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Multi Pixel Photon Counter (G-APD or Si-PMT) Hamamatsu Photonics

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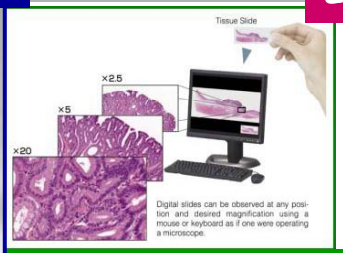
Solid Sate Division

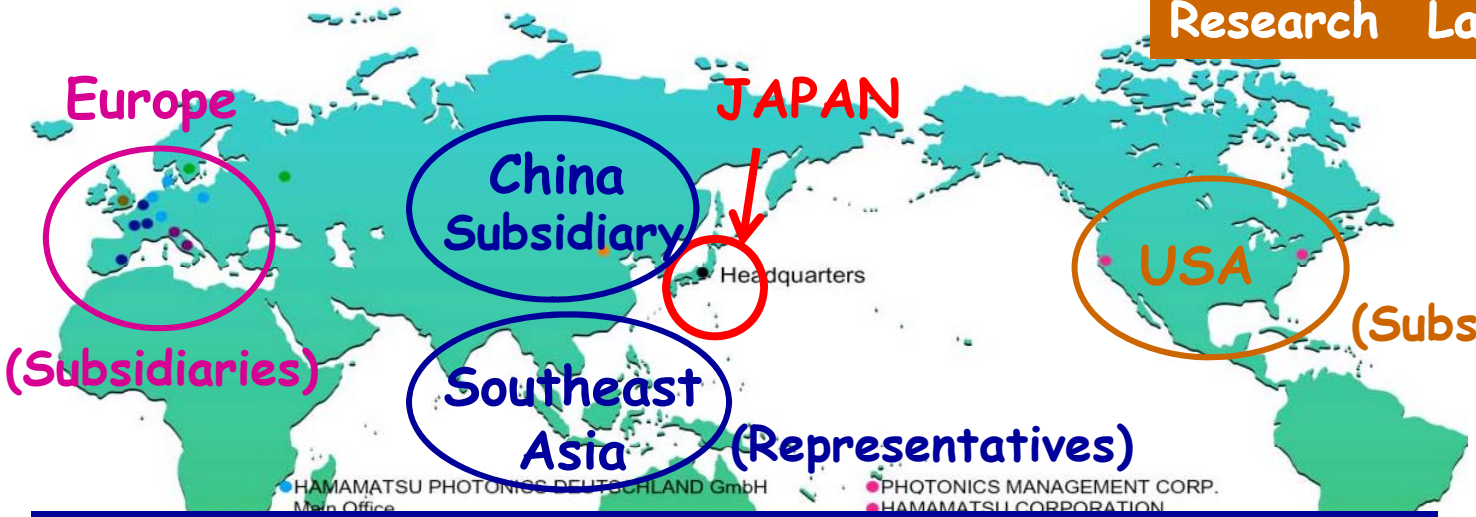
Electron Tube Division

Laser Group



Systems Division

Research Laboratories



Established : Sept.29.1953
Net Sales : (FY 2011) Yen 100B ($1.25B / €900M)
Employees : 4,000 (Group) (As of Sept.2011)

