Large-Aperture Hybrid Photo-Detector

Y. Kawai[1,5], H. Nakayama[2], A. Kusaka[2], H. Kakuno[2],
T. Abe[2], M. Iwasaki[2], H. Aihara[2], M. Tanaka[3],
M. Shiozawa[4], H. Kyushima[5], M. Suyama[5]

[1]*The Graduate University for Advanced Studies, Hayama, Kanagawa Pref., Japan*
[2]*University of Tokyo, Tokyo, Japan*
[3]*High Energy Accelerator Research Organization, Tsukuba, Ibaragi Pref., Japan*
[4]*Institute for Cosmic Ray Research, Kashiwa, Chiba Pref., Japan*
[5]*Hamamatsu Photonics K.K., Iwata, Shizuoka Pref., Japan*

Goal

To create a new photosensor to be the next generation massive water-Cherenkov detector

with

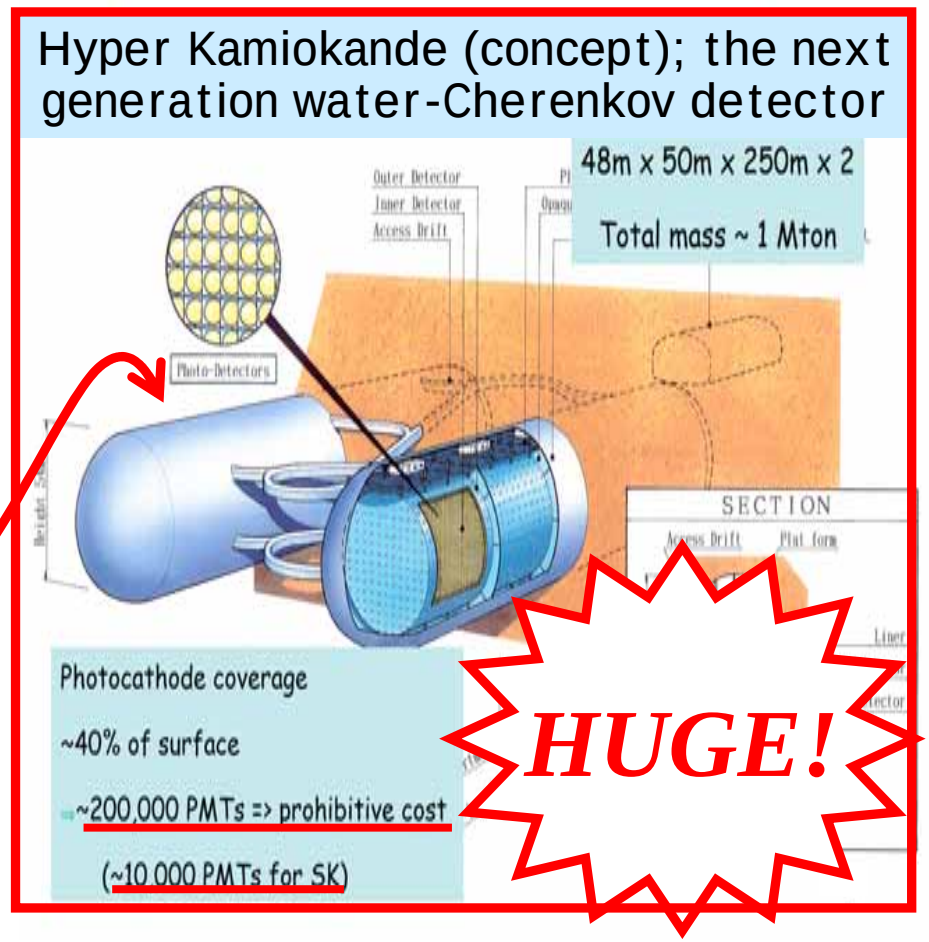
- ✓A large photocathode
- ✓Better time and energy resolution
- ✓Lower power consumption and
- ✓Simpler structure for lower cost

because...

