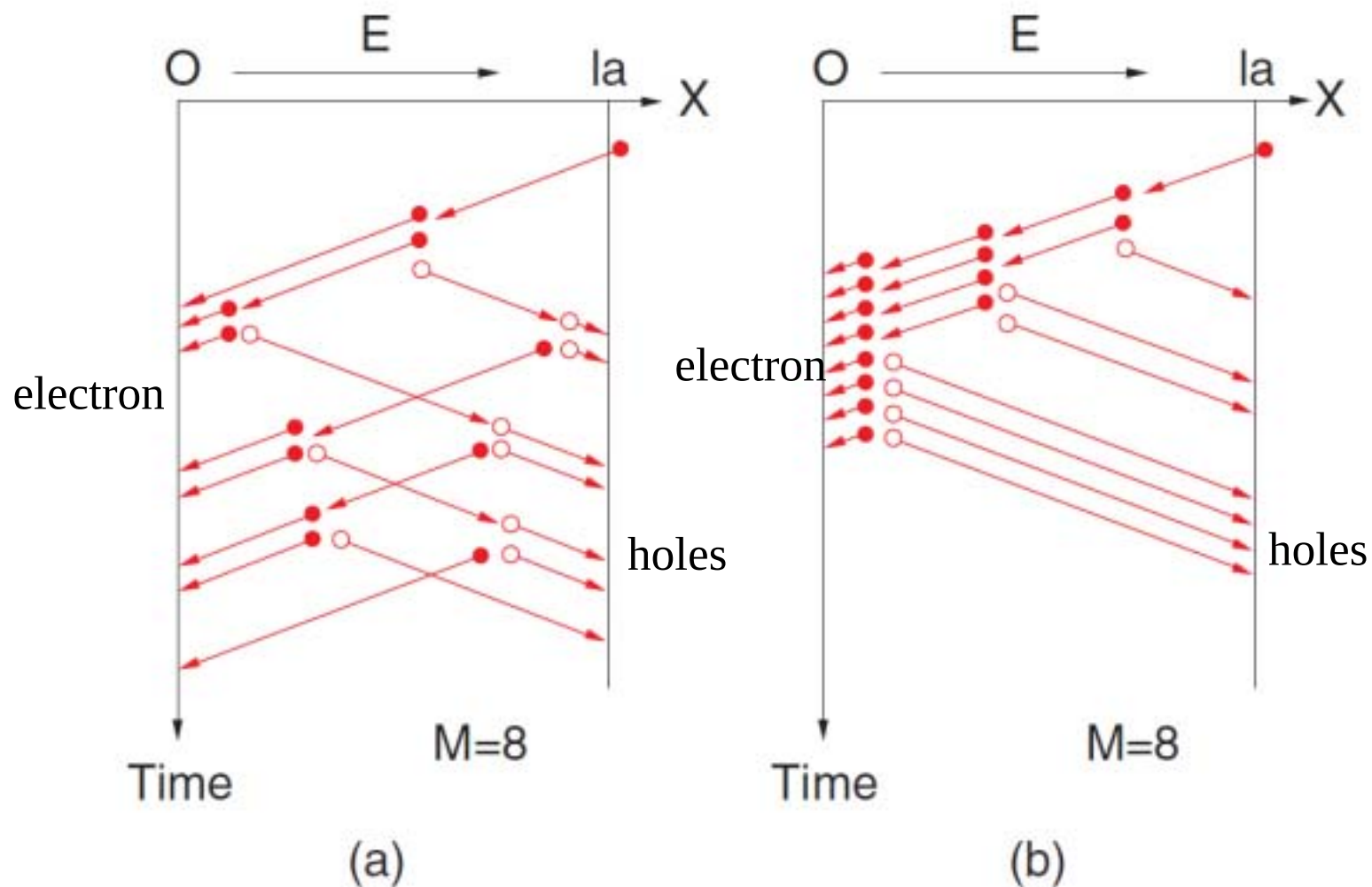


Photo Absorption coefficient of Silicon





Ionization coefficient for avalanche Multiplication



Schematic representation of the carrier-multiplication process, where the multiplication factor is 8: (a) carrier impact ionization takes place for both carriers; (b) only electron impact ionization takes place.

CMS(CERN) APD

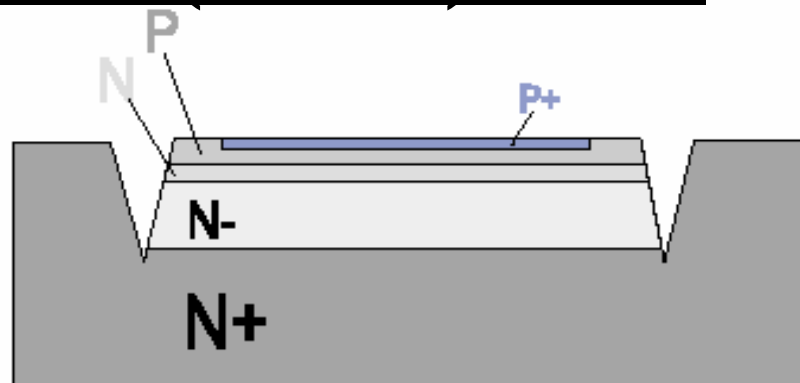
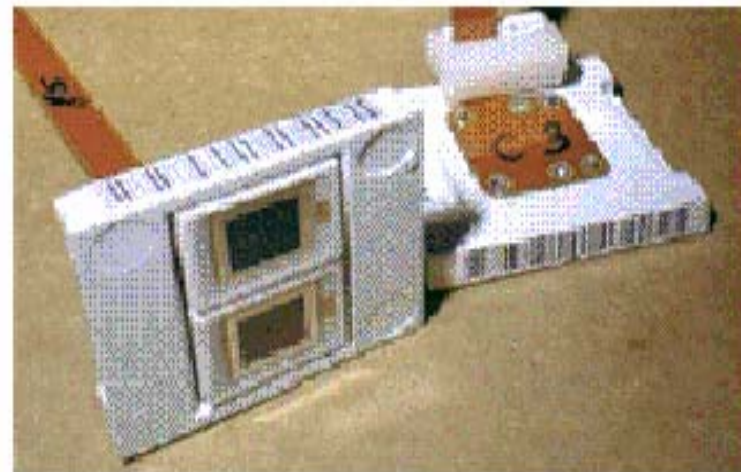
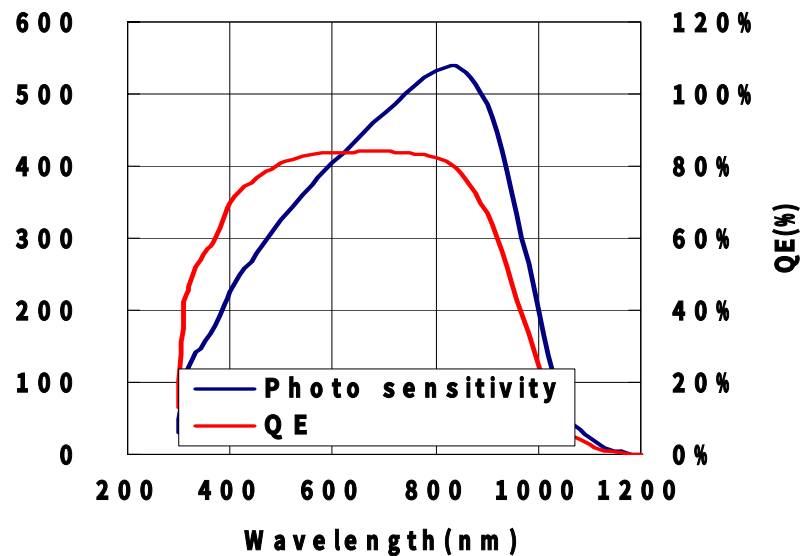


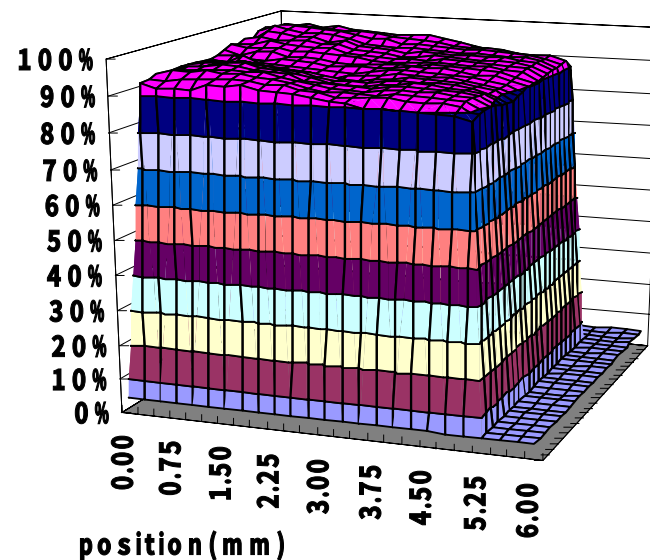
Figure 2: Structure of the selected APD

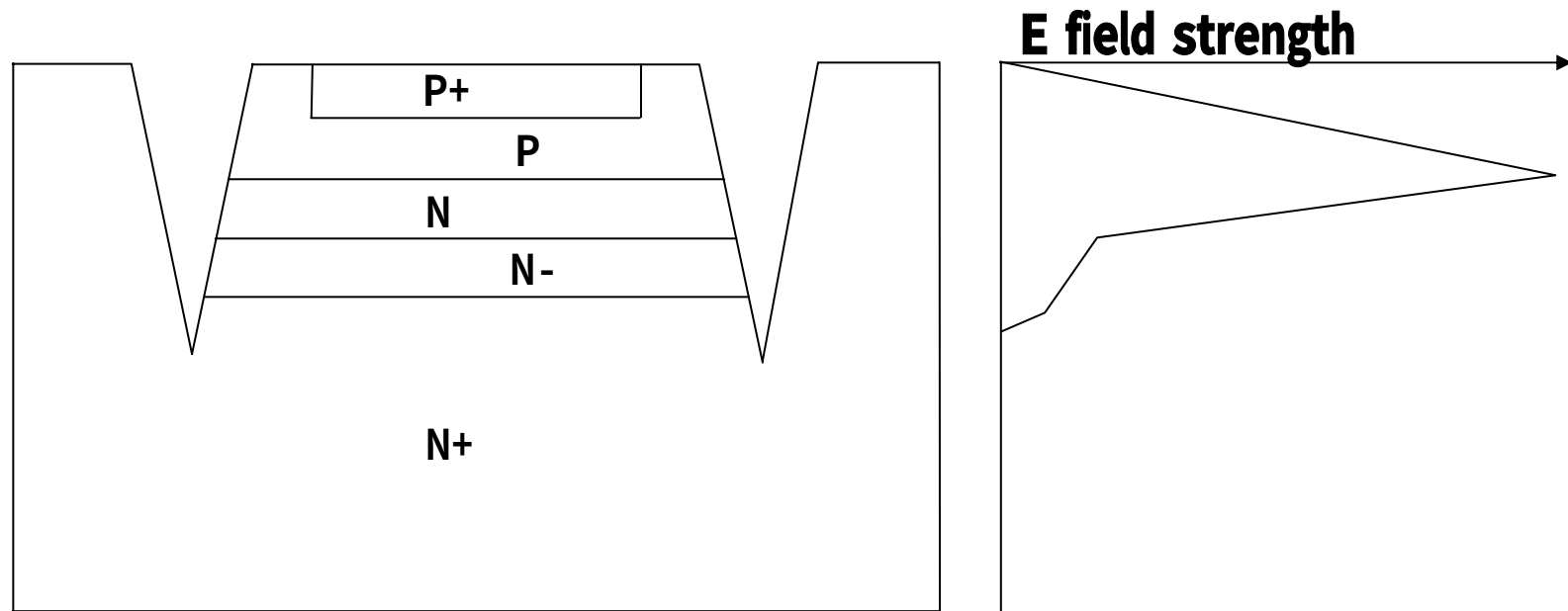
S8664-55 Spectral response curve



S8664-55 Gain Uniformity

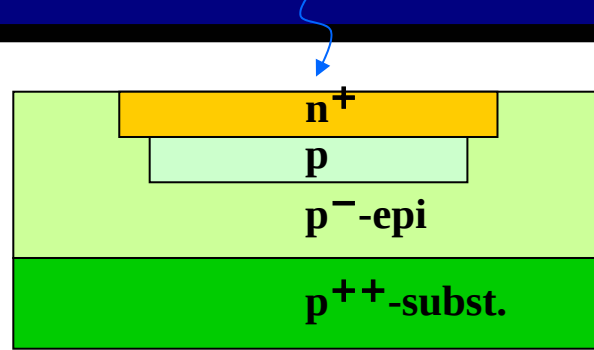
(Typ. M=50)



