

Recent development of VUV-NUV MPPC

New qCMOS image sensor for single photon counting and photon number resolving

Simona Ferrulli

Hamamatsu Photonics

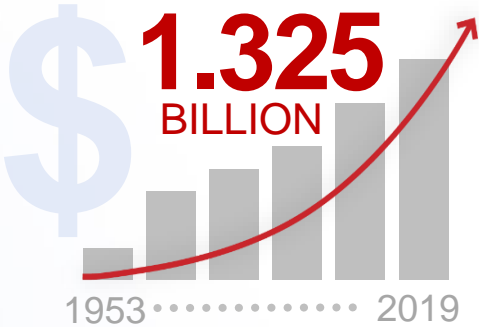
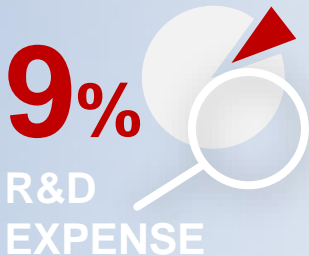
ASAPP

Perugia

June 23th 2023

Hamamatsu Photonics : A Driver in the Industry

« Our Technology capacity and scale by the numbers »



- UNITED NATIONS
GLOBAL COMPACT
- ✓ HUMAN RIGHTS
 - ✓ LABOUR STANDARDS
 - ✓ ENVIRONMENT
 - ✓ ANTI-CORRUPTION

*Figures taken in 2019

Hamamatsu Production Division



Electron Tube Division



