Accuracy in Powder Diffraction IV

High Performance Hybrid Pixel Detector and its Applications

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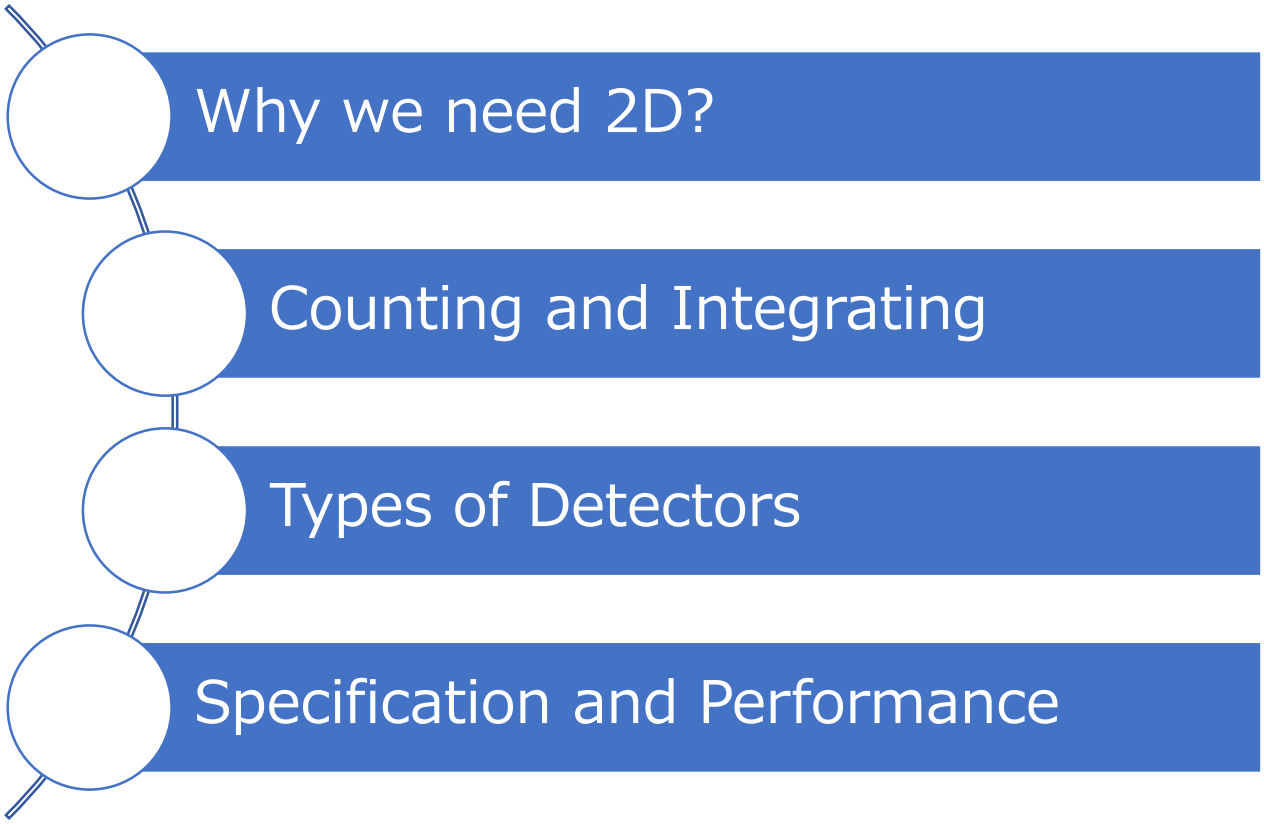
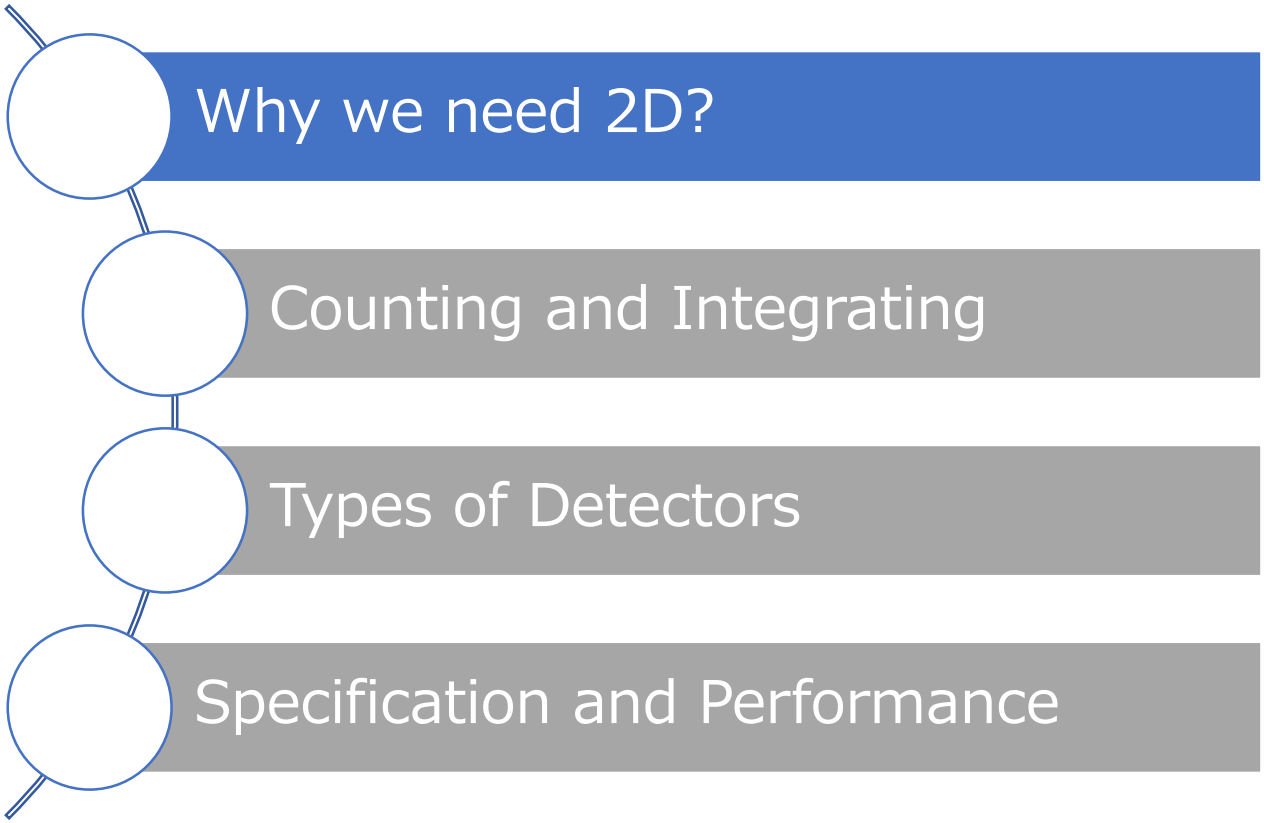
Outline