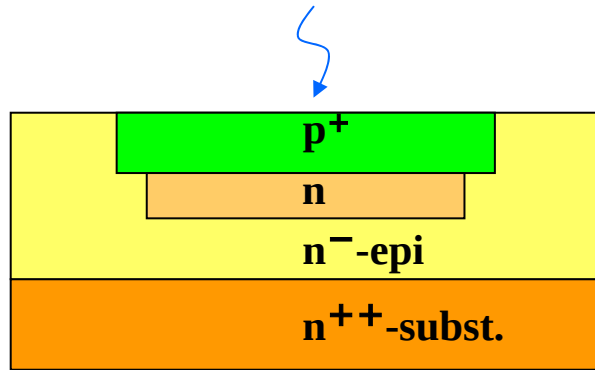


Hamamatsu Reverse Structure APD for CMS

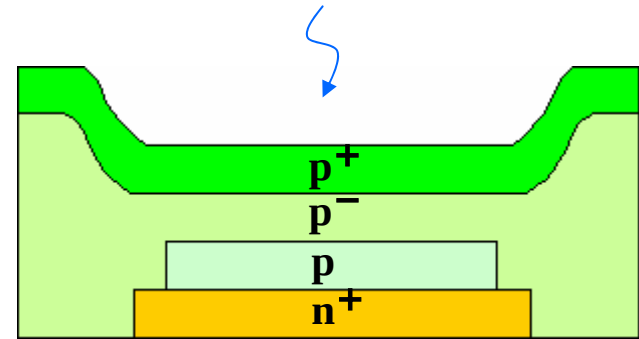
- **APD structure used in the electromagnetic Calorimeter of CMS.**
- **The p/n junction is formed in an epitaxial layer with 50 μm thickness.**
- **Bias 350 to 400V to get gain 50**



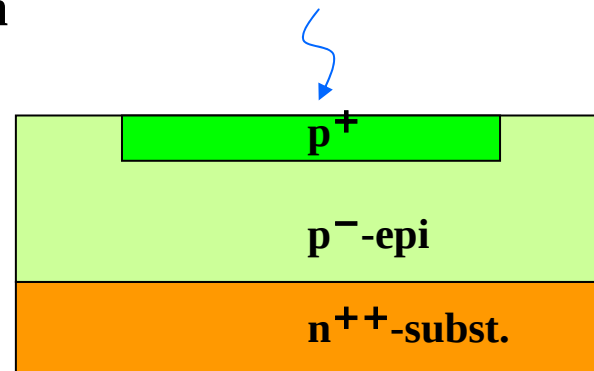
N/P-Reach through



P/N-Reach through

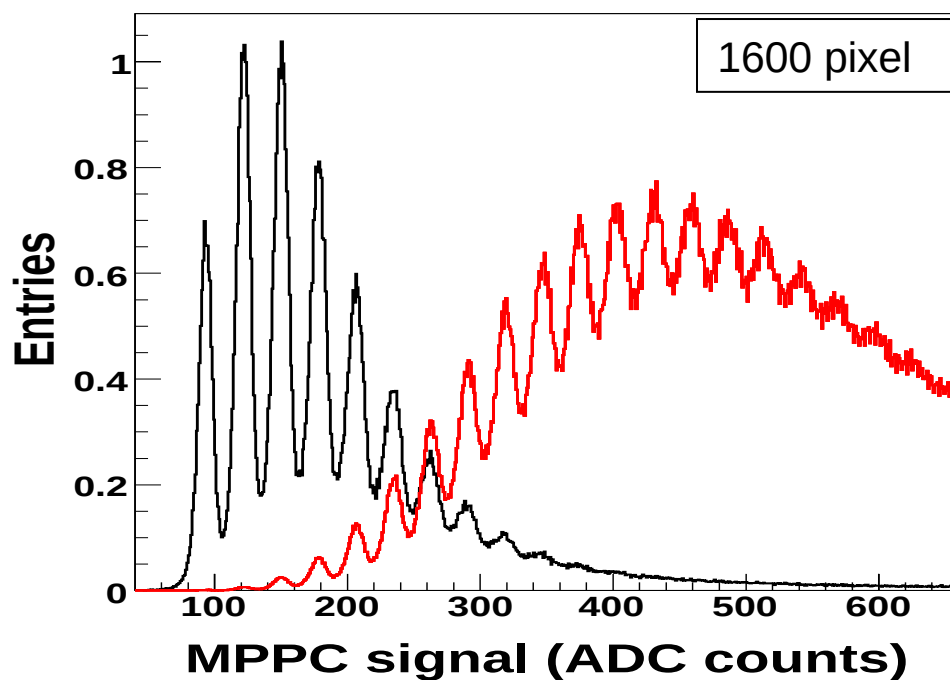


**N/P-Reach through
Back illumination type**



HPK Reverse structure

What are the characteristics of MPPC



■ Specification of 1mm□, MPPC

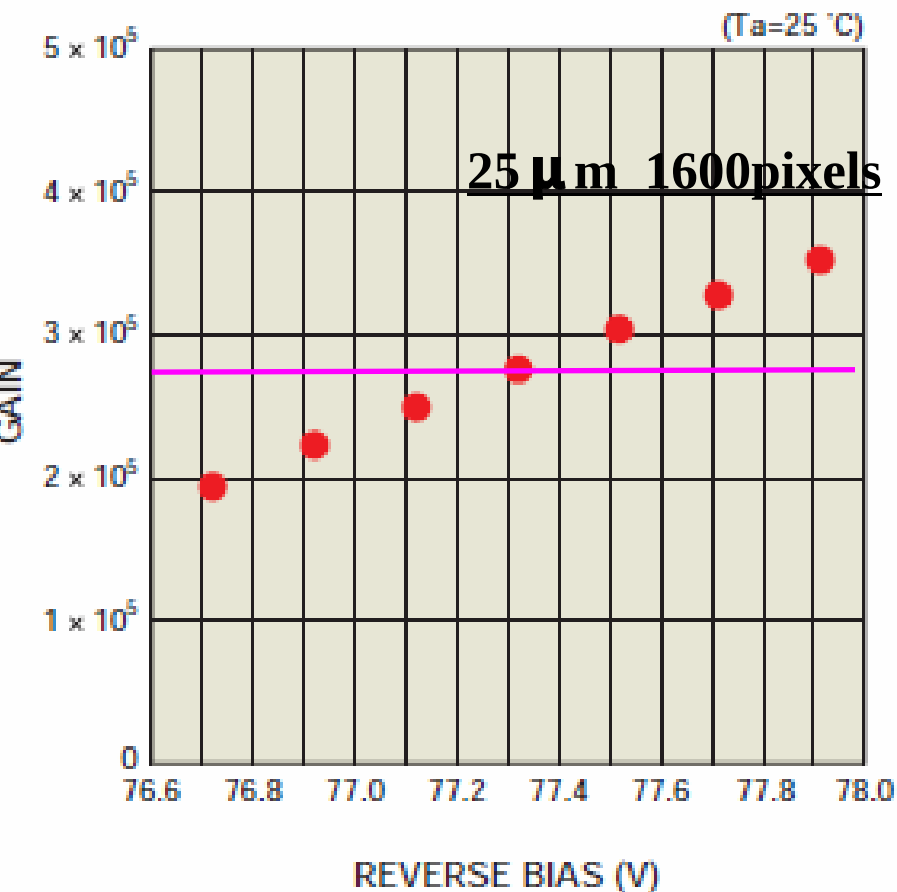
■ Electrical and optical characteristic (Ta = 25°C)

Parameter		1600	400	100	Unit
Chip size		1.5 x 1.5			mm
Effective active area		1 x 1			mm
Number of pixels		1600	400	100	—
Pixel size		25 x 25	50 x 50	100 x 100	um
Geometric efficiency		30.8	61.5	78.5	%
Sensitivity	$\lambda = \lambda_p$	400			nm
	Quantum efficiency	70 min.			%
	PDE	25	50	65	%
Operating voltage		77 ± 10	70 ± 10	70 ± 10	V
Gain		$2.75E+05$	$7.50E+05$	$2.40E+06$	—
Dark count		100	270	400	Kcps
Terminal capacitance		35			pF
Time resolution (FWHM)		250	220	250	ps
Temp coefficient of bias voltage		50			mV/°C

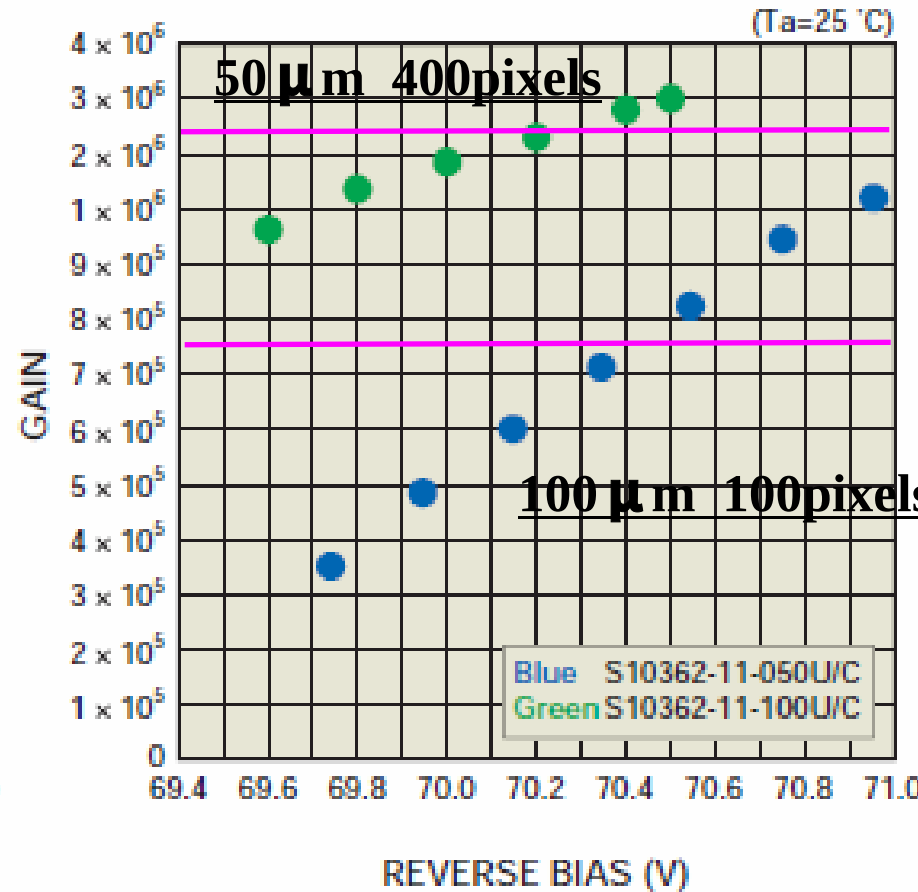
*The last letter of each product number indicates which type of package is used. (U : Can , C : Ceramic)

*1: The figures in PDE (Photon Detection Efficiency) include cross-talk and after pulse.