Energetiq Technology



Solid State Division



Global Strategic Challenge Center



Systems Division

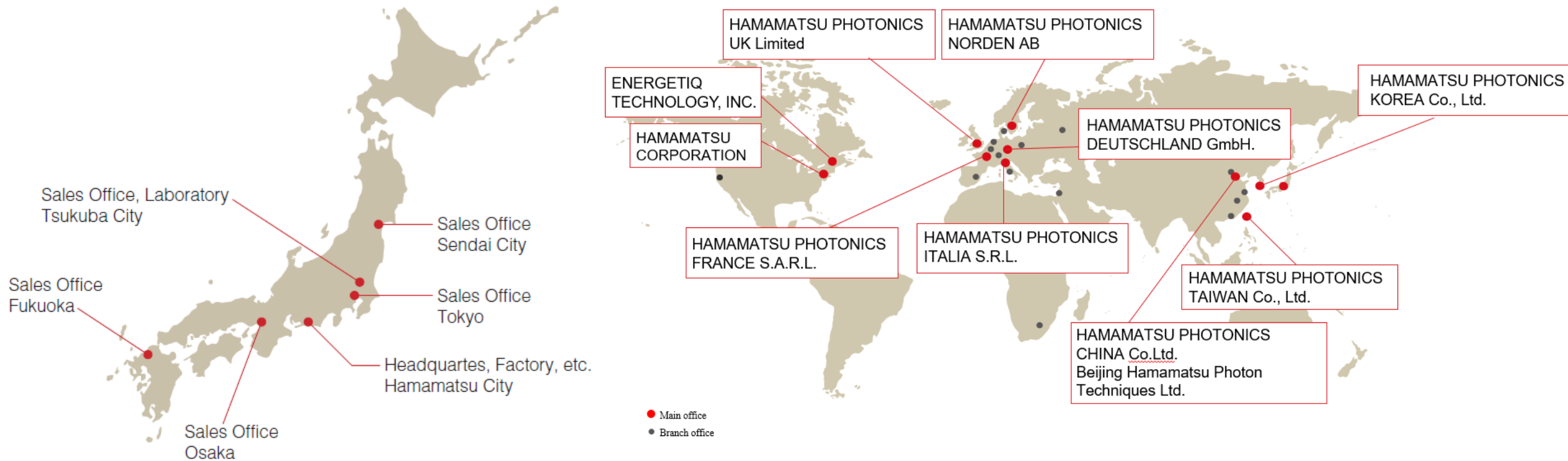


Central Research Laboratory



Laser Promotion Division

Where We are Located: HQ and sales offices

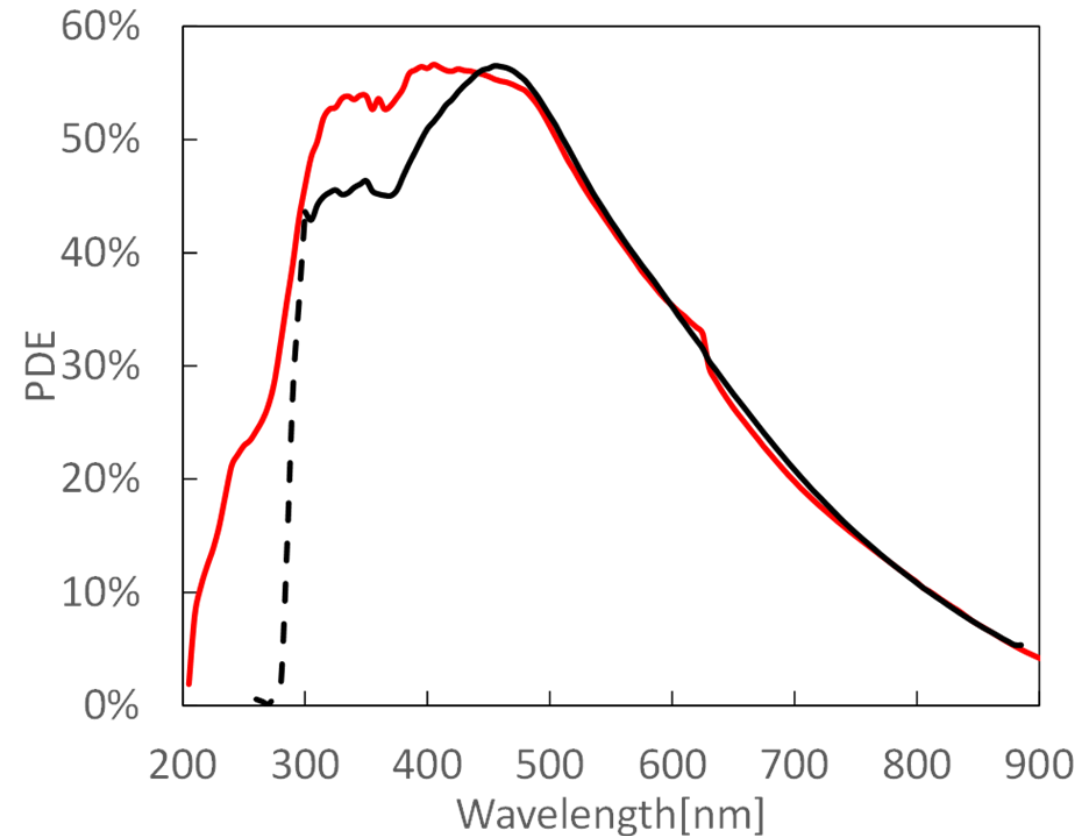


Recent development of MPPC

NUV MPPC for Cherenkov light detection

MPPC with improved NUV sensitivity

- MPPC prototype with increased NUV sensitivity
- 3x3mm² and 75μm cell size with no protection resin



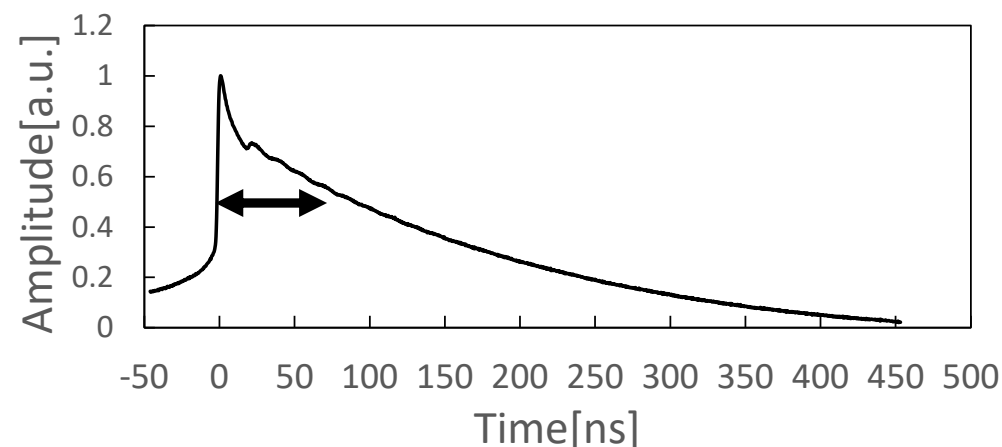
— Prototype : based on S13360 series (75μm)