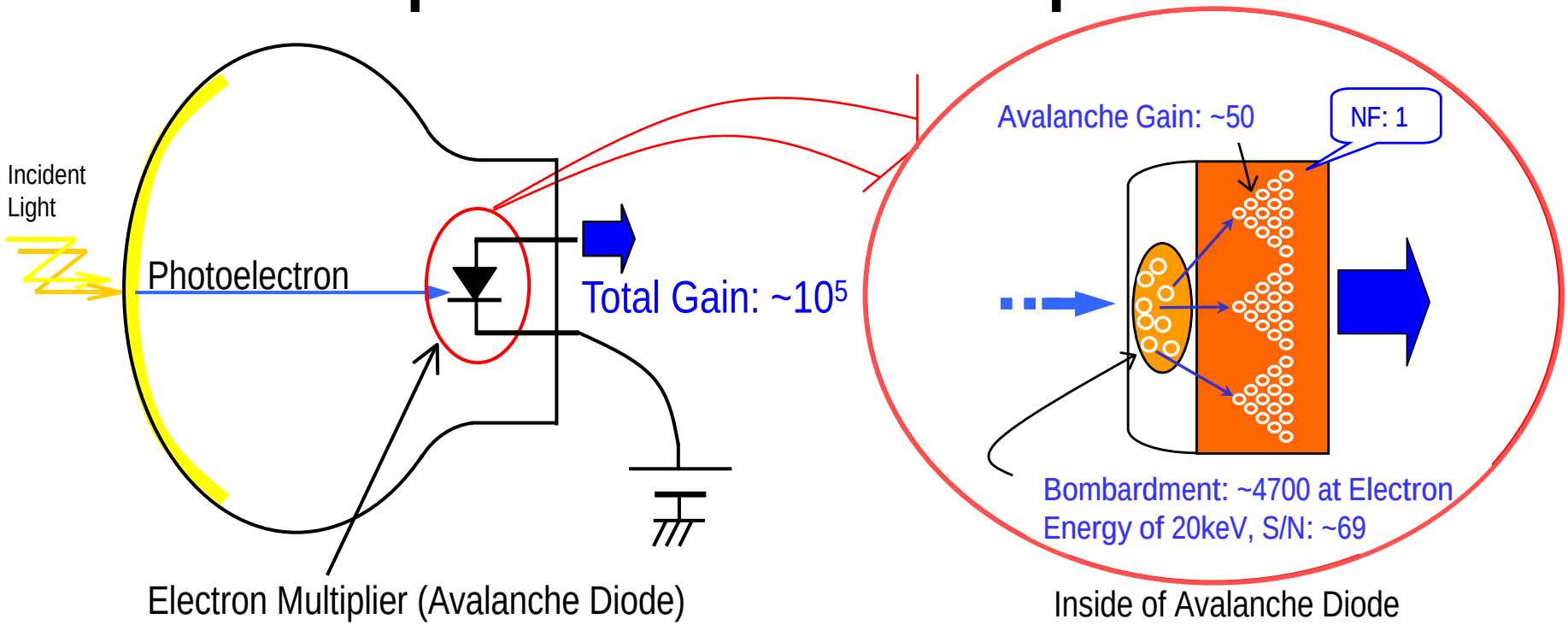
so...

our answer to the demand is the creation of the

Large-Aperture Hybrid Photo-Detector (HPD)



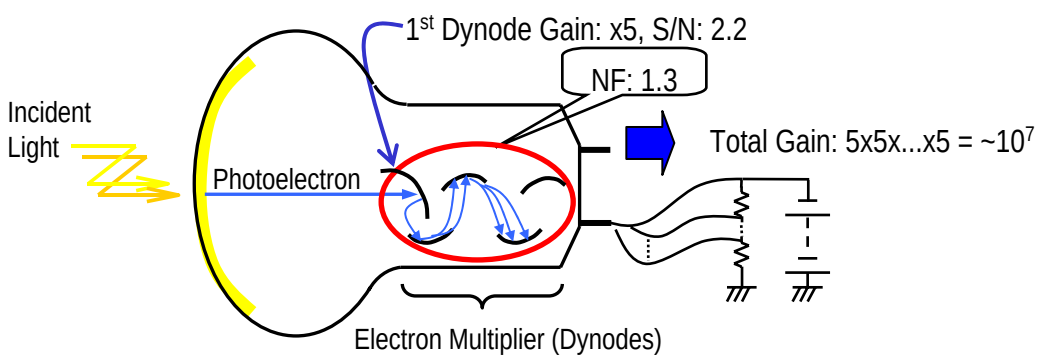
Principles of HPD Operation



HPDs

- ✓ have a simpler structure.
- ✓ are expected to save on production costs because they are suitable for quantity production with easier production and quality control.
- ✓ have better S/N but lower gain.

cf. Super Kamiokande Type PMT



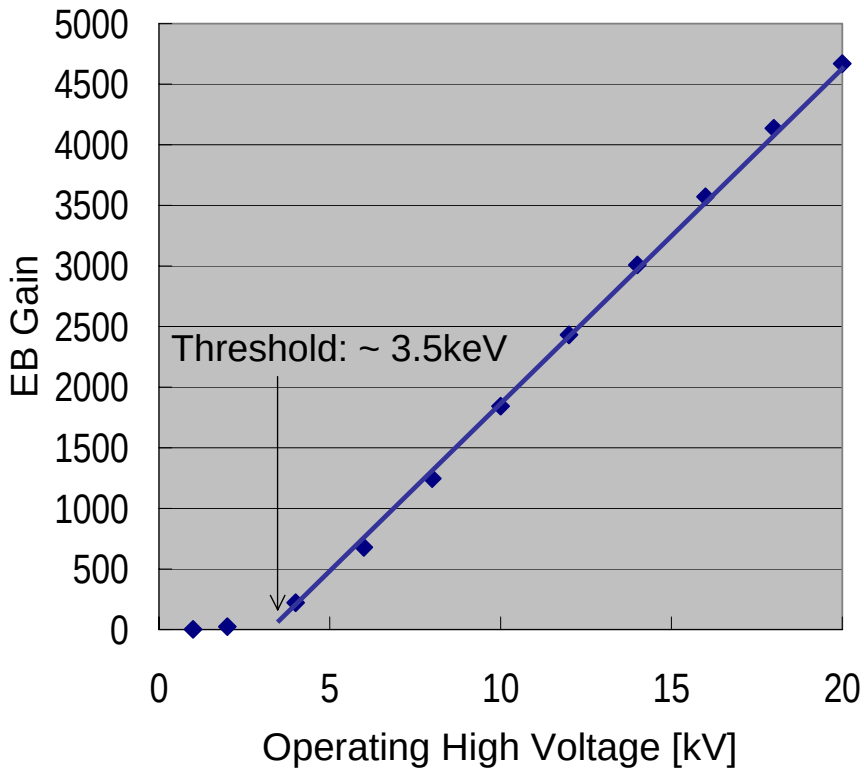
Comparison of Developed HPD and Conventional Large-Aperture PMTs