Bias vs. Gain

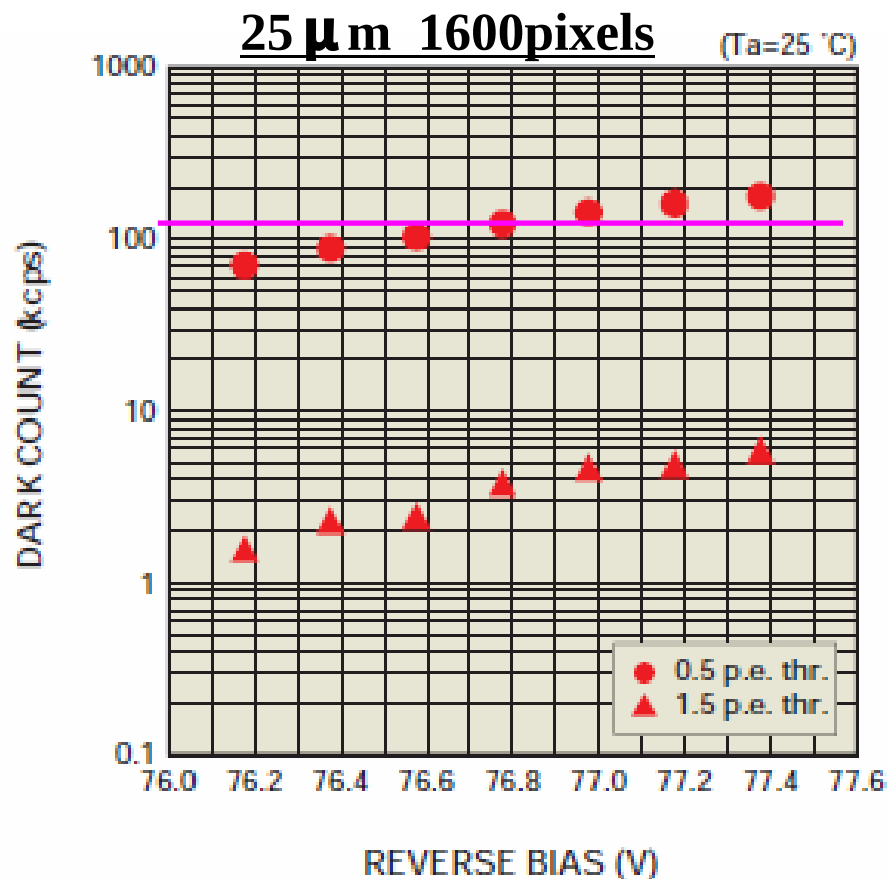


S10362-11-025U/C

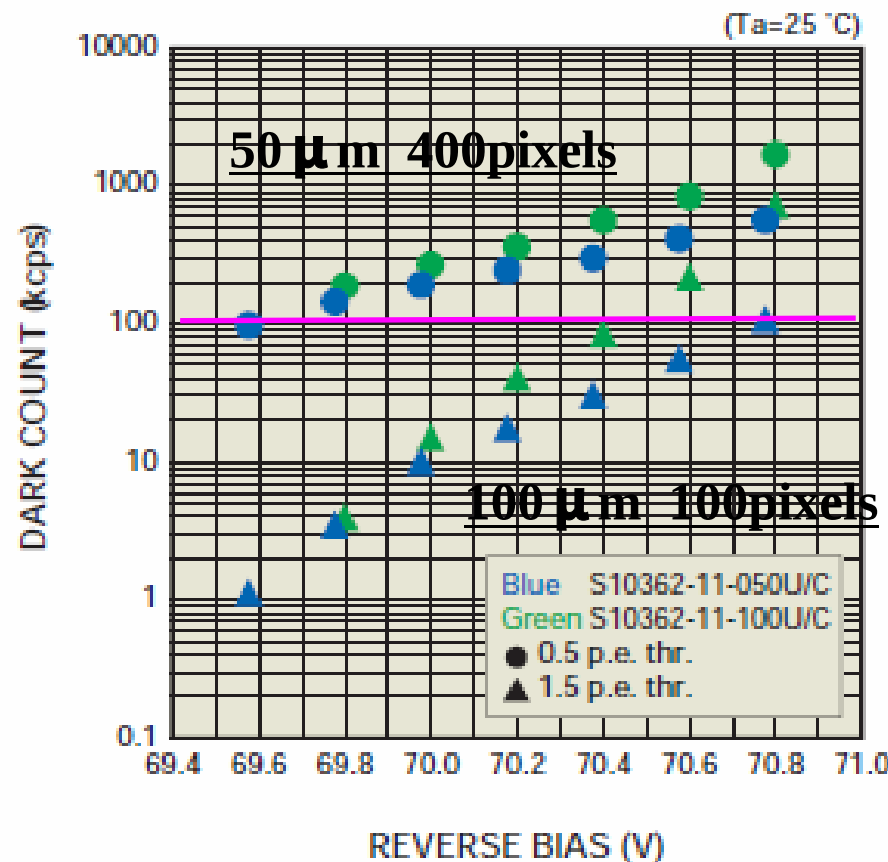


S10362-11-050U/C, -100U/C

Bias vs. Dark count

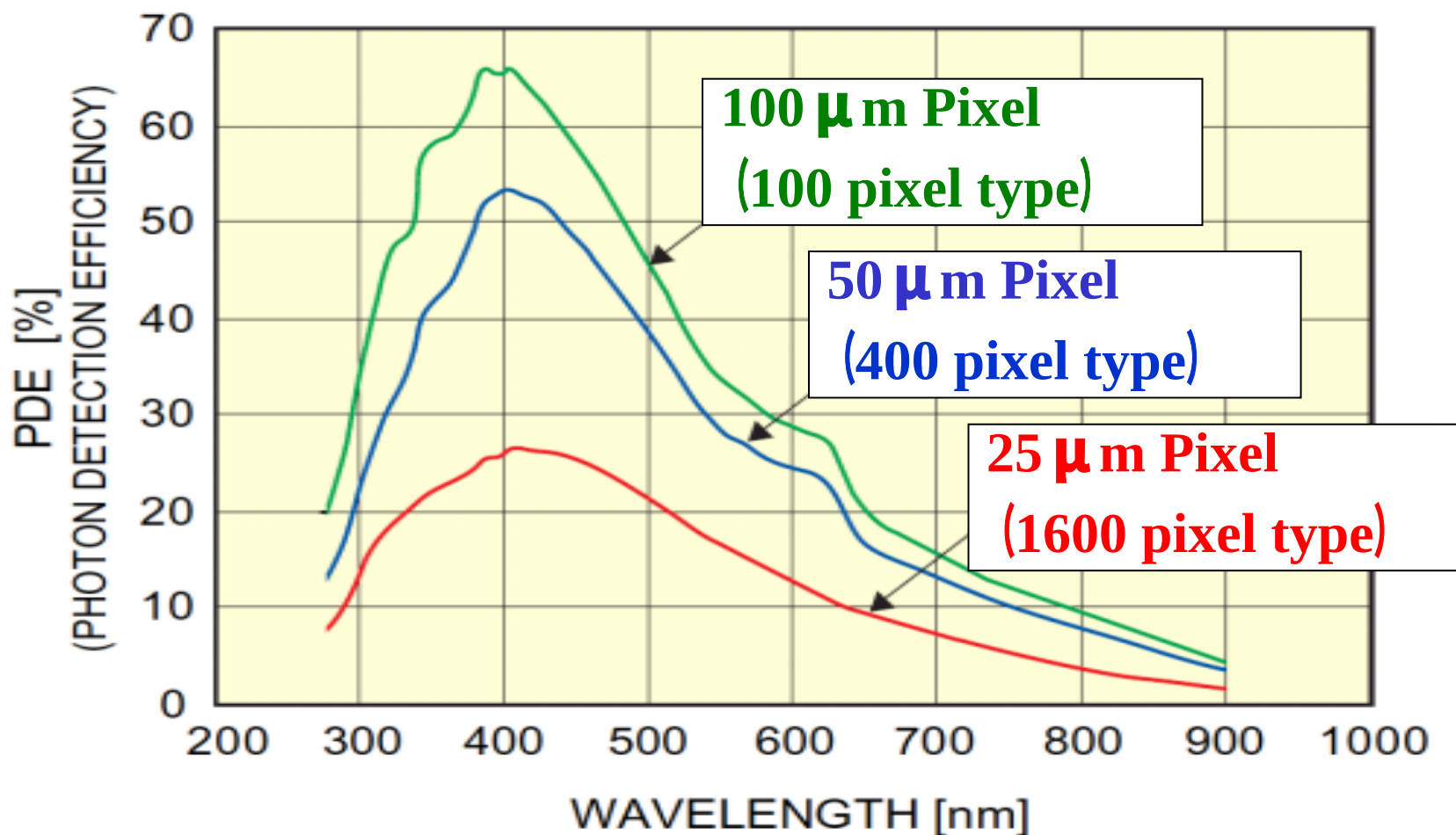


S10362-11-025U/C



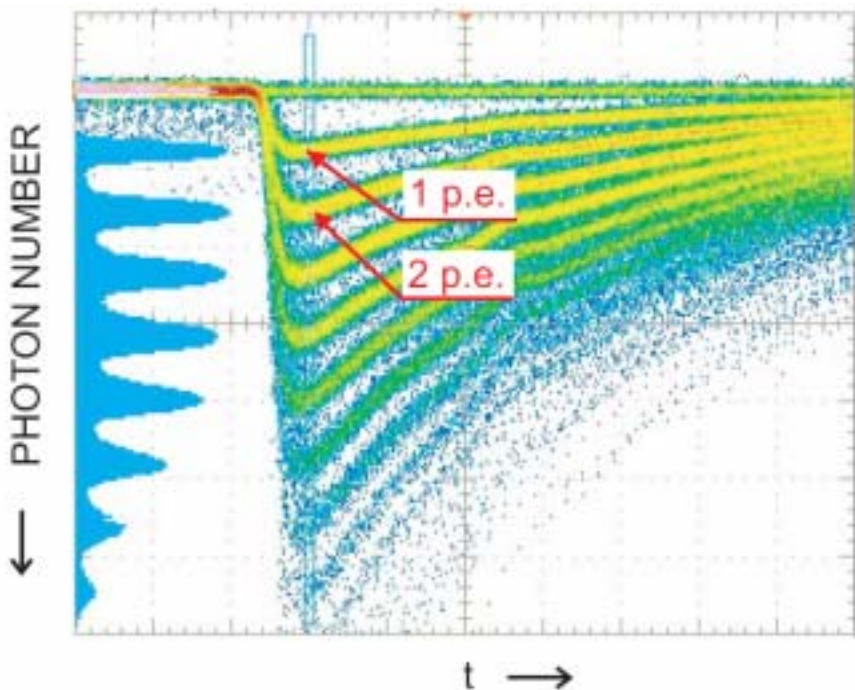
S10362-11-050U/C, -100U/C

Photon Detection Efficiency (PDE)