\80/$
\110/€

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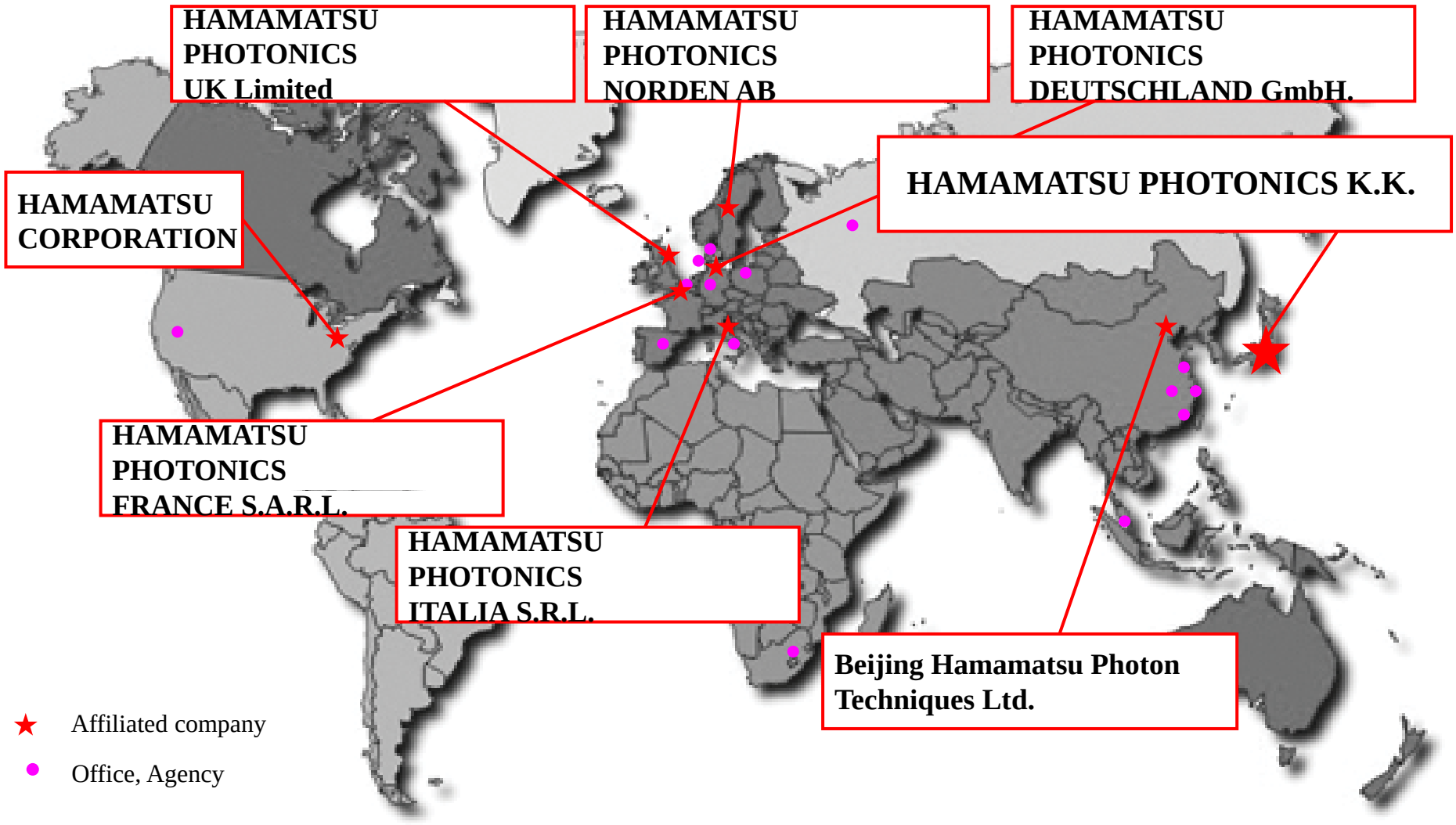
Worldwide propietary sales network



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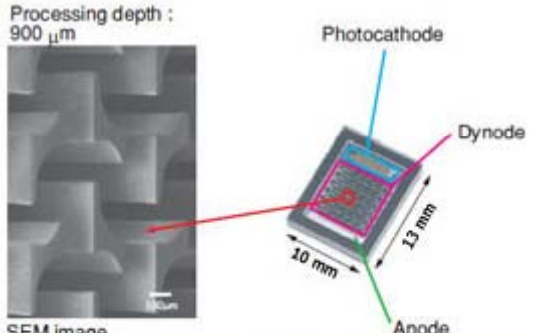
MPPC is a G-APD (SiPMT)