Parameters*		Developed HPD (13-inch HPD)	13-inch PMT (R8055)	20-inch PMT (R3600-02 for Super Kamiokande)
Order of Gain		10^5	10^7	10^7
Single Photon Time Resolution (σ)		190ps	1400ps	2300ps
Single Photon Energy Resolution		44% (preliminary)	70%	150%
Pulse Response	Rise Time	1ns	6ns	10ns
	Pulse Width	2.2ns	10ns	20ns
Transient Time		12ns	100ns	95ns
Dynamic Range (Signal Intensity in p.e.)		3000 p.e.	2000 p.e.	1000 p.e.

** Under rated operating voltage of 1.5kV for R8055 and 2kV for R3600-02. HV of +20kV bias voltage of 390V for HPD*

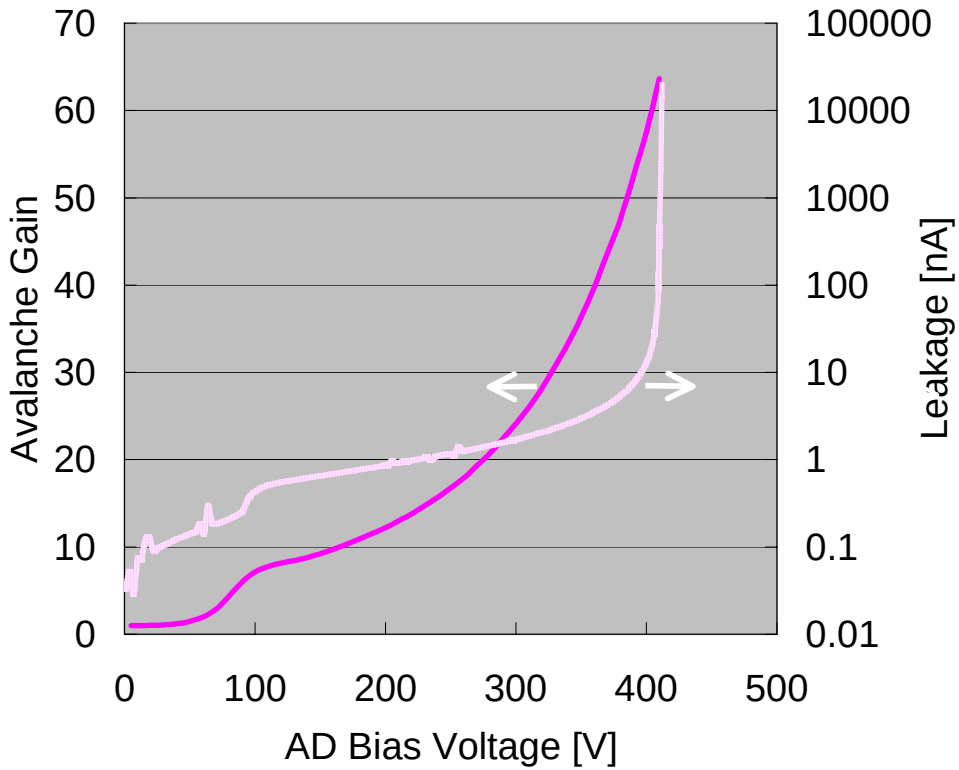
EB and Avalanche Gain

AD Bias=30V(fixed), HV=Swept



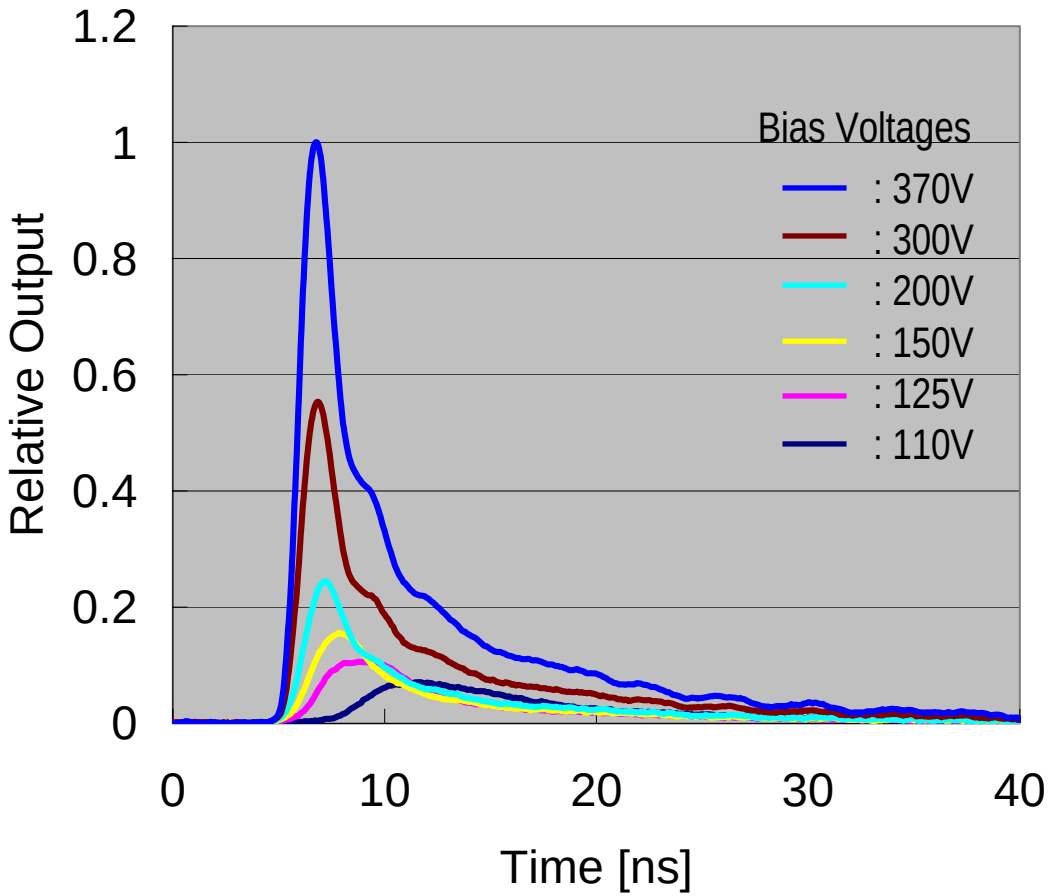
Gain=~4700 @20kV

HV=+10kV(fixed), Bias=Swept



Gain=~50 @390kV

Impulse Response (Raw Signal)



HV=+20kV(fixed), Bias=Swept

Light Source: Pulsed Laser

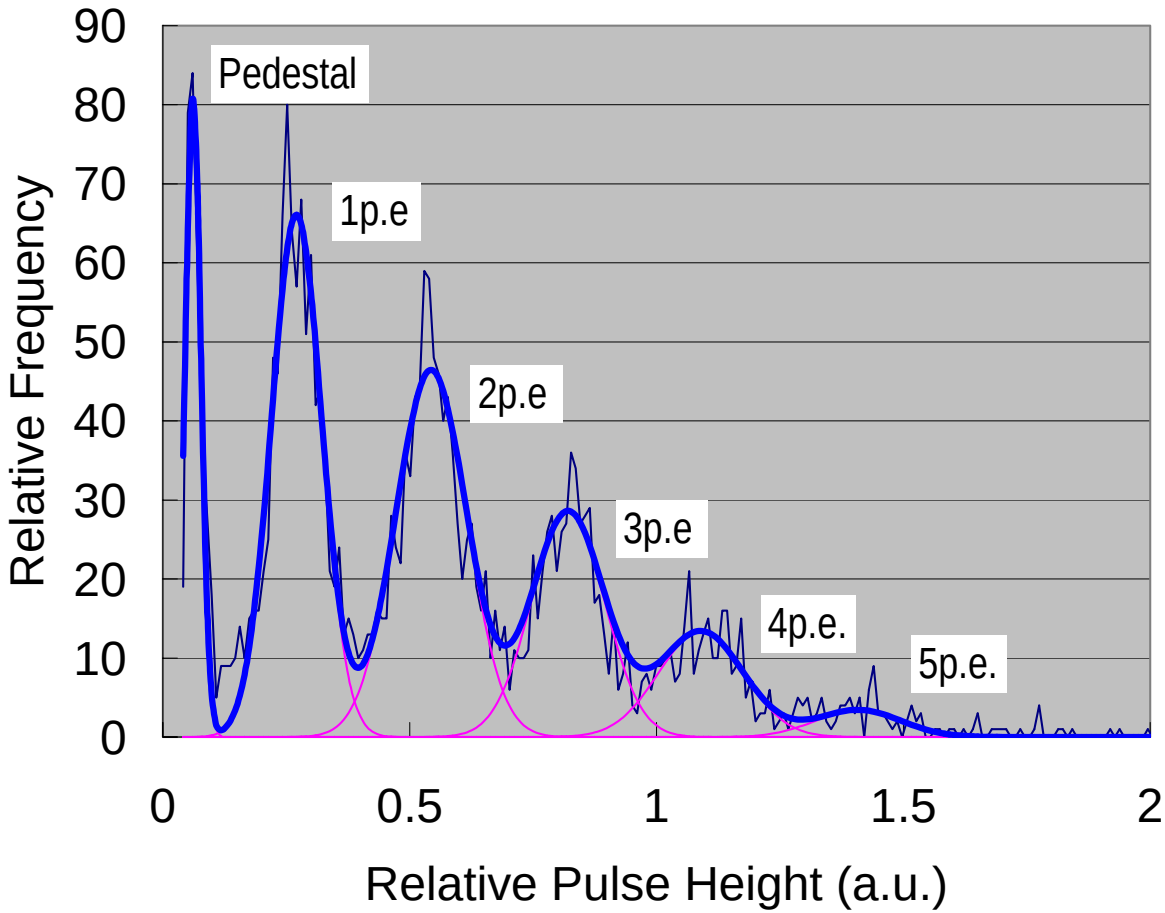
(PW: ~70ps, λ : ~400nm)