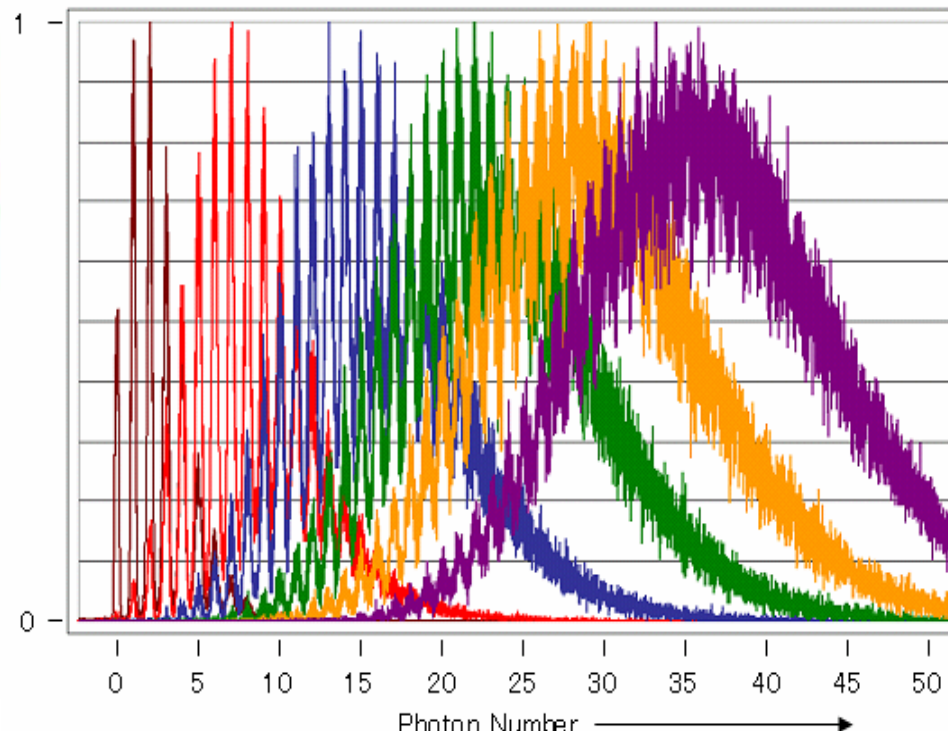


※including the cross-talk and after pulse

■ Output signal of MPPC

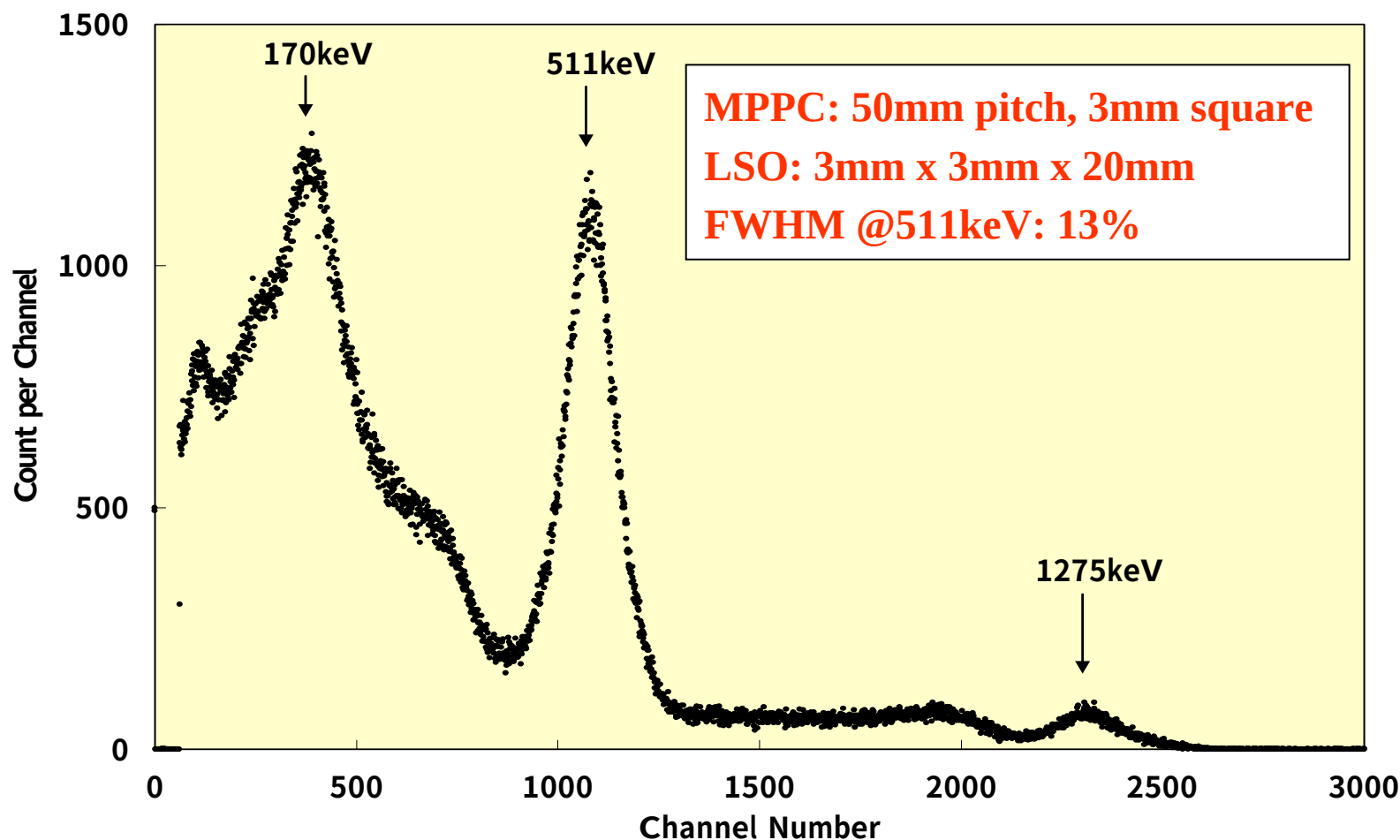


Photon counting by pulse height
(**liner Amp.**)



Photon counting by output charge
(**charge Amp.**)

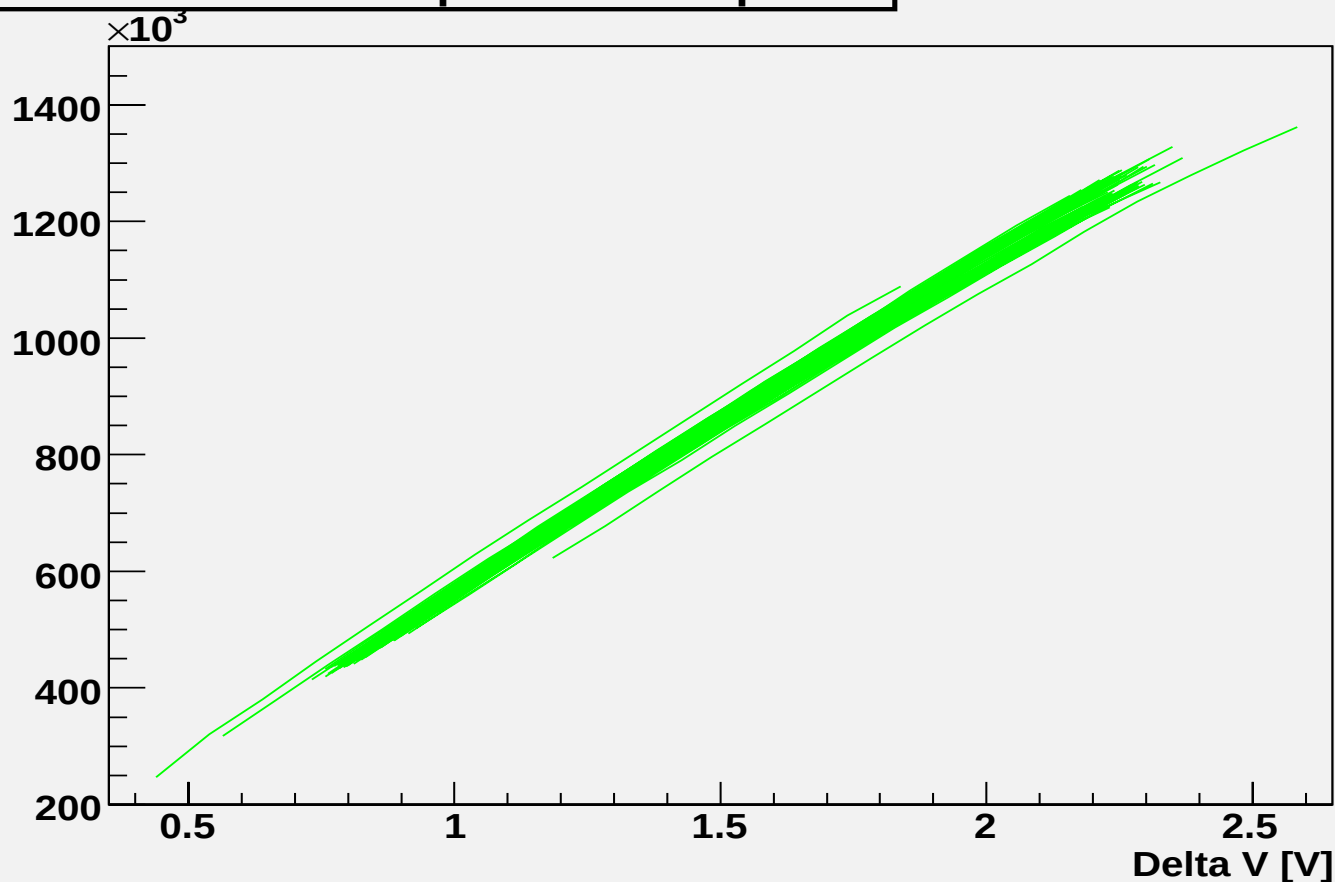
Energy Resolution



Gain uniformity

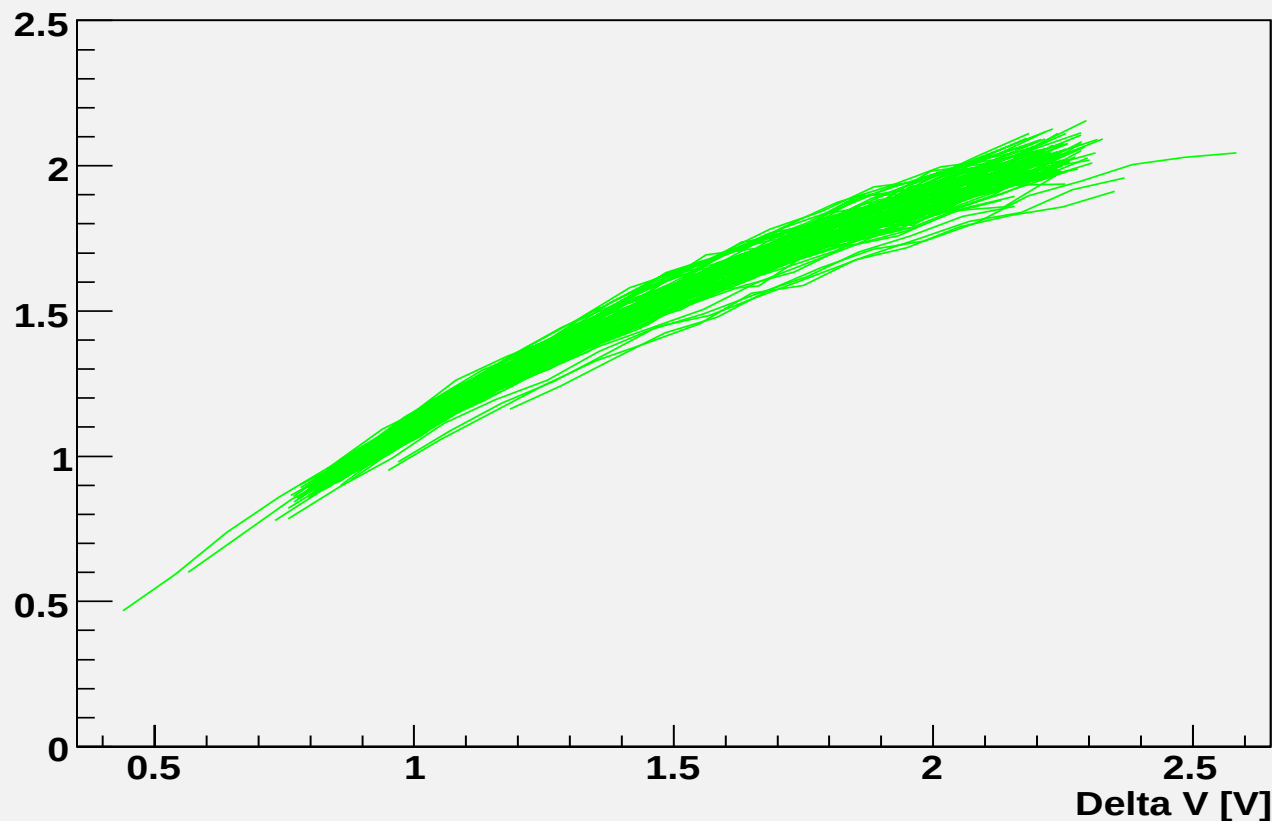
(400 pixel, 100 samples)