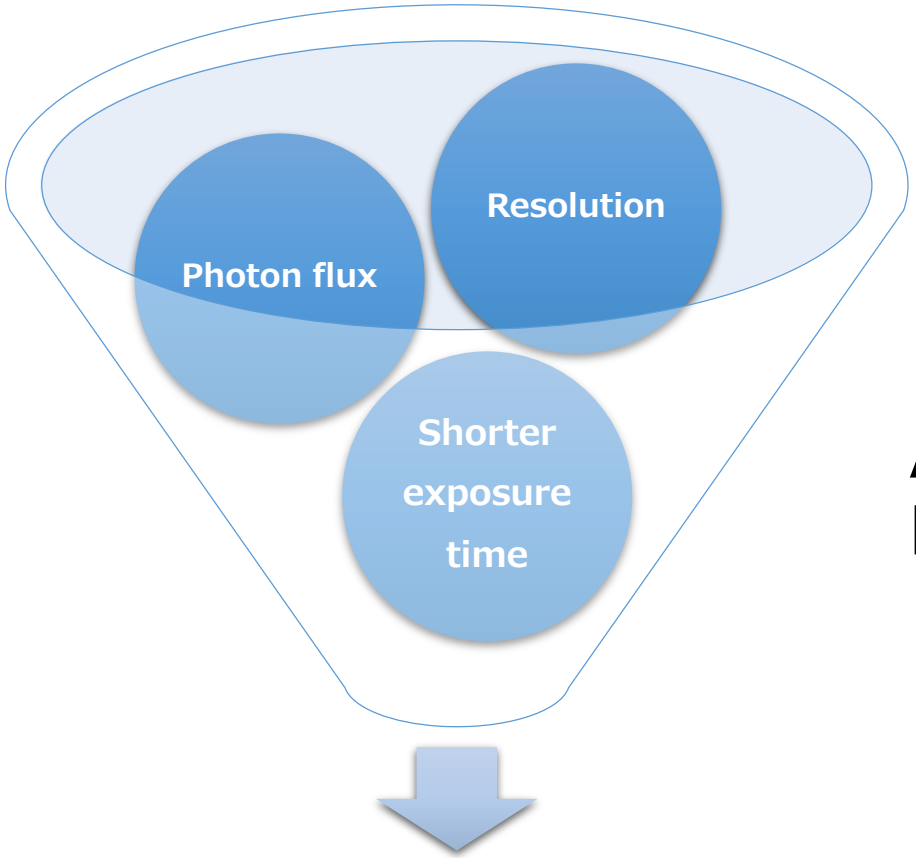


Outline



Why we need 2D?

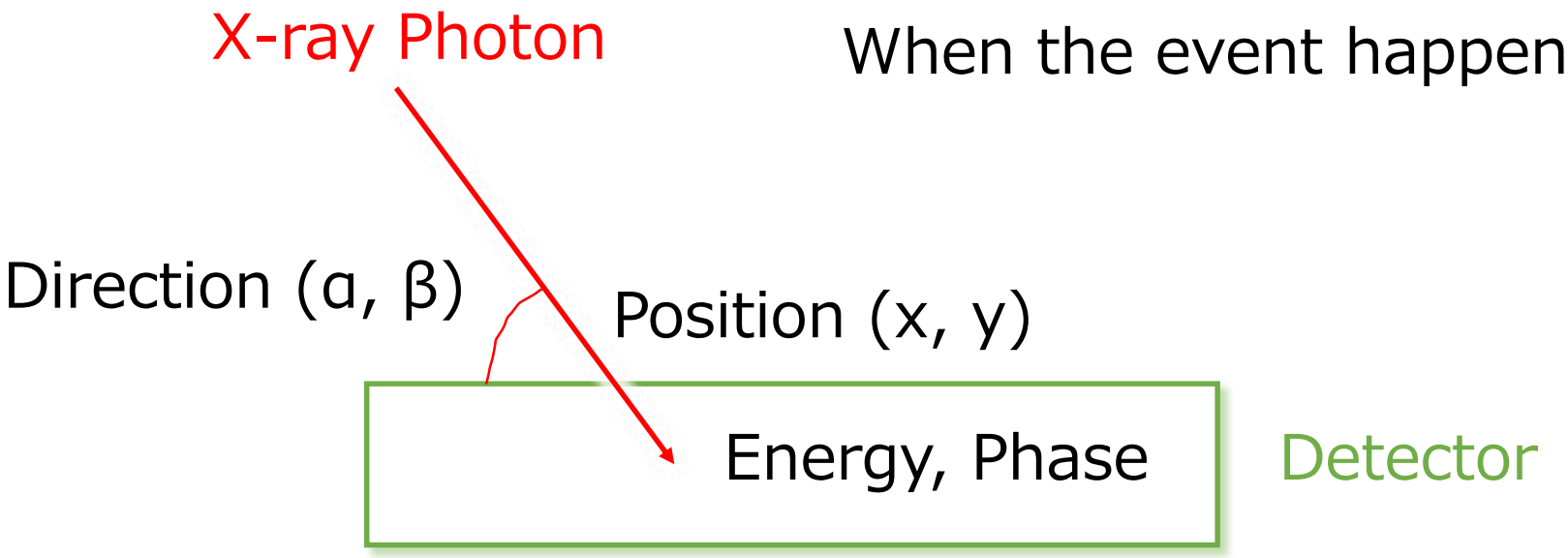
What is important for “Accuracy”?



All Limited by Detector!

Higher data quality

What is the "Ideal" X-ray Detector



Never misses photons!

Why we need 2D?