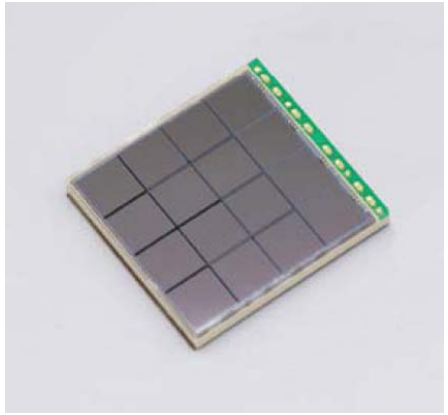
SiPMT is not a PMT

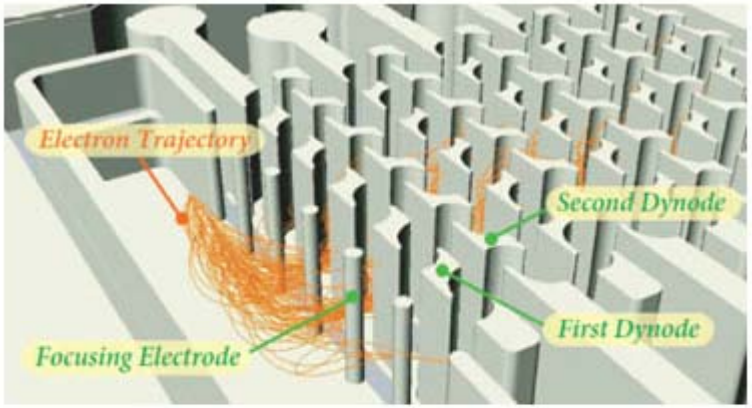
SiPMT is an APD

in Geiger mode

- small
- thin
- MEMS applied technology
- custom made flexibility
- current PMT equivalent function







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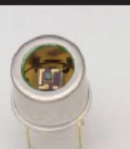
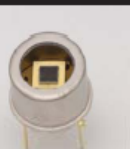
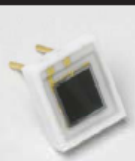
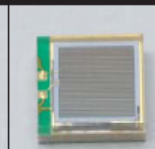
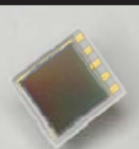
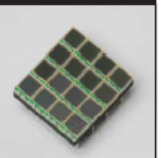
MPPC standard

■ MPPC lineup (conventional type)

Type	Metal type (TE-cooled)			Ceramic type		Plastic package (Surface mount type)			2D array type (Array)	2D array type (Array)
Image										
Type no.	S10362-11 (-U series)	S11028 series	Preliminary	S10362-11 (-C series)	S10362-33 (-C series)	S10362-11 (-P series)	S10931 series	S10984 series	S10985 series	S11064 series
Effective active area	1 × 1 mm	1 × 1 mm	3 × 3 mm	1 × 1 mm	3 × 3 mm	1 × 1 mm	3 × 3 mm	1 × 4 mm (1 × 4ch array)	6 × 6 mm (2 × 2ch array)	3 × 3 mm/ch (4 × 4ch array)
Pixel size (μm)	25 × 25	25 × 25	25 × 25	25 × 25	25 × 25	25 × 25	25 × 25	25 × 25	25 × 25	25 × 25
	50 × 50	50 × 50	50 × 50	50 × 50	50 × 50	50 × 50	50 × 50	50 × 50	50 × 50	
	100 × 100	100 × 100	100 × 100	100 × 100	100 × 100	100 × 100	100 × 100	100 × 100	100 × 100	50 × 50
Package	Metal (TO-18)	Metal (TO-8)	Metal (TO-8)	Ceramic	Ceramic	Plastic	Plastic	Plastic	Ceramic	Plastic