Gain Delta V : 400pixel 100samples

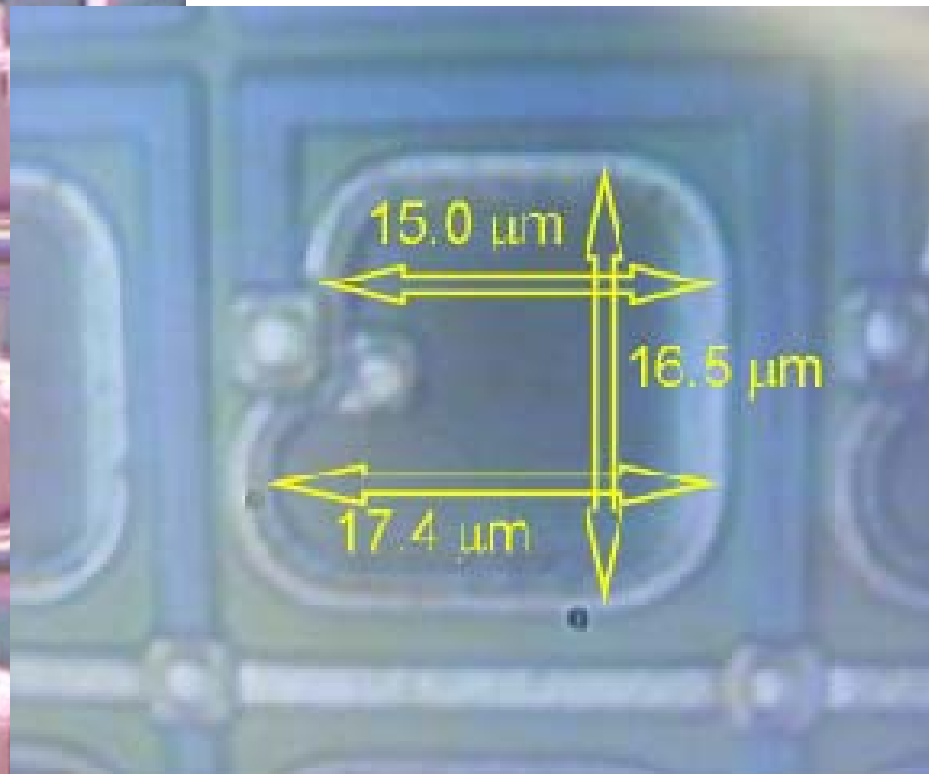
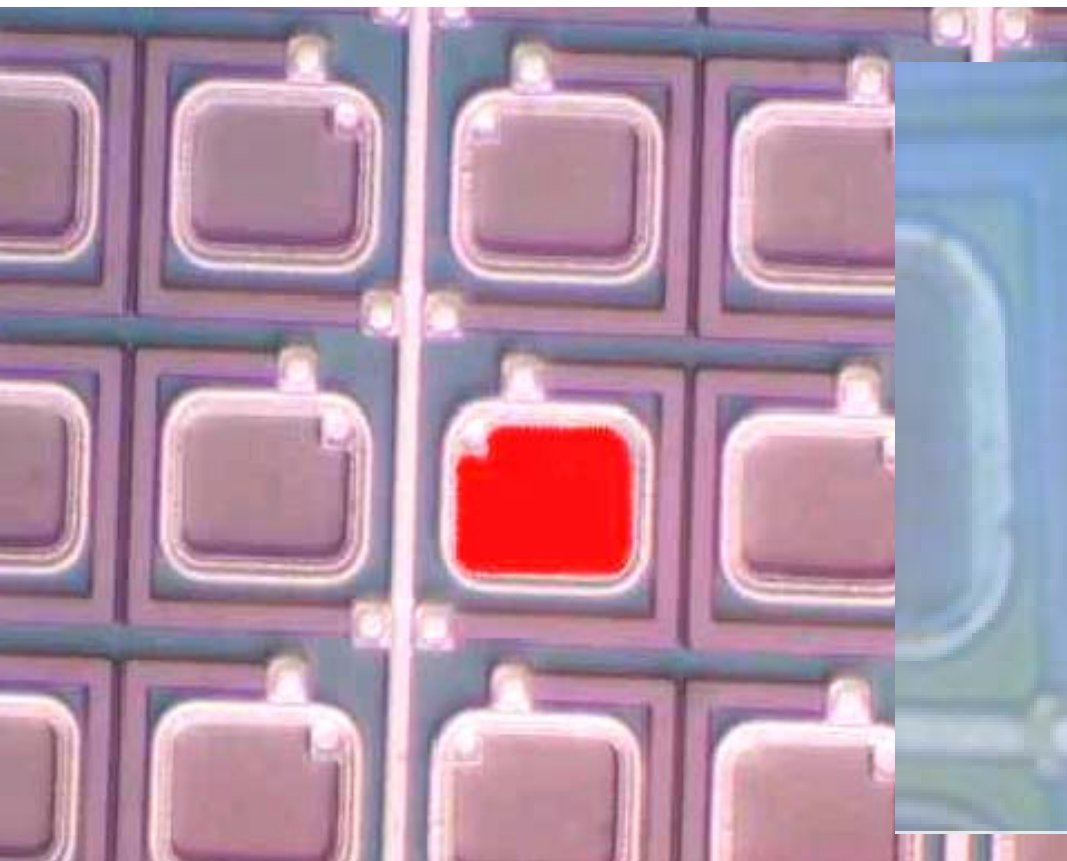


PDE uniformity (400 pixel, 100samples)

PDE Delta V : 400pixel 100samples



1600 pixel Microscopic view

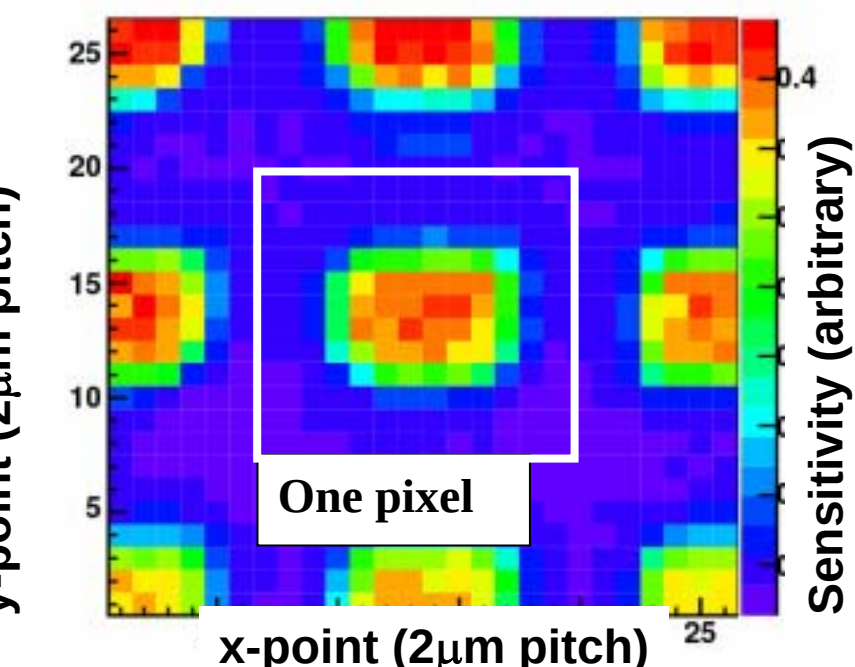


S10362-11-025U (2006.12)

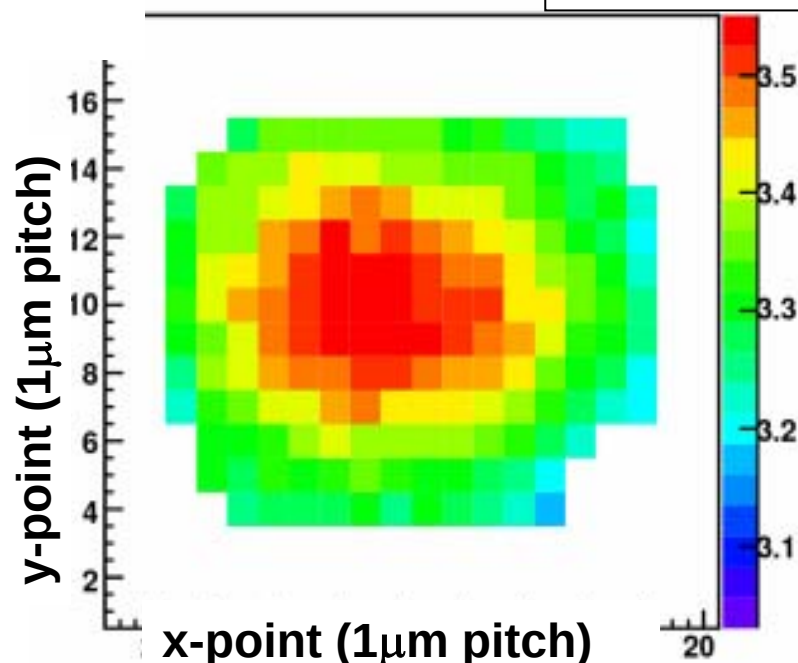
Laser Scan in One Pixel

- Pin-point scan : YAG laser ($\lambda = 532 \text{ nm}$) with spot size $\sim 1 \mu\text{m}$.
- Variation of photon sensitivity and gain in one pixel are evaluated.
- Observed variation is 2 ~ 5 % in a sensitive area for the 100 / 400 / 1600 pixel MPPCs.

1600 pixel Sensitivity



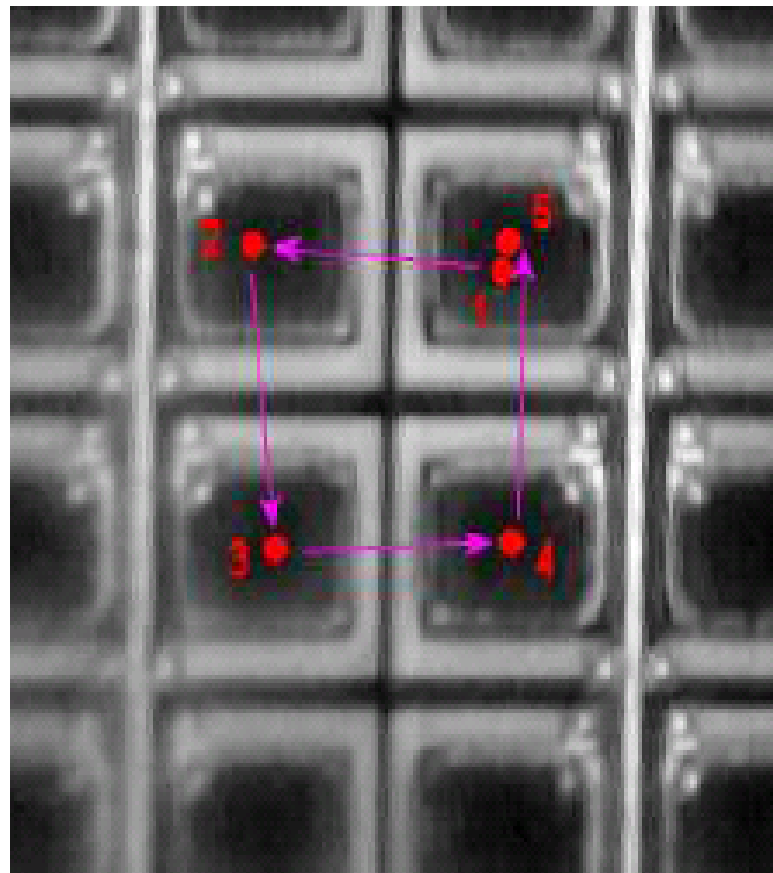
1600 pixel Gain



Variation $\sim 3 \%$

Time resolution at center in different pixel

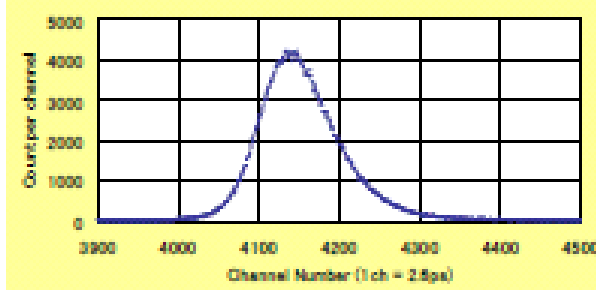
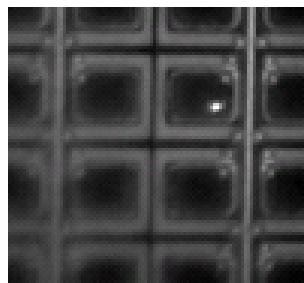
MPPC: MPPC:1mm² 50 μ m pitch