Single Crystal

Powder

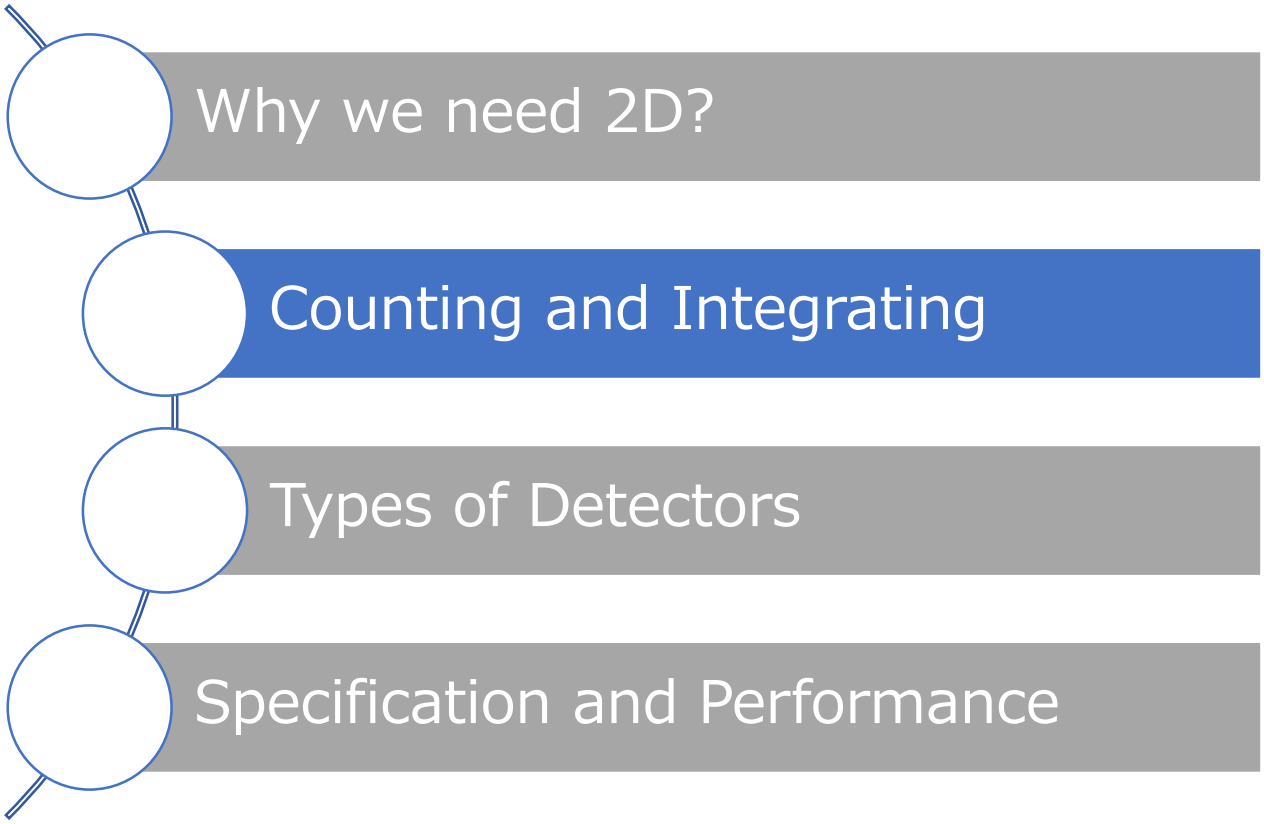
- Texture
- Orientation

Ideal Powder

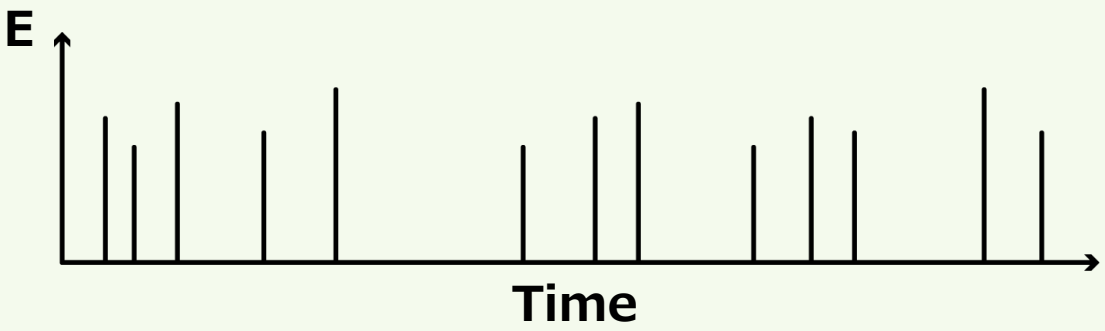
2D

1D

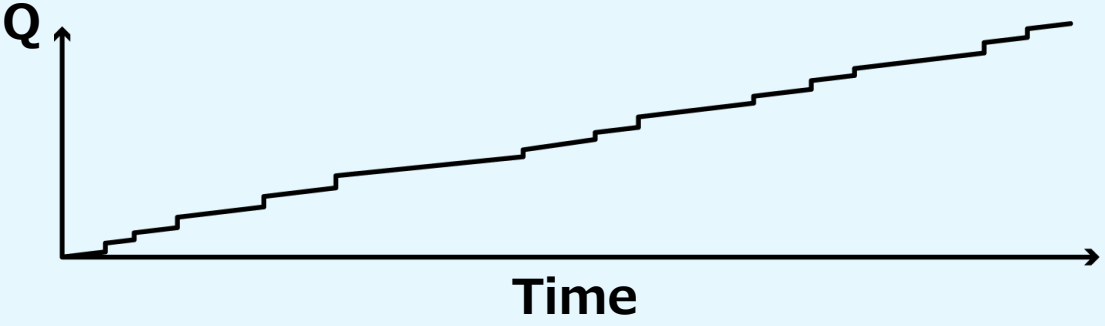
Outline



Counting and Integrating

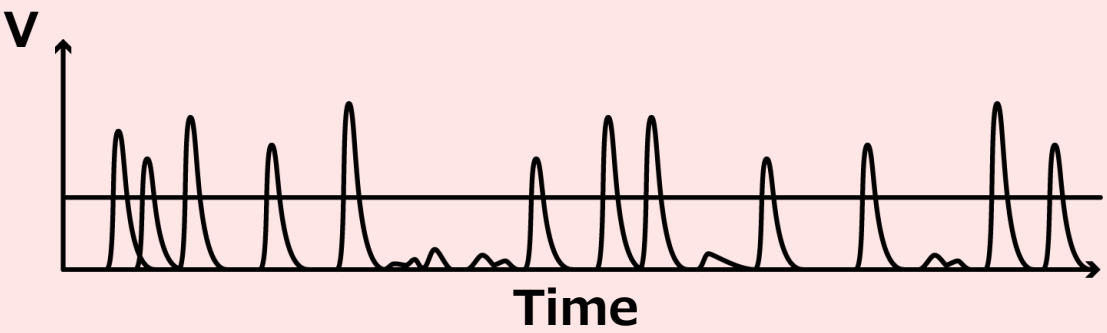


X-ray Photon



Photon Integrating

- Integrates all charge generated by photon and noise.