— Conventional : S14520 series (75μm)

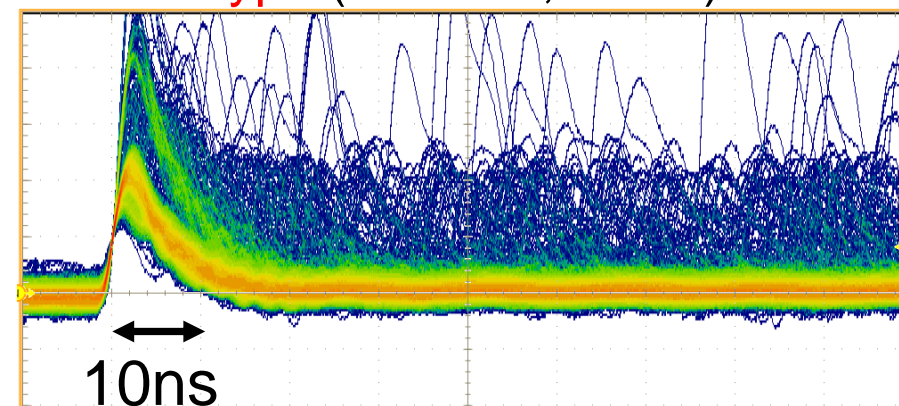
MPPC waveform shaping

- Atmospheric Cherenkov experiment (high background)
- High event rate (new scintillator in development, new experiment with increased luminosity)
- Improved waveform to suppress pile up, achieved with quenching resistor tuning

Conventional product (6x6mm², 75μm)



Prototype (6x6mm², 75μm)