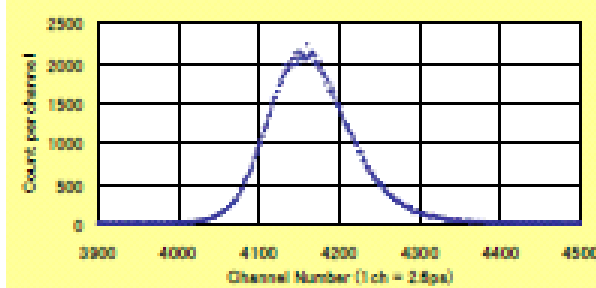
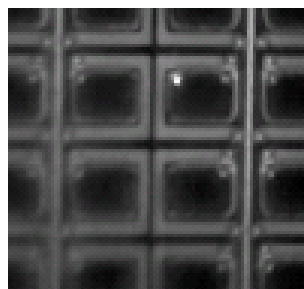
	FWHM (ps)	FWTM (ps)
1	199	393
2	197	389
3	209	409
4	201	393
5	195	383

Time resolution in one pixel

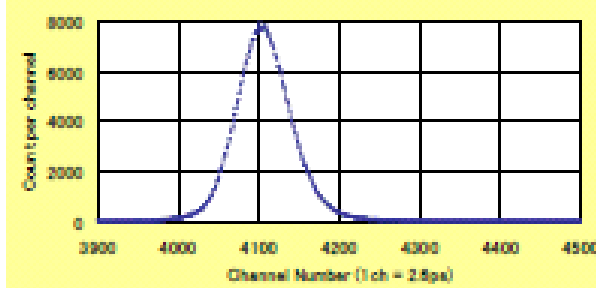
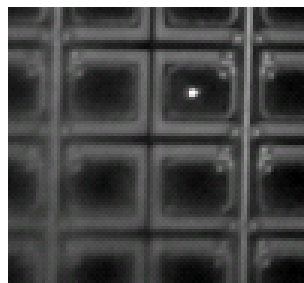
MPPC: 1mm² 50 μ m pitch



FWHM = 263 ps

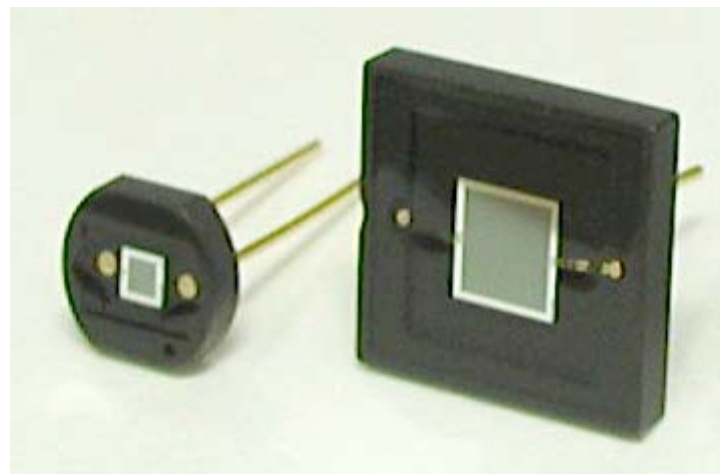
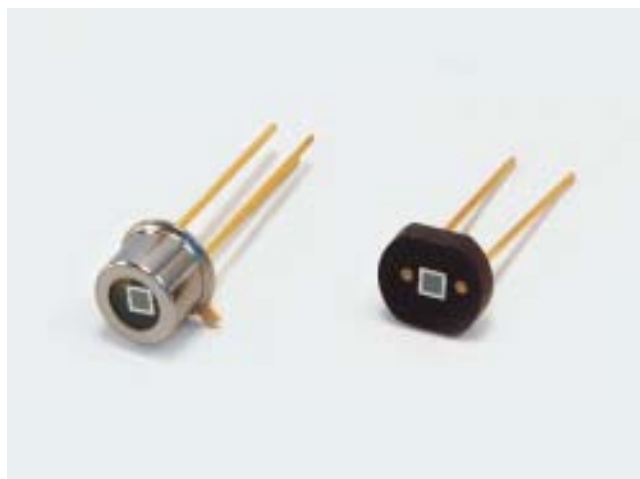


FWHM = 294 ps

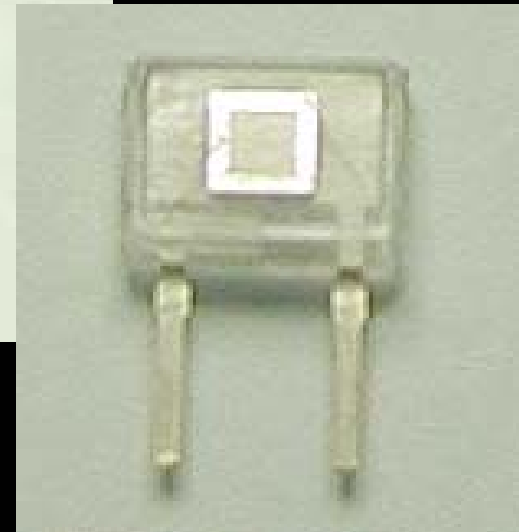
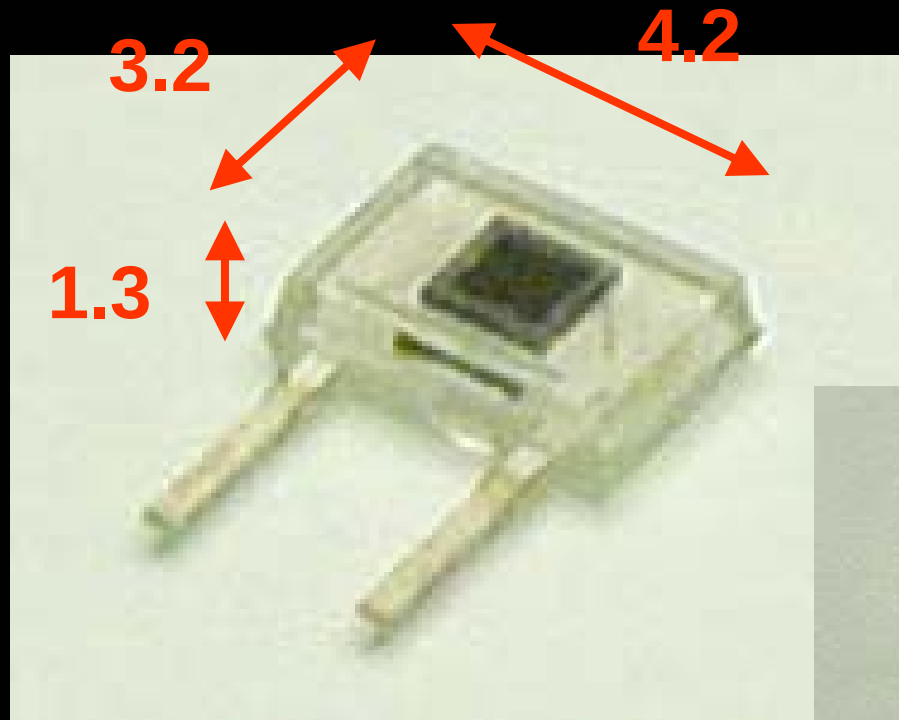