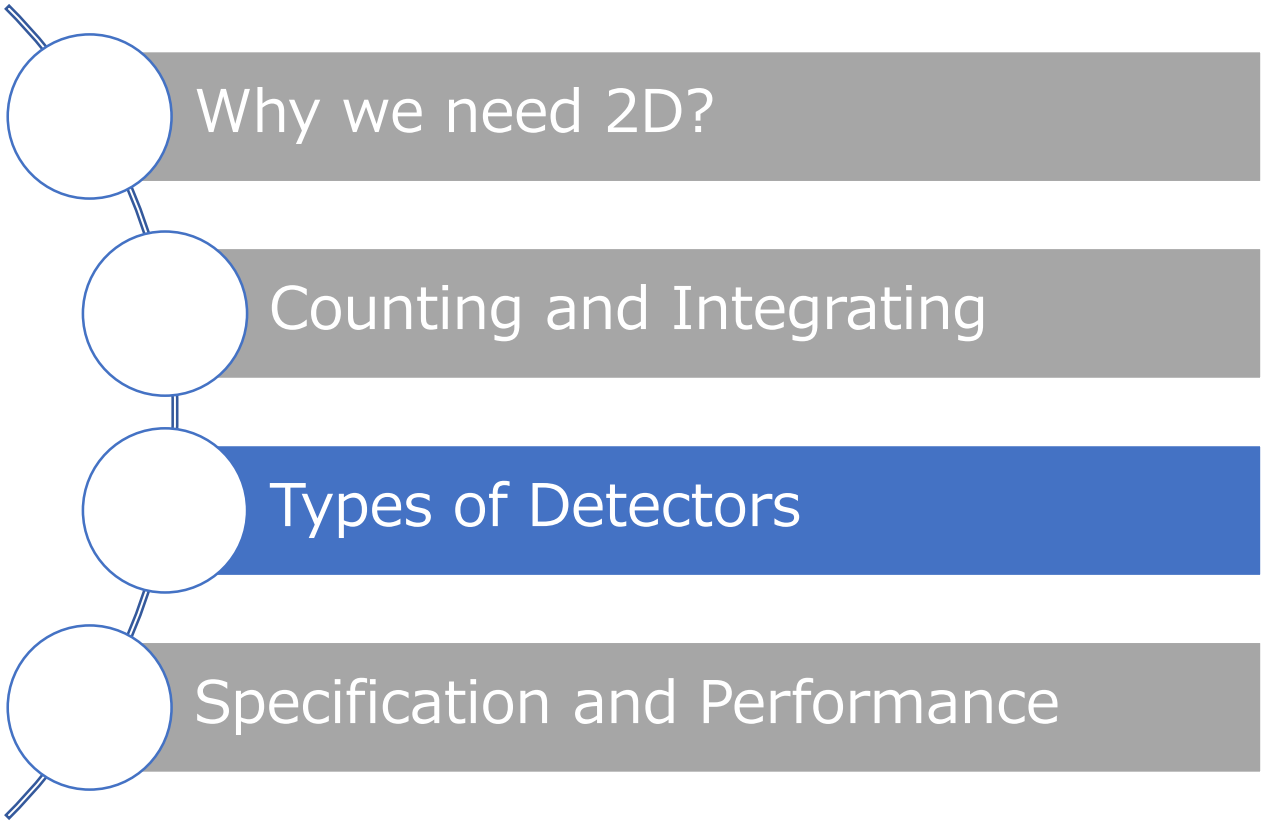
Photon Counting

- Discriminate X-ray pulse from noise by height.

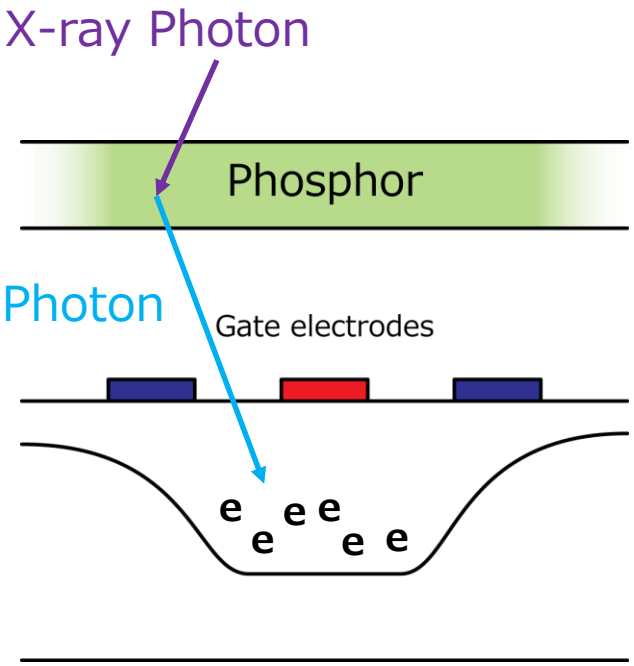
Detector Materials

Photon Integrating	Photon Counting
Phosphor • CCD • CMOS	**Semiconductor** • HPAD (Hybrid Pixel Array Detector)
IP (Image Plate)	**Gas** • MWPC (Multi-Wire Proportional Counter) • MPGD (Micro-Pattern Gas Detector)
X-ray Film	

Outline



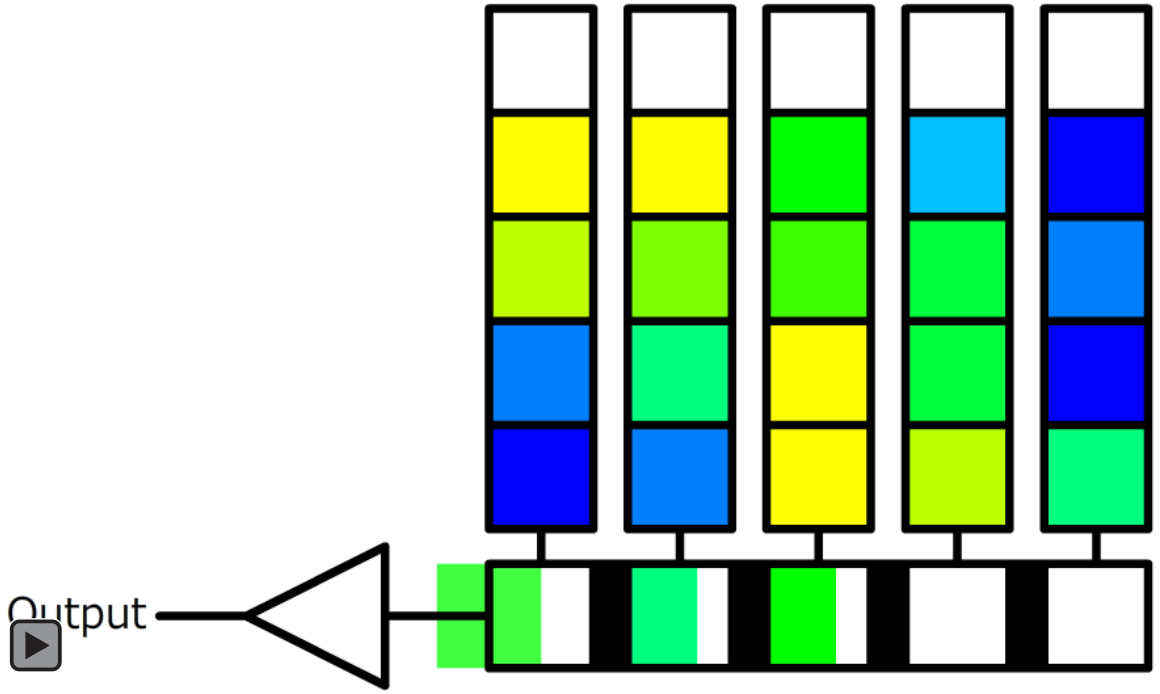
Charge Coupled Device (CCD)



Single Pixel

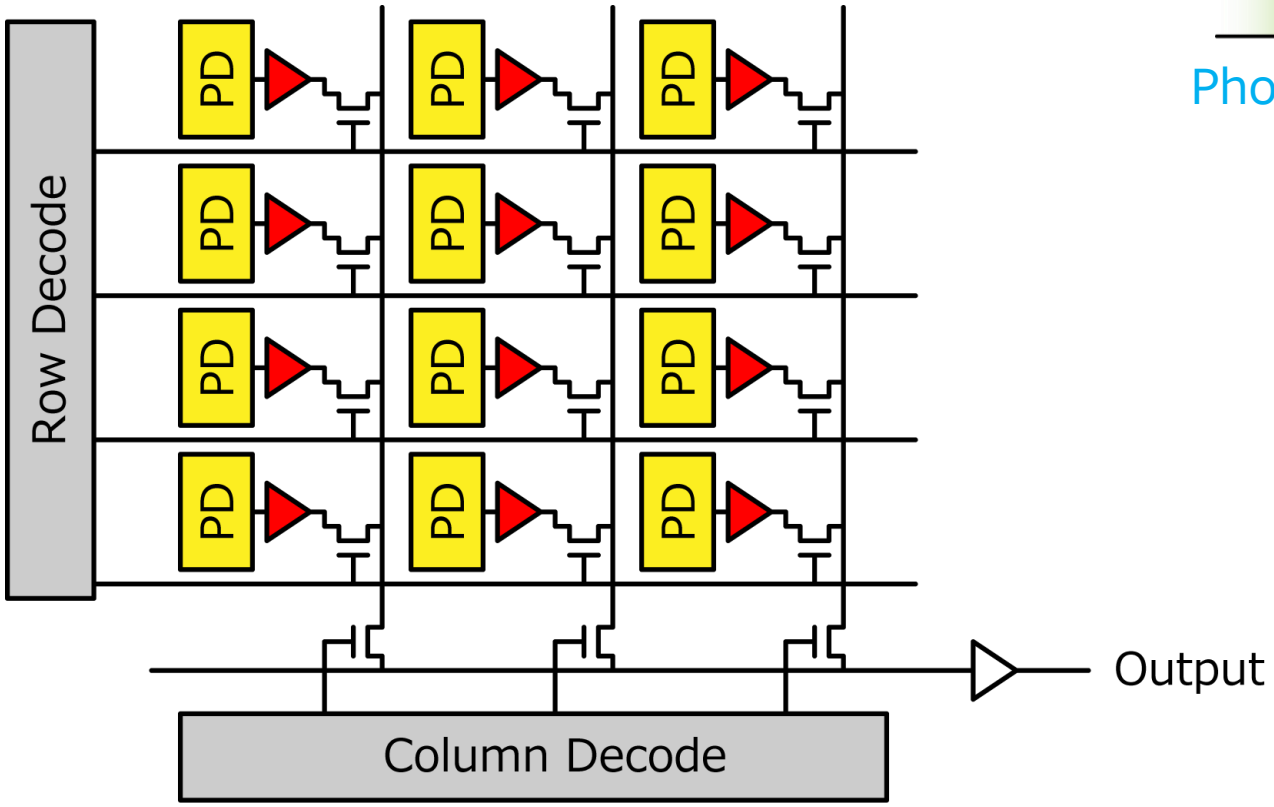
Electrons are integrated in a potential well