Conventional product

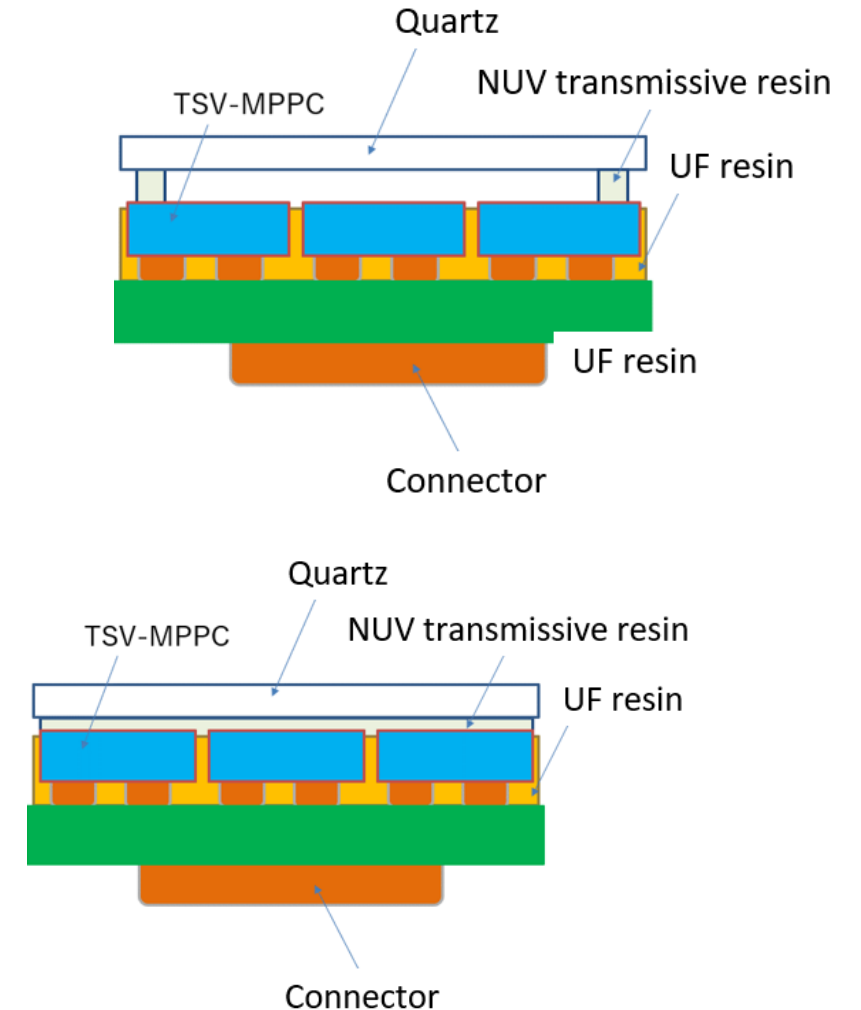
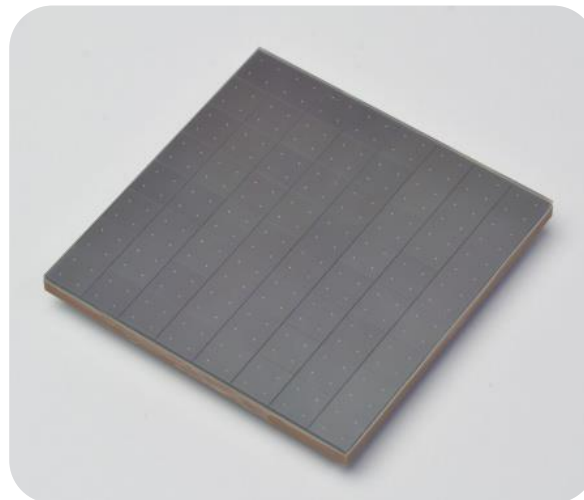
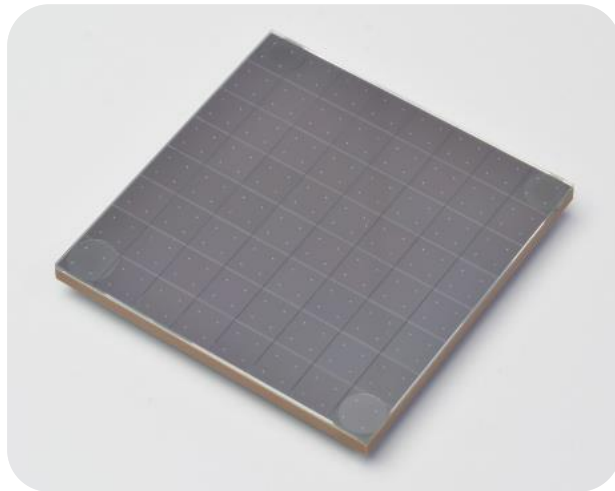
about 90ns

Prototype

about **7ns**

MPPC arrays challenges

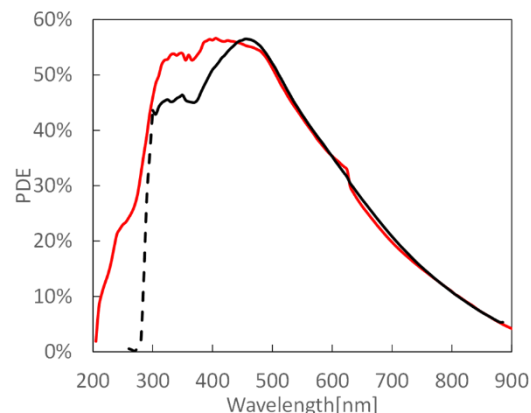
- Achieved in arraying TSV MPPCs including a protective layer keeping the high NUV sensitivity
- Combination of a quartz window and NUV transmissive resin