Rise Time: ~1ns

Pulse Width: ~2.2ns

for Bias Voltages of over 350V

Multi-Photoelectron Pulse Height Spectra



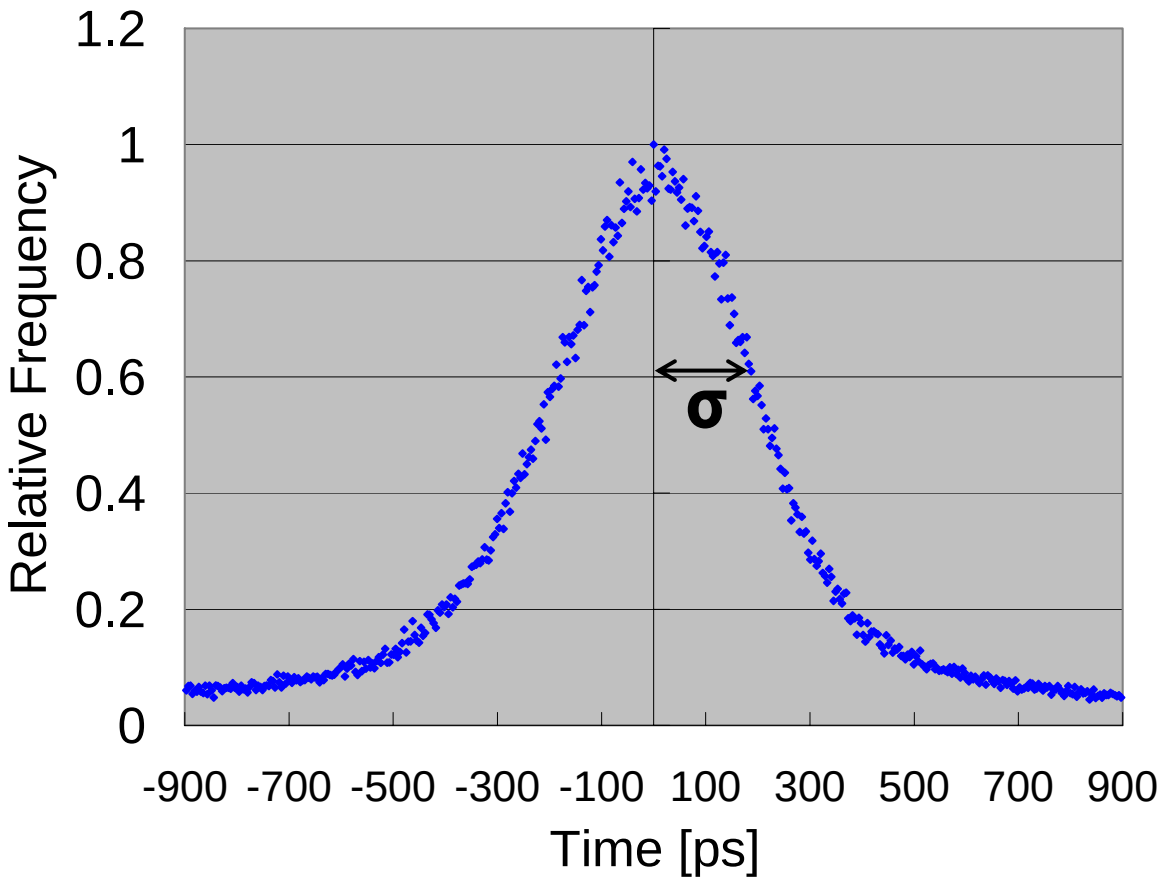
HV=+20kV, Bias=370V

Light Source: Pulsed Laser

(PW: ~70ps, λ : ~400nm)