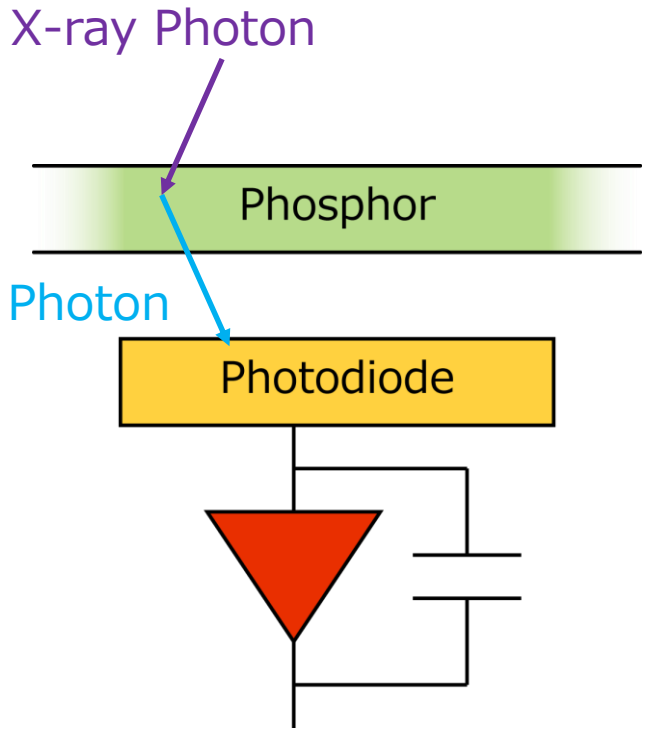
Similar to shift register



Complimentary Metal-Oxide Semiconductor (CMOS)

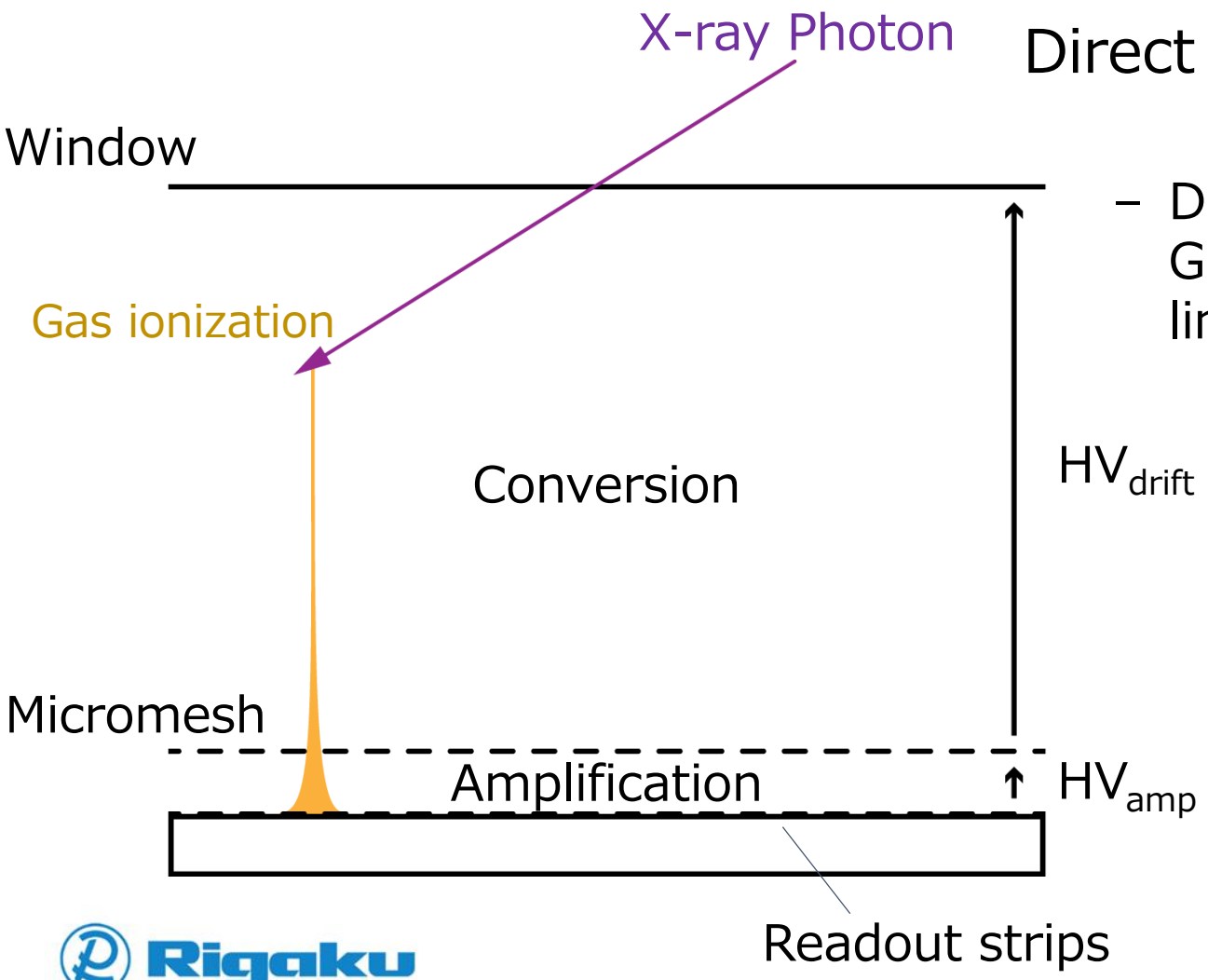
Similar to random access memory





Single Pixel

Micro-Pattern Gas Detector (MPGD)