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Specifications (Typ. Ta=25 °C, unless otherwise noted)

Parameter	Symbol	S10362-11 series			Unit
		-025U, -025C, -025P	-050U, -050C, -050P	-100U, -100C, -100P	
Effective active area	-	1 × 1			mm
Number of pixels	-	1600	400	100	-
Pixel size	-	25 × 25	50 × 50	100 × 100	μm
Fill factor *1	-	30.8	61.5	78.5	%
Spectral response range	λ	320 to 900			nm
Peak sensitivity wavelength	λp	440			nm
Photon detection efficiency *2 (λ=λp)	PDE	25	50	65	%
Operating voltage range	-	70 ± 10 *3			V
Dark count *4	-	300	400	600	kcps
Dark count Max. *4	-	600	800	1000	kcps
Terminal capacitance	Ct	35			pF
Time resolution (FWHM) *5	-	200 to 300			ps
Temperature coefficient of reverse voltage	-	56			mV/°C
Gain	M	2.75×10^5	7.5×10^5	2.4×10^6	-

*1: Ratio of the active area of a pixel to the entire area of the pixel
*2: Photon detection efficiency includes effects of crosstalk and afterpulses.
*3: For the recommended operating voltage of each product, refer to the data attached to each product.
*4: 0.5 p.e. (threshold level)

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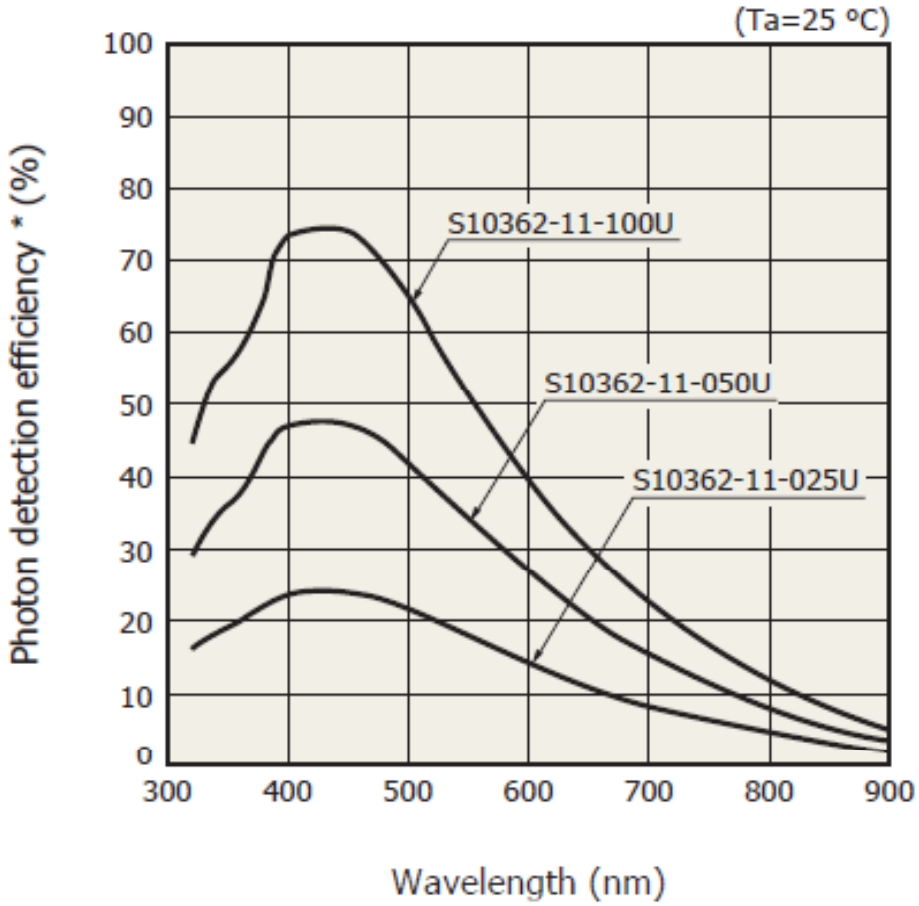

* Photon detection efficiency includes effects of crosstalk and afterpulses.