Resolution for Single Photon Signal: ~ 44%

Time Resolution for Single Photon Signal



HV=+20kV, Bias=370V

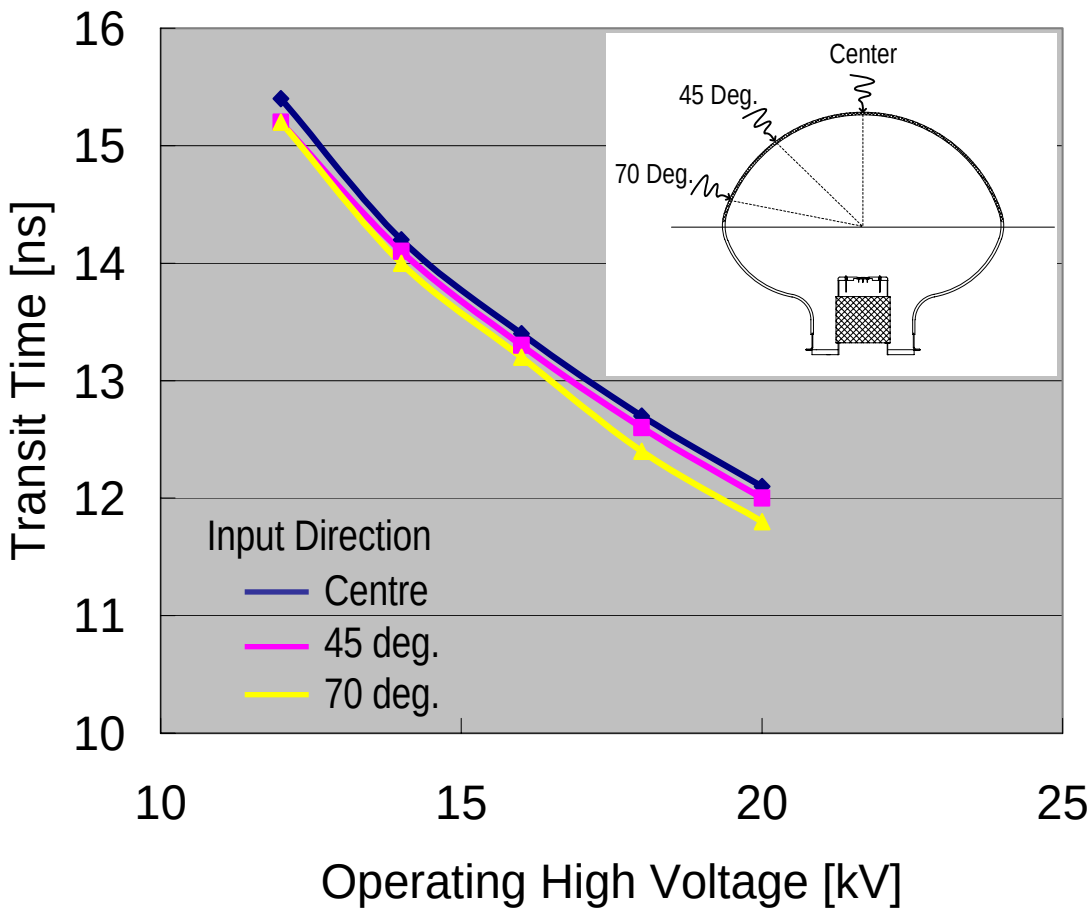
Light Source: Pulsed Laser

(PW: ~70ps, **λ** : ~400nm)

Time Resolution for Single Photon Signal (**σ**): ~190ps

(~440ps in FWHM)

Photoelectron Transit Time



HV=Swept, Bias=290V

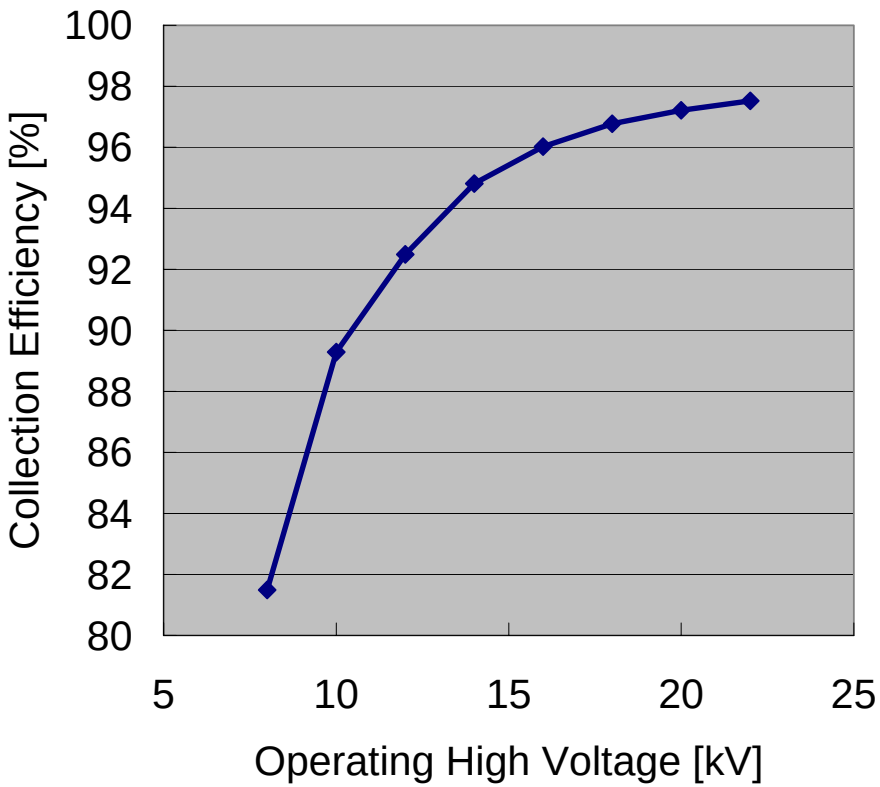
Light Source: Pulsed Laser

(PW: ~70ps, λ : ~400nm)