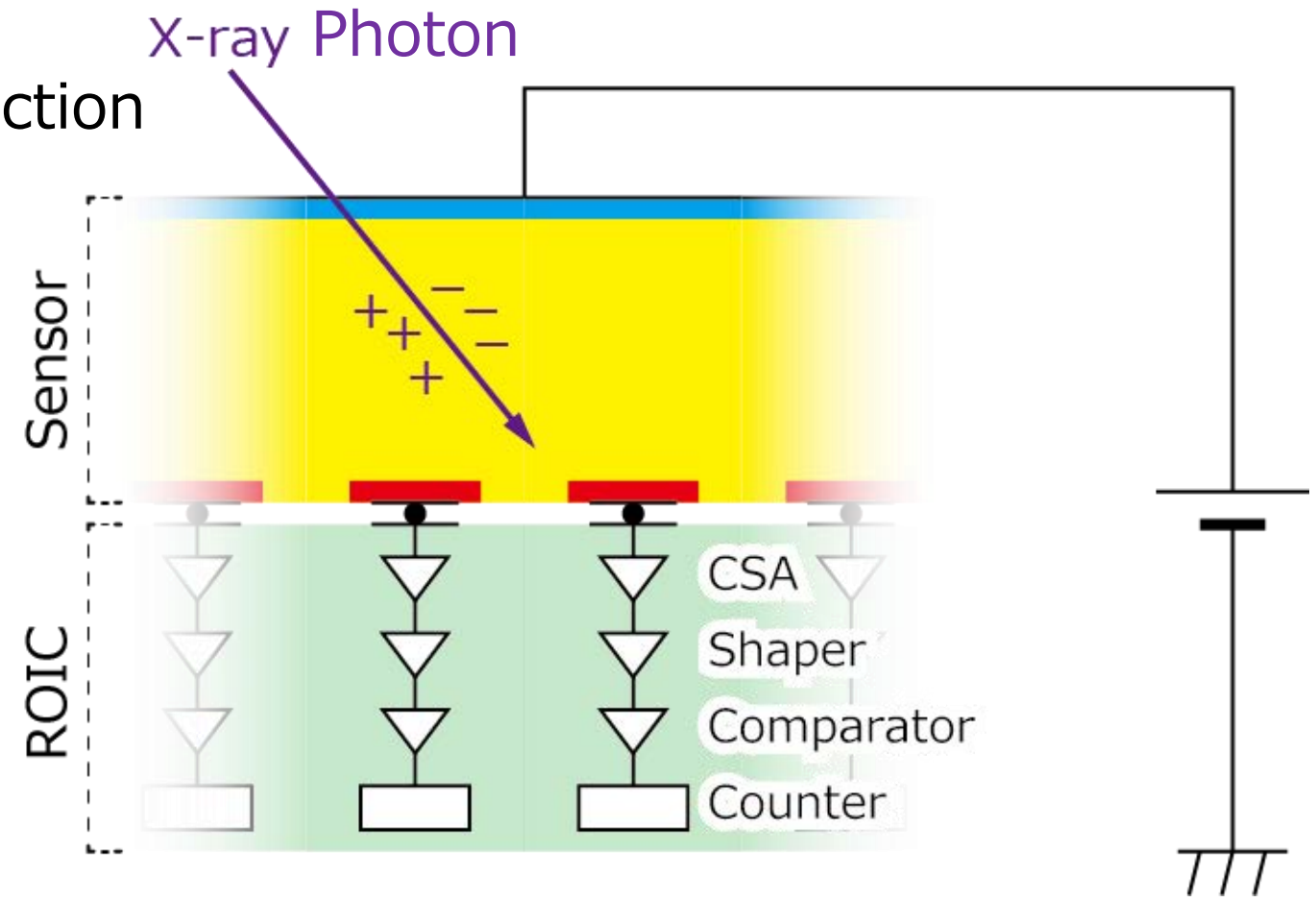


Direct Detection by Gas

- Delay line readout: Global count rate limitation

Hybrid Pixel Array Detector (HPAD) : Closest one to the Ideal Detector

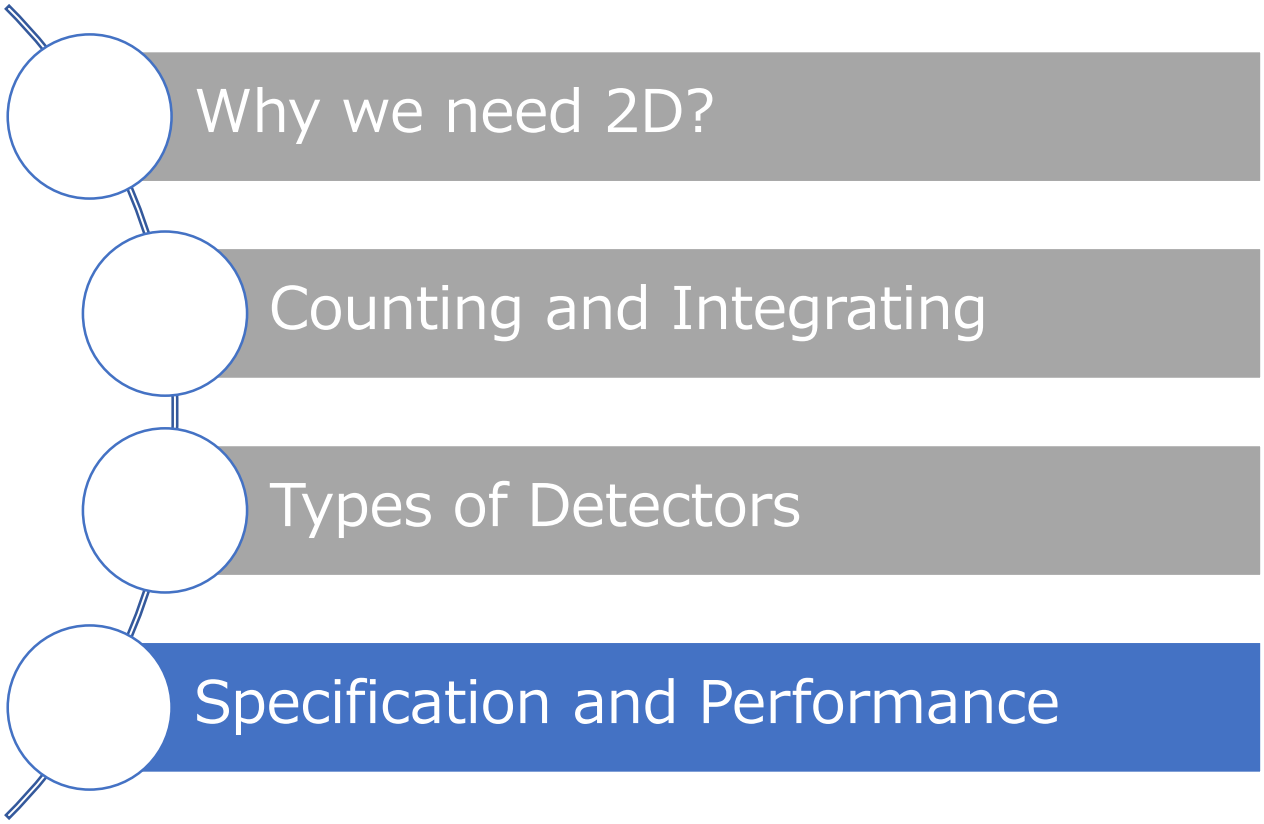
Direct detection



Compare HPAD to CCD, CMOS and MPGD

	Photon Integrating		Photon Counting	
	CCD	CMOS	MPGD	HPAD
Sensitivity at Cu K (electron/photon)	50	150	200	2000
Read noise (electron, rms)	~ 20	~ 200	0	0
Dynamic range	10^4	10^4	10^8	10^6
Dark Current (photons/sec/μm²)	~ 10^{-7}	~ 10^{-5}	0	0
Readout time	~ 1000 ms	~ 500 ms	~ 200 ms	~ 5 ms