Release information for Cherenkov light detection

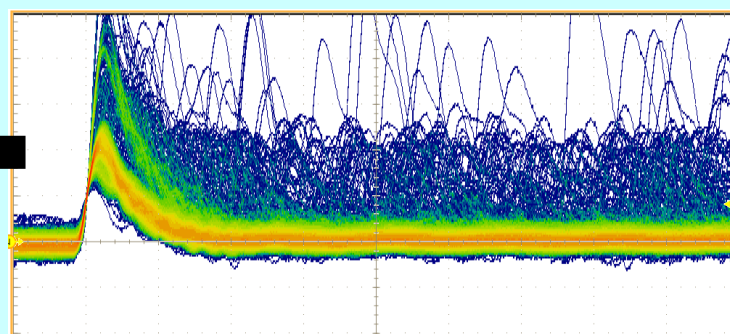
1

High NUV sensitivity with quartz



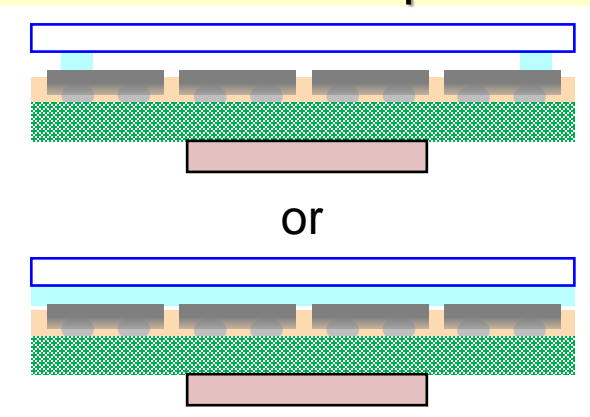
2

Pile up suppression by reducing capacitance

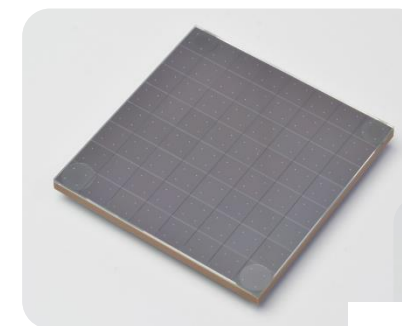


3

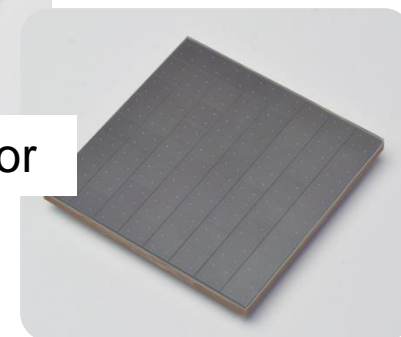
Large area
small dead space



➤ Sample are now available.