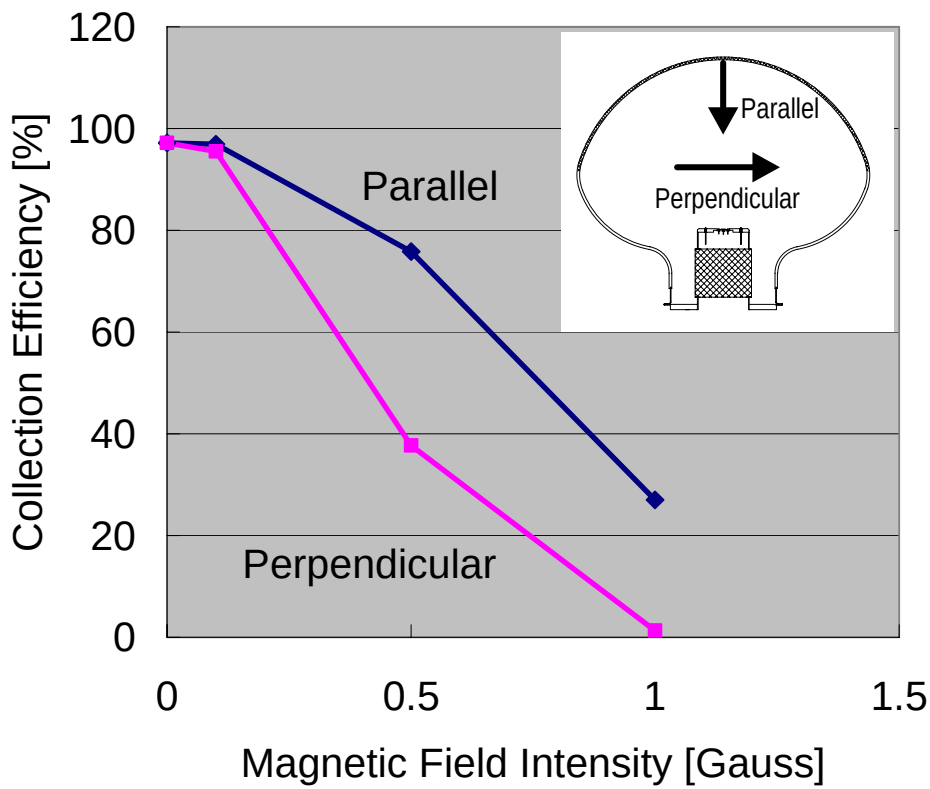
Transit Time: ~12ns for HV of 20kV

Photoelectron Collection Efficiency and Effect of Magnetic Field (*Simulation*)

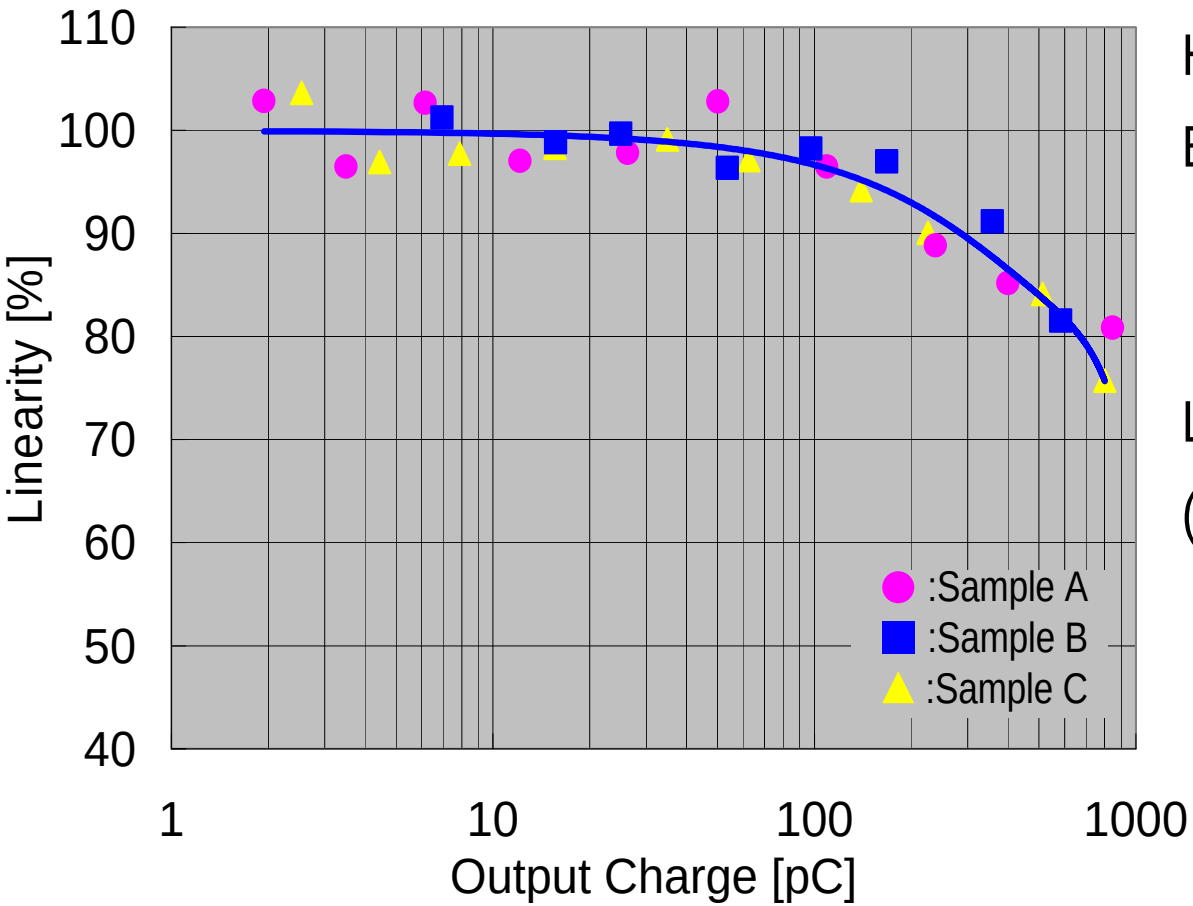
Photoelectron Collection Efficiency as a function of HV (No Magnetic Field)