Outline



Comparison of photon integrating and counting

	Photon Integrating	Photon counting
Detector Material	Phosphor (CCD, CMOS), IP, Film	Semiconductor, Gas
Energy resolution	NO	YES
Dark Current	YES	NO
Read noise	YES	NO
Dead time	NO	YES
Application Fields	Lab, SR, XFEL	Lab, SR

Detective quantum efficiency

HPAD (Si 300 um)	99 % @ 8.04 keV
MWPC, MPGD (3 atm, 1 mm)	80 % @ 8.04 keV

Spatial resolution

HPAD	= 1 pixel (~ 100 μm)
MPGD	~ 250 μm FWHM Gaussian

Count rate

HPAD	local 100 kcps / pixel
MPGD	local 100 kcps / pixel
	global 2 Mcps

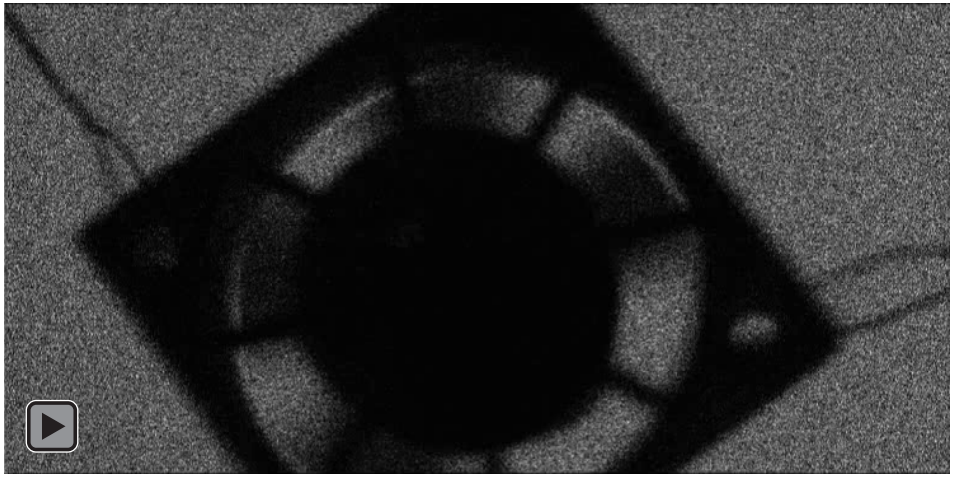
HPAD Chip Specifications

Detector	Medipix 2	PXD-18k*	XPAD3	PILATUS II
Pixel Size	55 x 55 μm	100 x 100 μm	130 x 130 μm	172 x 172 μm
Countrate	7×10^7 cps/mm^2	2×10^8 cps/mm^2	4×10^7 cps/mm^2	3×10^7 cps/mm^2
Energy resolution	23 %	20 %	12 %	6 %
Read time	256 μs	7 ns / 3.7 ms	1 ms	2.3 ms

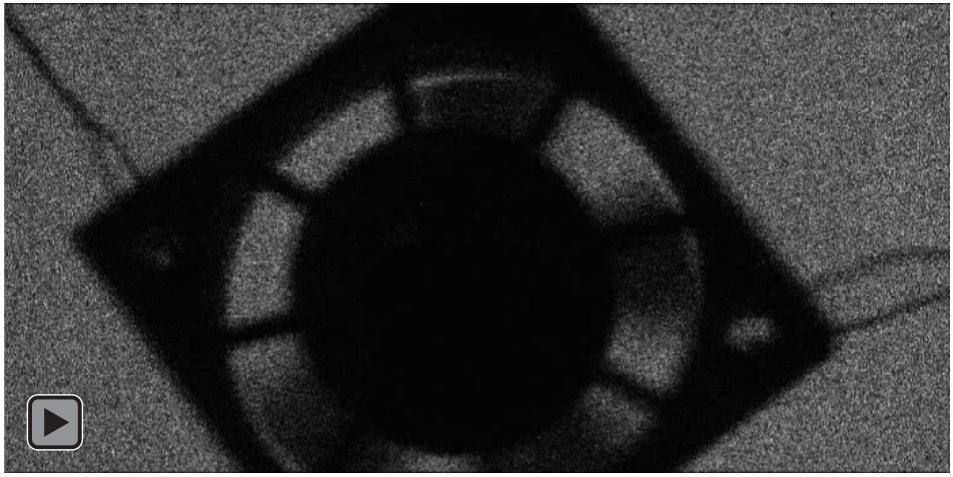
*P. Maj et al., *Nulc. Intrum. Meth. A* **697**, 32-39 (2013)

Zero dead time Measurement

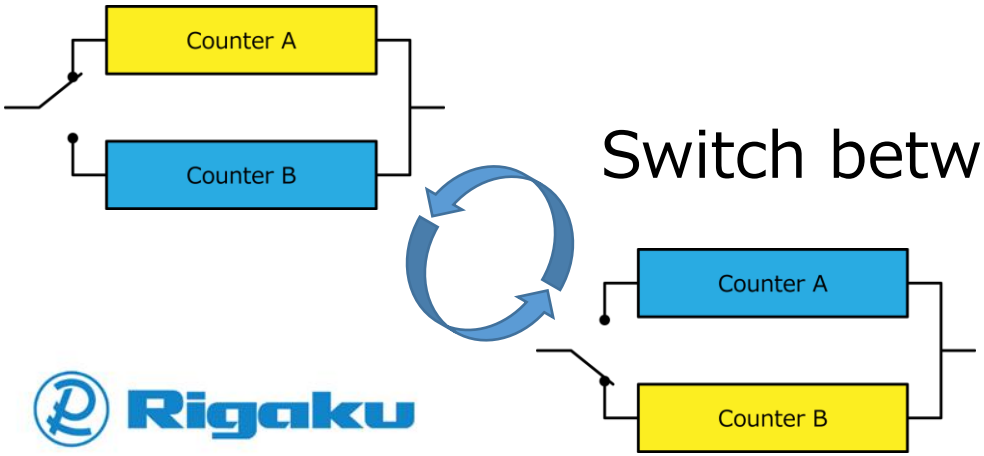
Read time: 7 ns (571 fps)



Read time: 3.7 ms (183 fps)