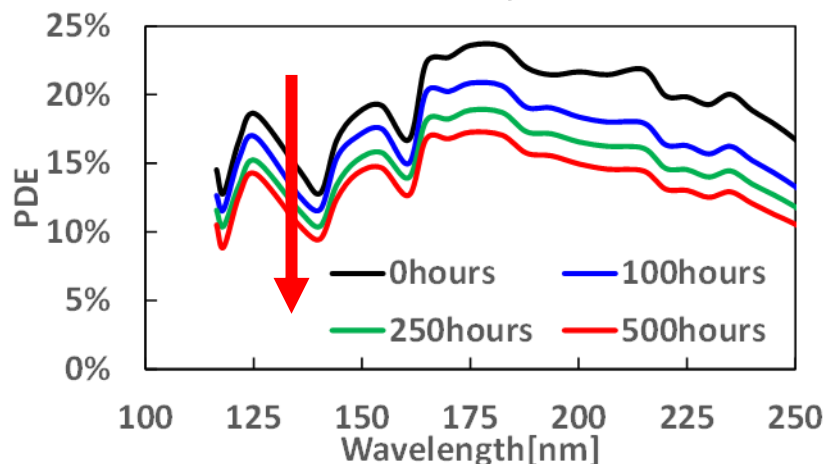
or



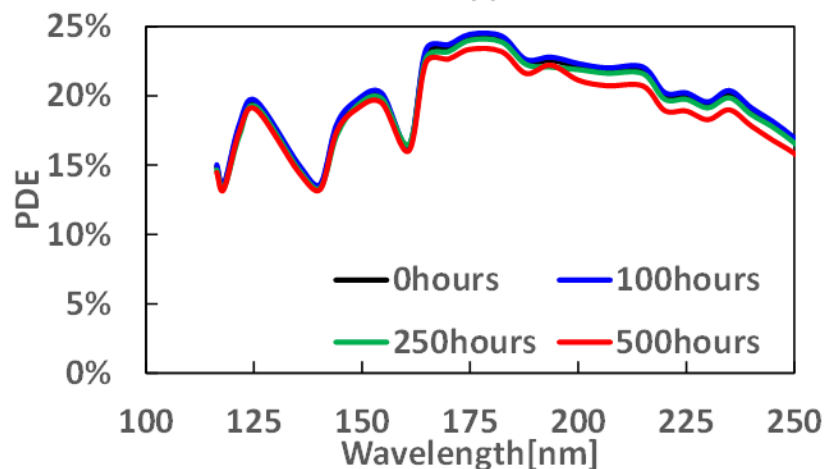
Recent development of MPPC

VUV MPPC for dark matter and Neutrino

Conventional product



Prototype



High Temperature/High humidity test

- high temperature : 60°C
- high humidity : 90%

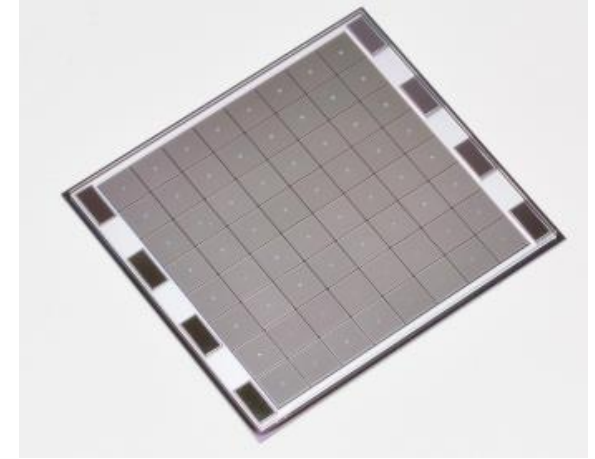
Test acceleration **89 times** @T:25°C, RH:60%
(*Vapor pressure accelerating model, confidence level :60%)

Almost no change in sensitivity up to 500 hours

※plan to continue High Temp/High Humidity test until 1,000 hours

Low RI (radioisotope) package for MPPC array

- Developed a silicon package for MPPC with low RI value
(silicon wafer formed pattern + TSV-MPPC chip mounted above)
- Ongoing development of a further improved new package (CoF: Chip on Film)