Collection Efficiency as a function of Magnetic Field (at HV of +20kV)



Dynamic Range



HV=+20kV(fixed),

Bias=290V for Sample A

370V for Sample B

390V for Sample C

Light Source: Pulsed Laser

(PW: ~70ps, λ : ~400nm)

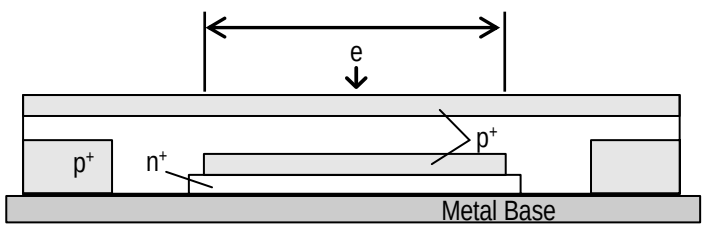
-3% Deviation at Output Charge of 100pC (~3000p.e. input signal intensity equivalent at total gain of ~2x10^5)

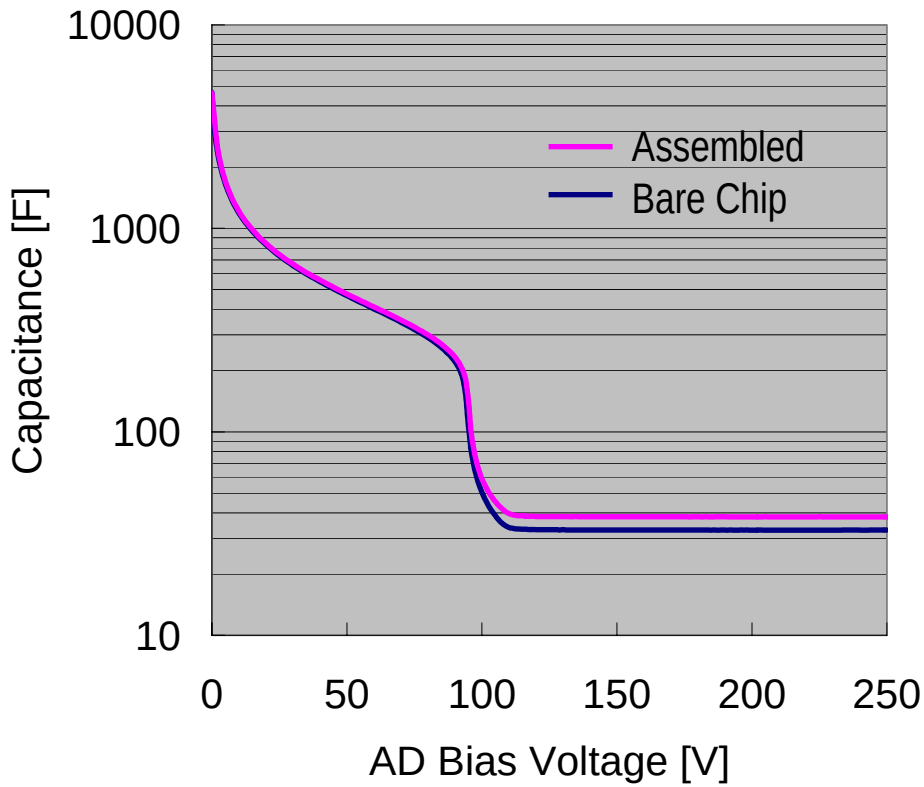
Incorporated Avalanche Diode and its C-V Characteristics

Capacitance: ~40pF over bias voltage of 120V (assembled on the base)

Backside Illumination Avalanche Diode

Effective Area: 5mm in dia.





Summary

We have developed a 13-inch HPD and confirmed

- ✓Fast Time Response; Rise Time of ~1ns, Pulse Width of ~2.2ns
- ✓Excellent Single Photon Time Resolution of ~190 ps (σ)
- ✓Excellent Single Photon Energy Resolution of ~44 %
- ✓Total Gain of >2 x 10^5

Promising as a photosensor for the next generation water-Cherenkov detector.

Next Steps

- ☐Optimization of manufacturing process
- ☐Evaluation of long-term operation stability

Acknowledgments

- This work has been supported by SENTAN, JST.
- We thank the members of HAMAMATSU PHOTONICS for their enthusiastic contribution to this work.