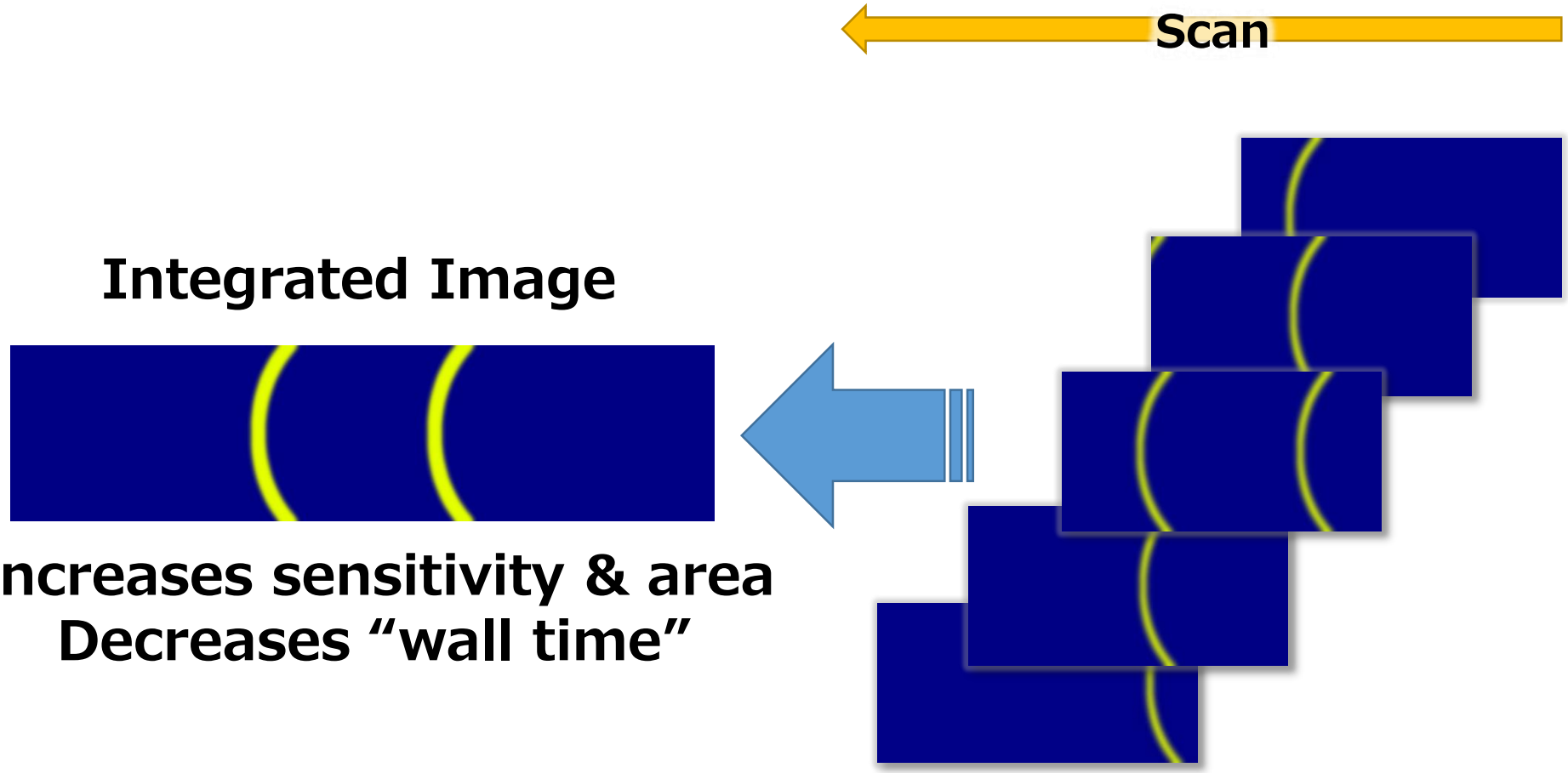
Exposure time 1.75 ms / frame



Switch between 2 Counters

Rigaku

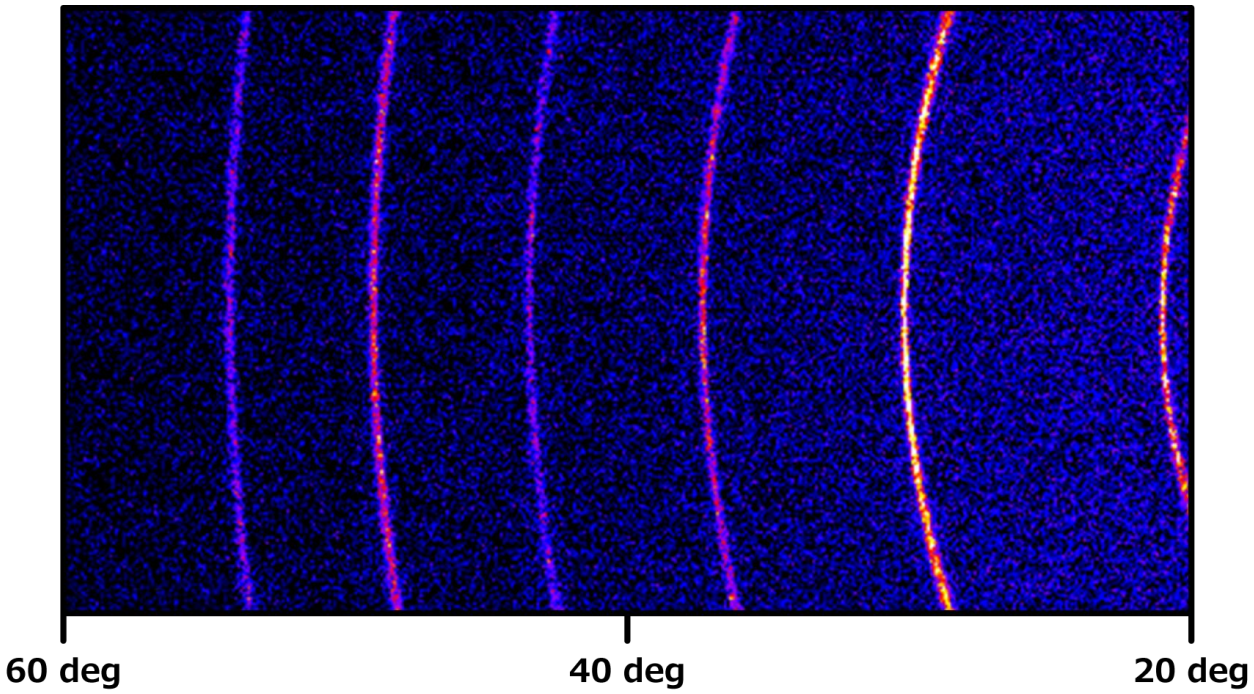
Time Delay Integration (TDI)



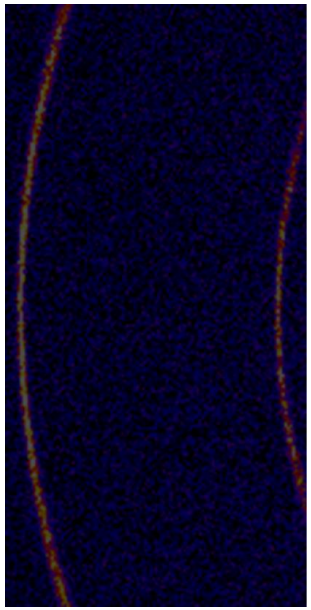
Increases sensitivity & area
Decreases “wall time”

Time Delay Integration (TDI)

Sample : LaB_6
Scan Speed: 10° / min
Cu Target : 40 kV, 30 mA



TDI Image



Single Image

Summary

2D detector

- More information and shorter measurement time

Photon counting

- Very high signal to background ratio

Hybrid pixel array detector

- High quantum efficiency and spatial resolution

Fast readout (Zero dead time mode)

- In-situ measurement

HPAD promises us a higher quality of data.

Thank You

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