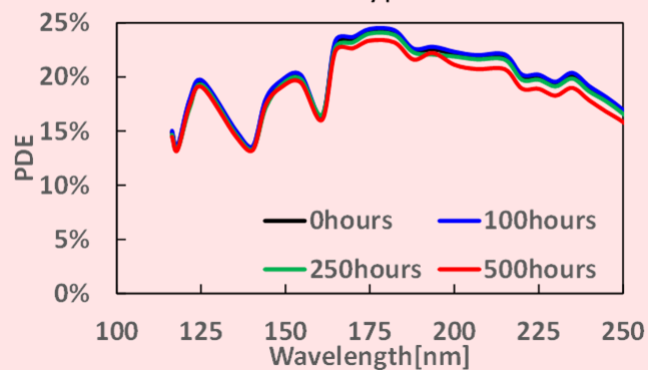


Release information for dark matter and Neutrino

1

improved the long
period reliability

Prototype



+

2

CoF PKG as RI PKG



➤ Sample release planned for summer in 2023

Recent development of scientific cameras

qCMOS camera Orca Quest

Cameras made to measure

GEN II sCMOS

1.4e- rms

ORCA-Flash 4.0 V2



ORCA-Flash 4.0 V3



GEN III sCMOS

0.7e- rms

ORCA-Fusion



ORCA-Fusion BT



qCMOS

0.27e- rms

qCMOS



BACK ILLUMINATED CMOS TECHNOLOGIES

LOW NOISE TECHNOLOGIES

2011

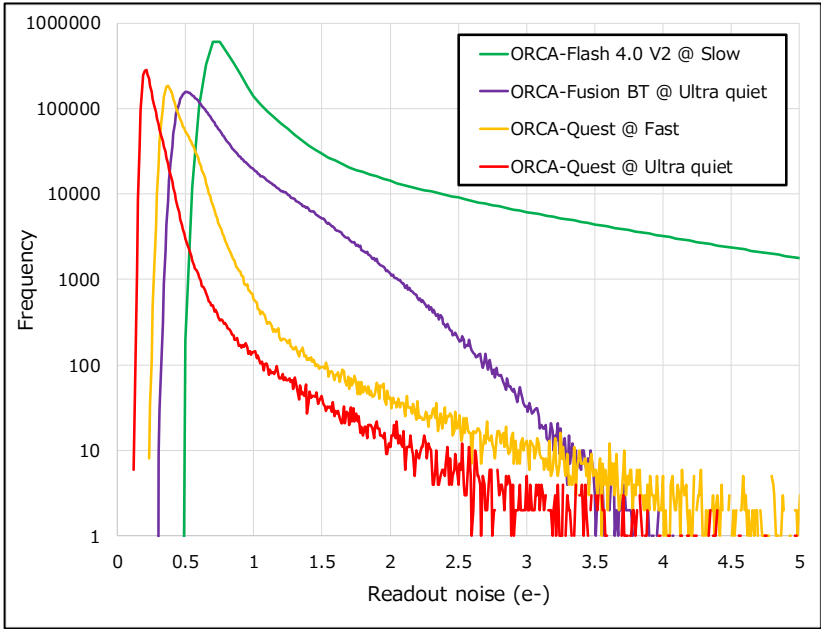
2016

2018

2020

2021...