FWHM = 192 ps

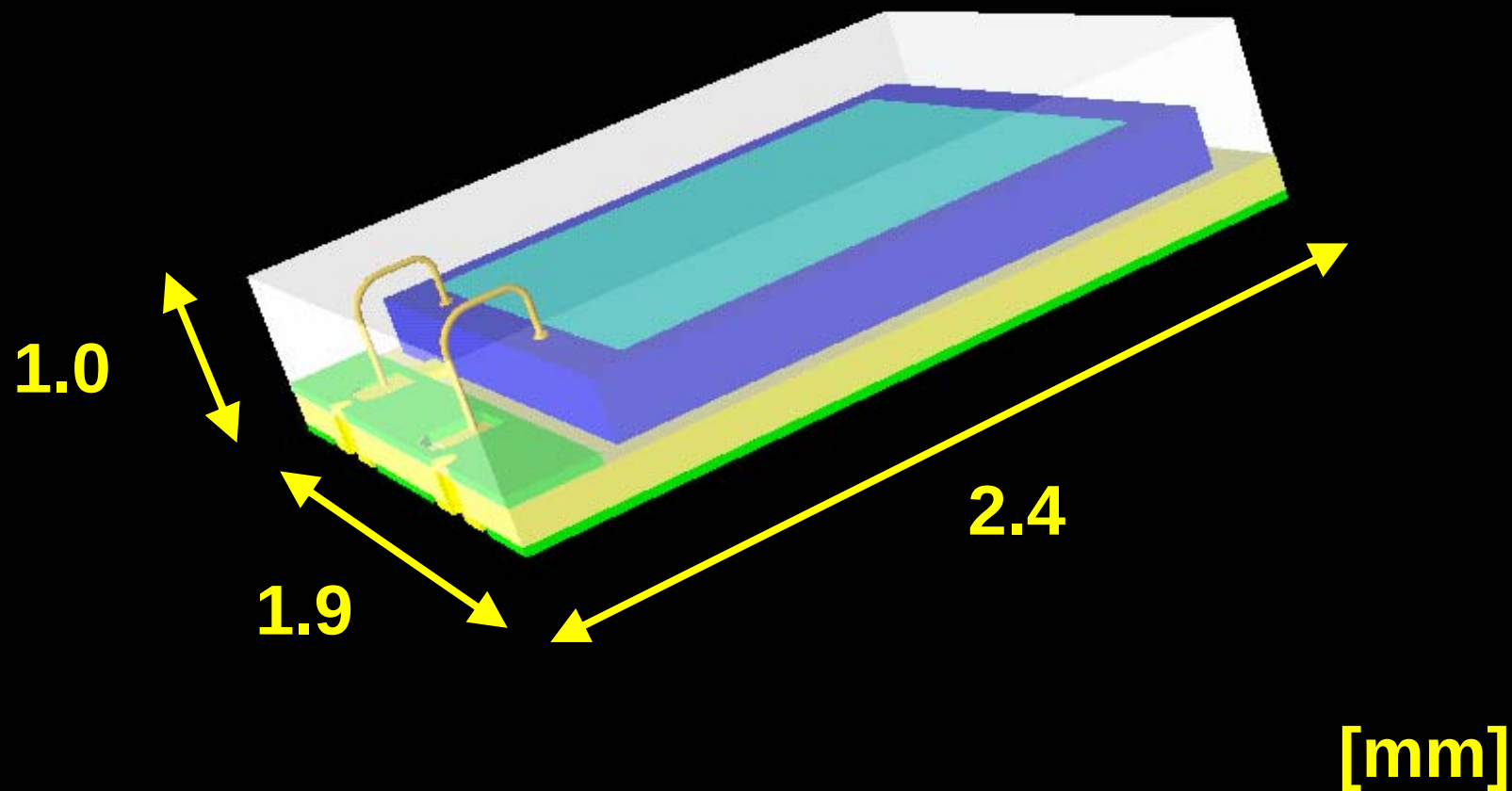
Package Developments



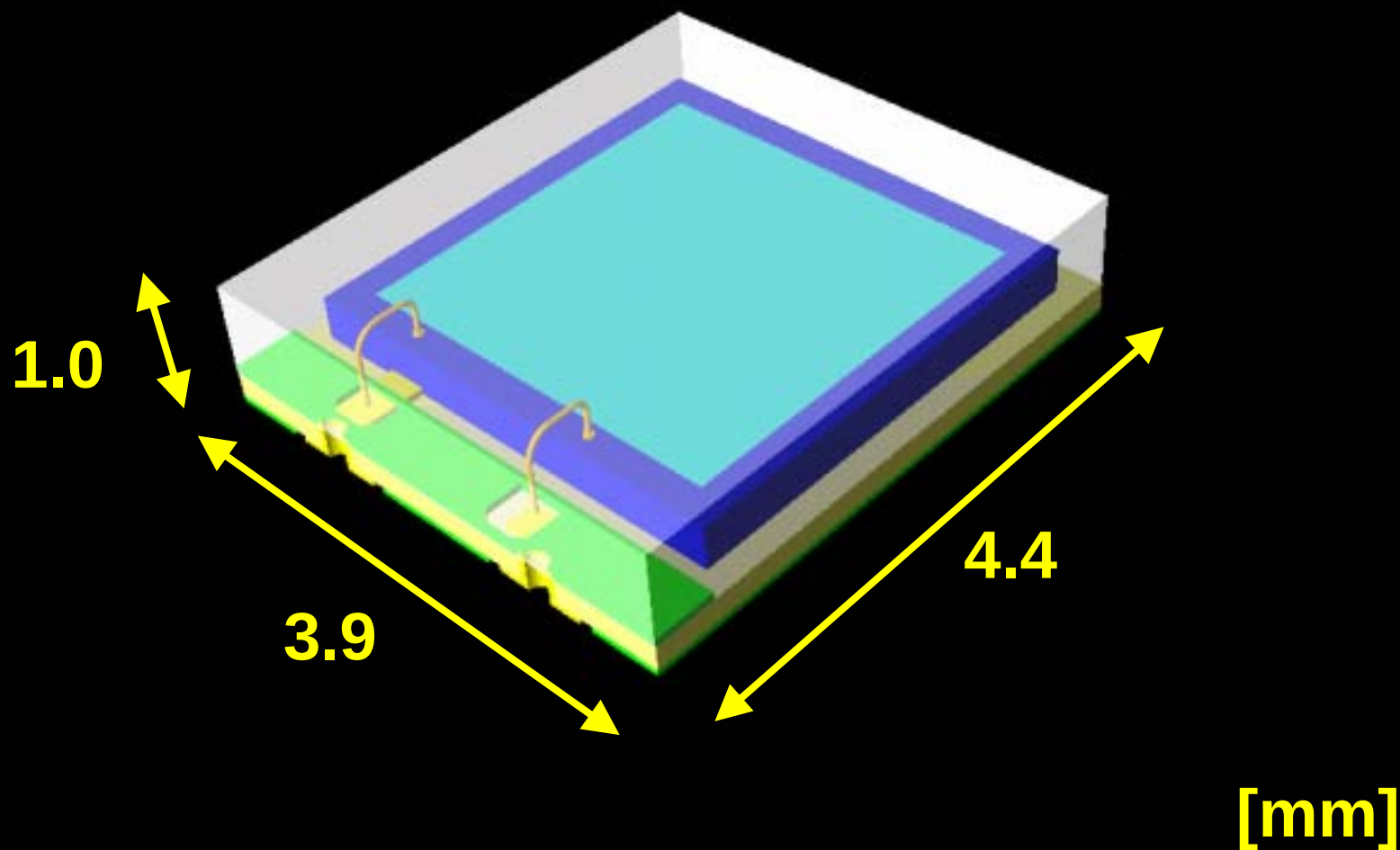
Plastic PKG (1mm $\square$ $\times$ 1ch.)



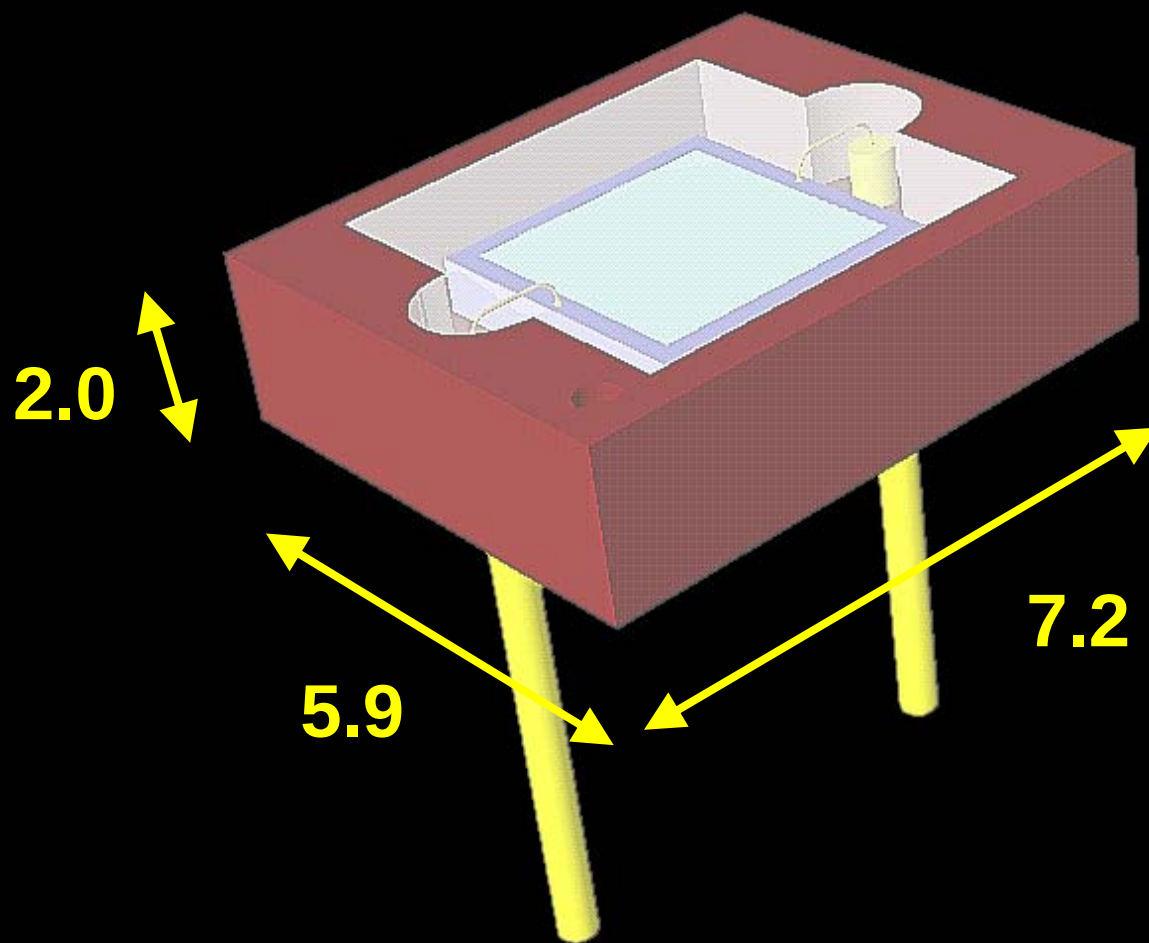
SMD PKG (1mm□ × 1ch.)



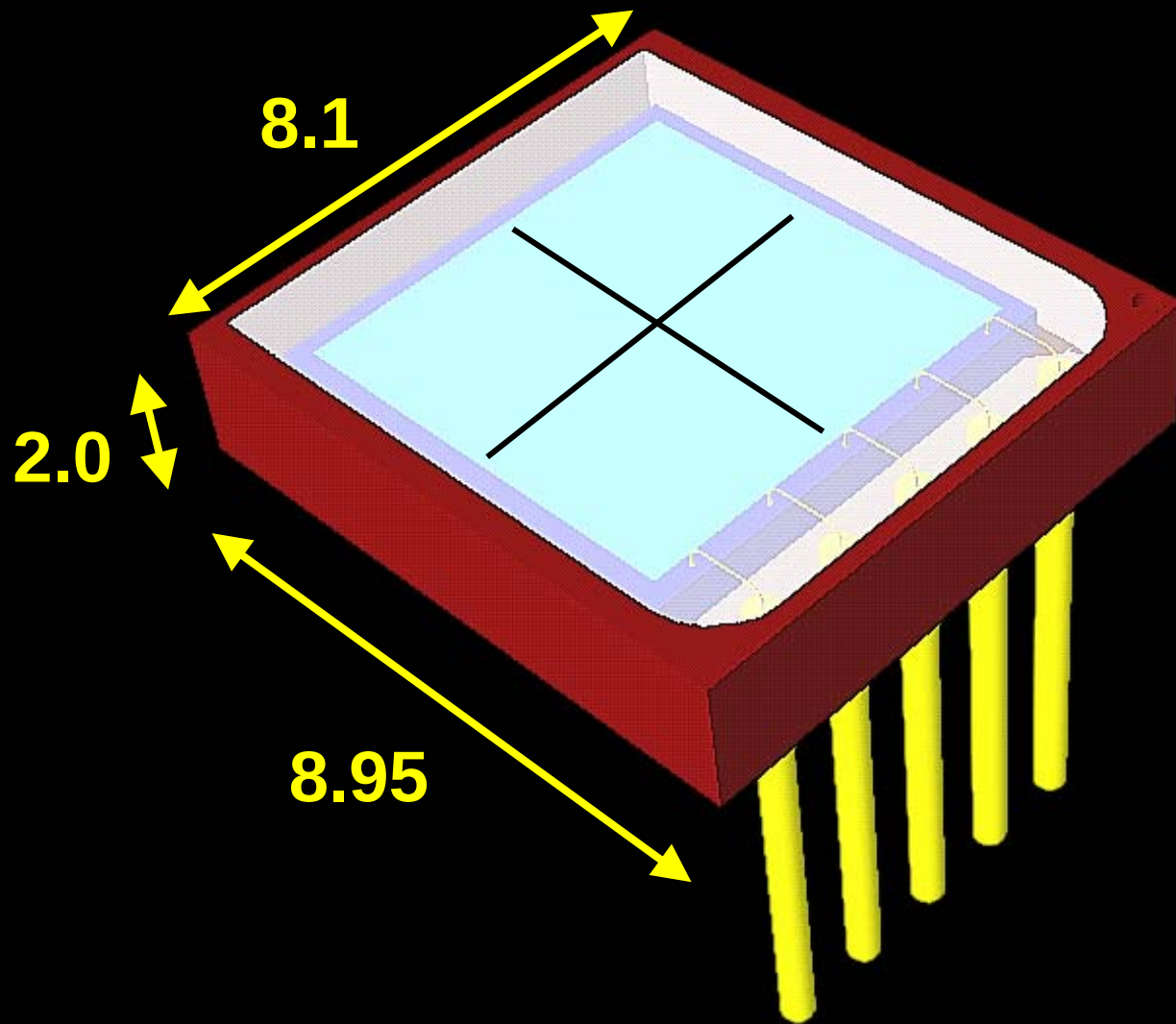
SMD PKG (3mm□ × 1ch.)



CERAMIC PKG (3mm□ × 1ch.)



CERAMIC PKG (3mm□ × 4ch.)



■ MPPC's future plan

- Increase reproducibility and uniformity

- Large sensitive area , Array and Matrix

- Enhance PDE

- Suppress after pulse and cross talk

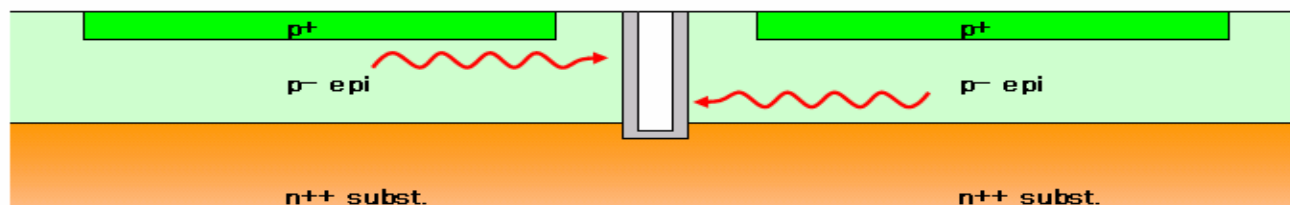
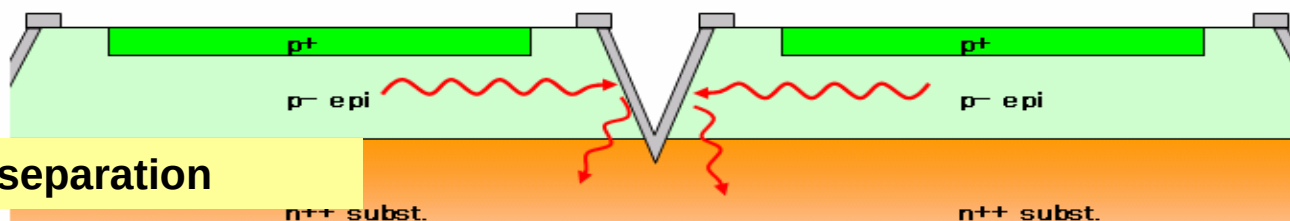
- Quenching resistance optimization

- Package development (small, cheap, rugged)

- Custom design (pitch, package, array)



Al optical separation and Trench etching



MPPC Module

Features

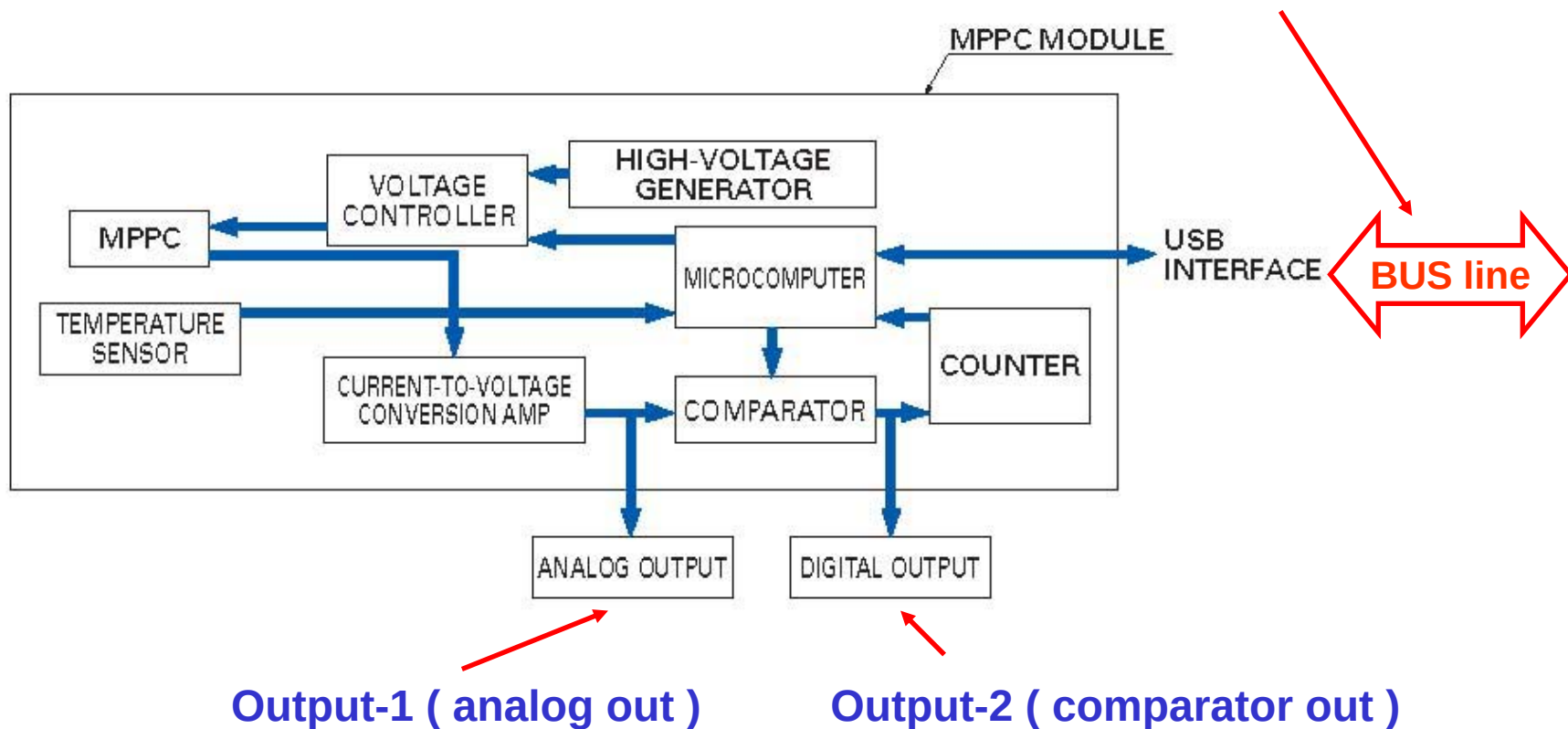
- Employs a Geiger-mode multi-pixel APD(MPPC)
- Integrates a signal readout circuit ideal for MPPC
- Built-in high-voltage circuit and temperature-compensated circuit
- Three types of output:
analog, comparator, pulse calculation value
- USB interface for easy handling: driven by USB bus power
- Compact and light weight



MPPC Module block diagram

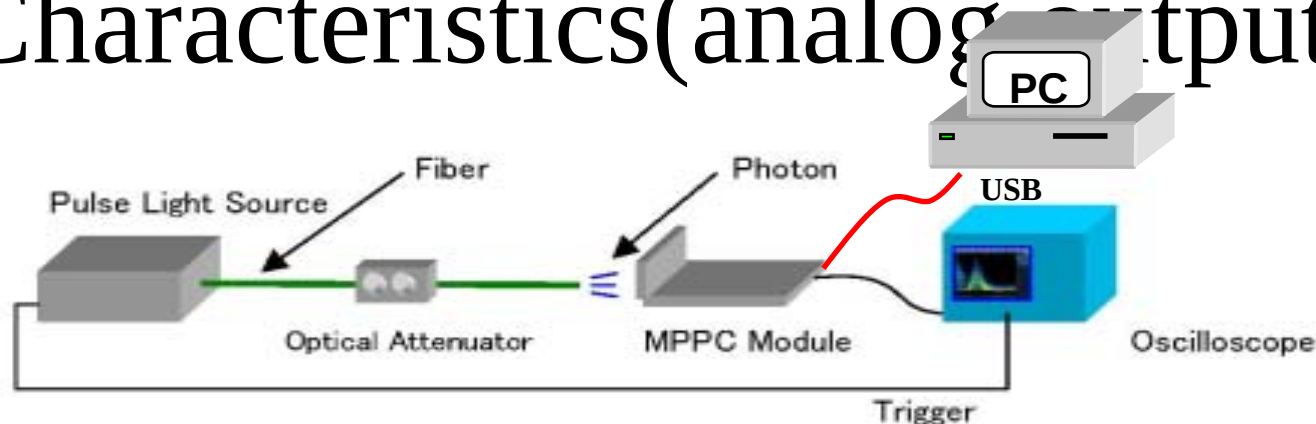
Power (Use USB bus power)

Output-3 (pulse calculation value)

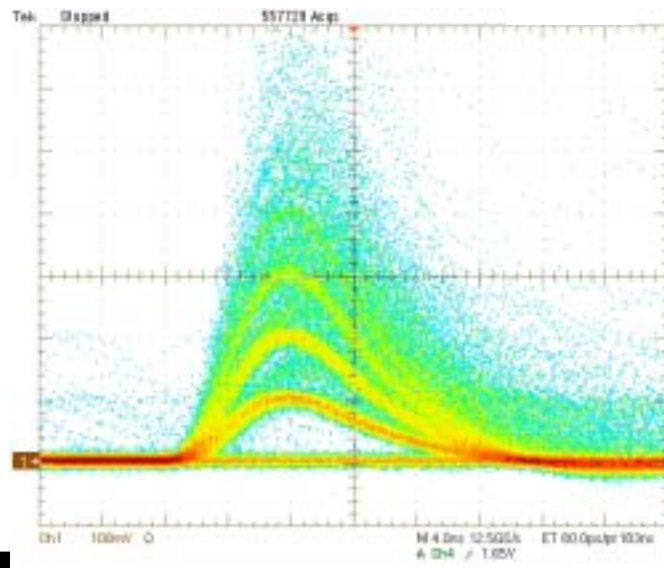


Characteristics(analog output)

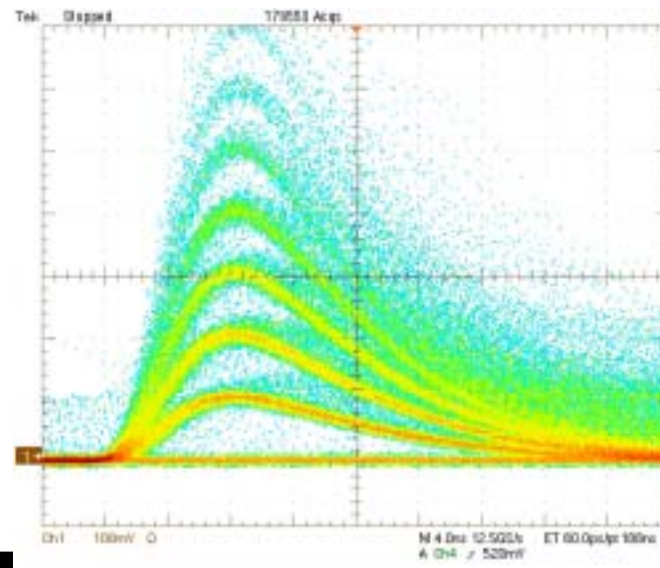
Me



C10507-11-025U

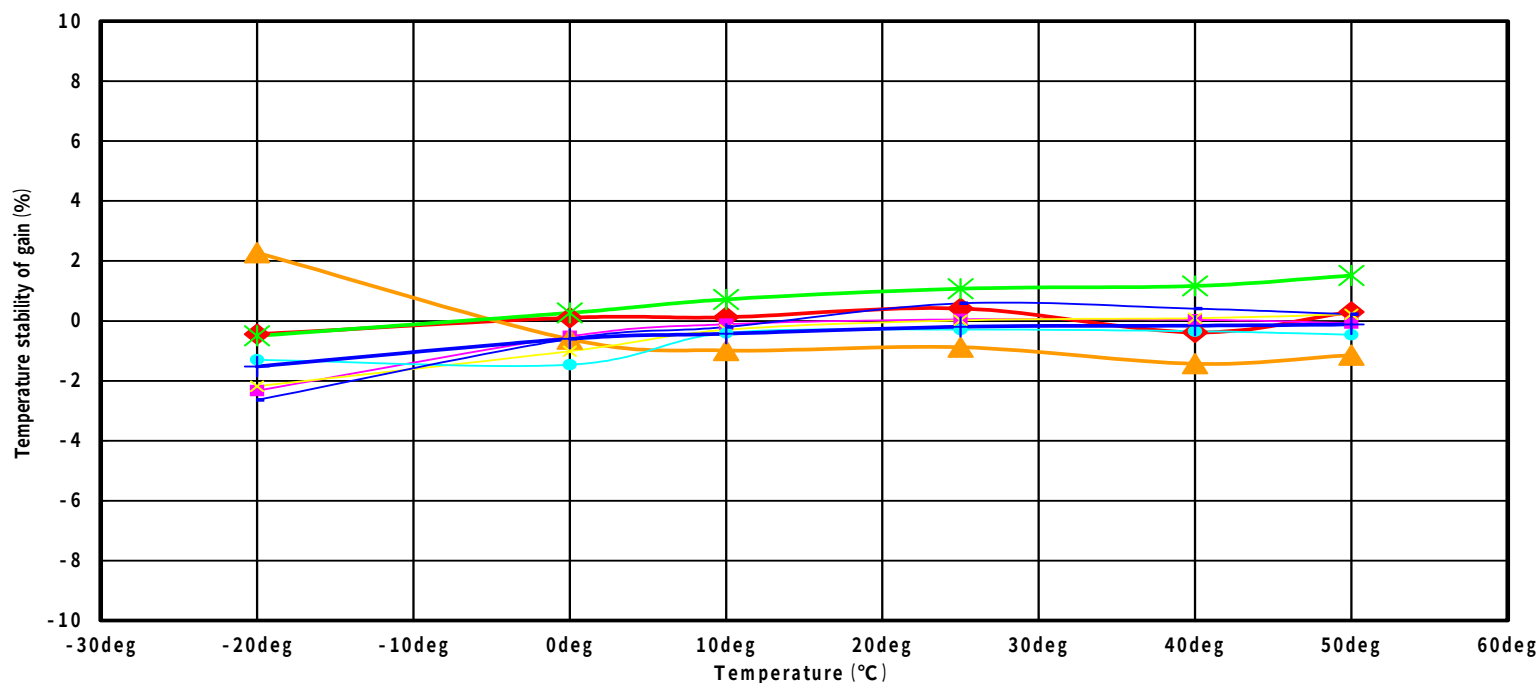


C10507-11-050U



Characteristics(temperature stability of Gain)

Gain temperature characteristics



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