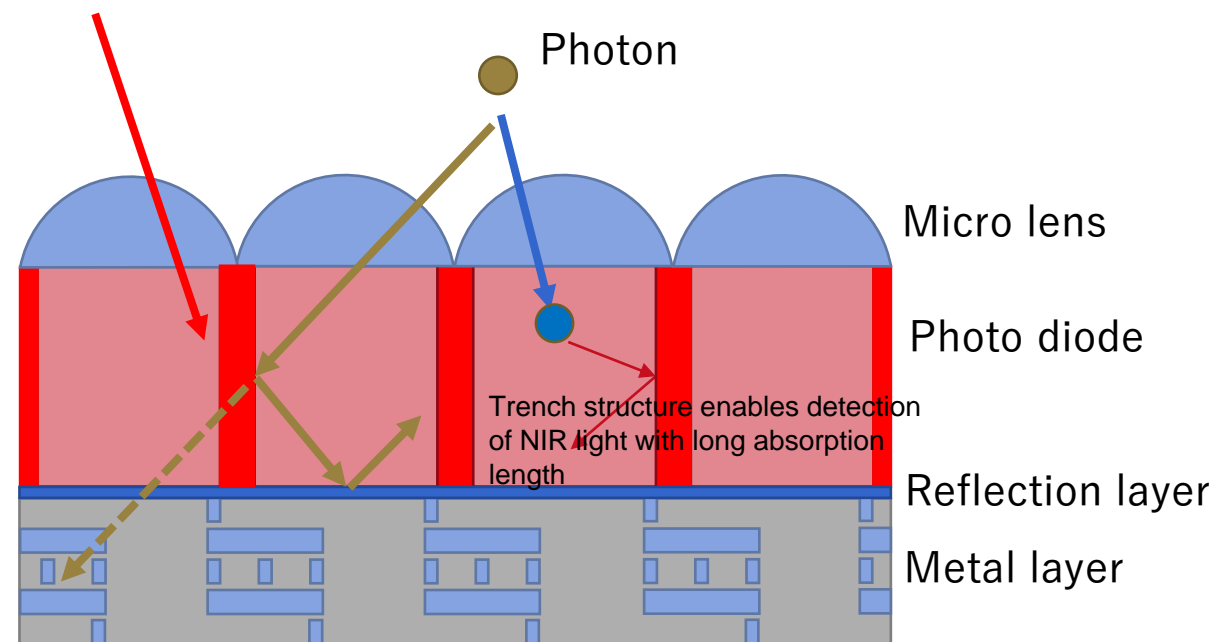
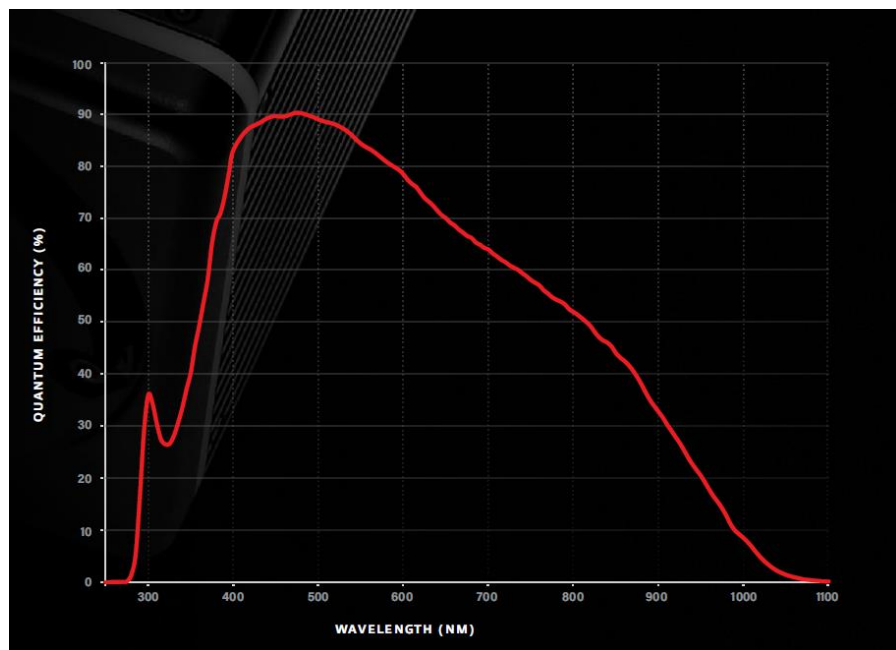
Spec table- ORCA QUEST



Target specification		
Pixel number	9.4 Mpixels	
	4096 (H) × 2304 (V)	
Pixel size	4.6 μm□	
Effective area	18.860 mm(H) × 10.598 mm(V)	
QE	90% (Peak @ 475nm)	
	51% (800 nm)	
	32% (900 nm)	
Full well capacity	7000 e-	
Scan mode	Fast @120 fps	Ultra quiet @5 fps
Readout noise (typ)	0.43 e- rms @120 fps	0.27e- rms @5 fps
Dynamic range	14000:1	25900:1
Dark current	0.008 e-/pixel/s @ -30 °C	
Cooling temperature	-30 °C(water cooling) -20 °C(air cooling)	
Readout mode	Normal area	
	Light sheet	
	-	Photon number resolving @5 fps
Binning	2 × 2	
	4 × 4	
Subarray (ROI)	Available	
Interface	CoaXPress × 4 (Quad CXP-6)	
	USB 3.0	

Quantum efficiency and Deep Trench Isolation

- Chip is backilluminated, but has microlenses
 - Minor UV sensitivity
- High QE in IR, good MTF



Improved NIR QE without degradation of MTF

Thank You!

www.hamamatsu.com

Contacts:

info@hamamatsu.it

ferrulli@hamamatsu.it