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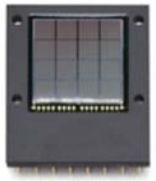
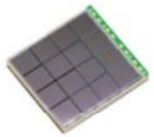
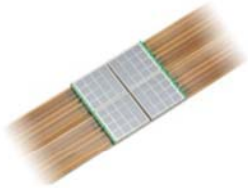
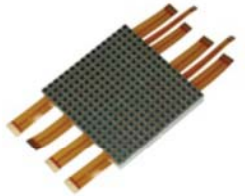
MPPC. New products

NEW	NEW	NEW	NEW	Prototype
				
4x4ch monolithic array PWB package S11827-3344MG	**4x4ch monolithic array** SMD package buttable S11828-3344M	**4x4ch monolithic array** with FPC (15 cm) buttable S11829-3344MF	**4x4ch monolithic array** with FPC (5 cm) buttable S11830-3344MF	**8x8ch discrete array** with FPC buttable S11834-3388DF

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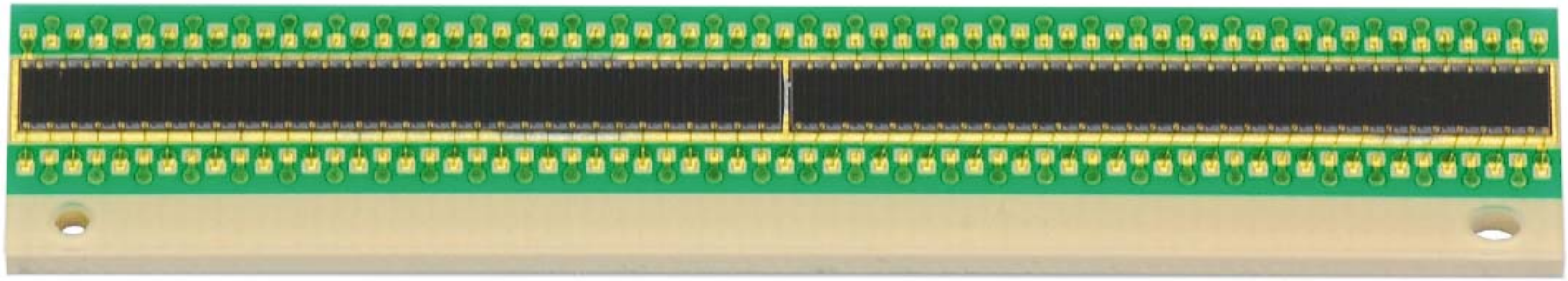
MPPC: Custom products

MPPC linear array 128ch - developed for fiber tracker

2 chips/assembly
Gap between active area of chips : 250um (= 1ch)
Buttable device (aimed gap : also 250um)
Thin epoxy layer: optimizing spatial resolution



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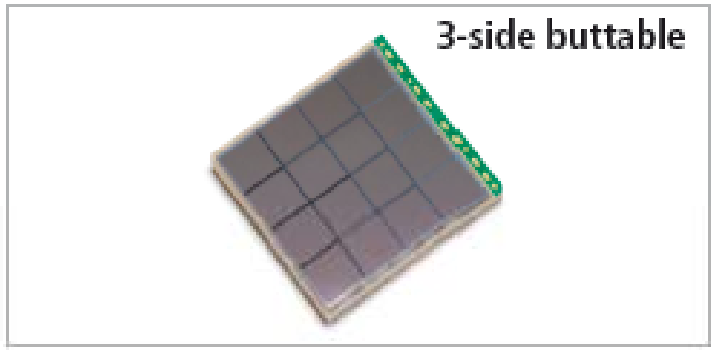
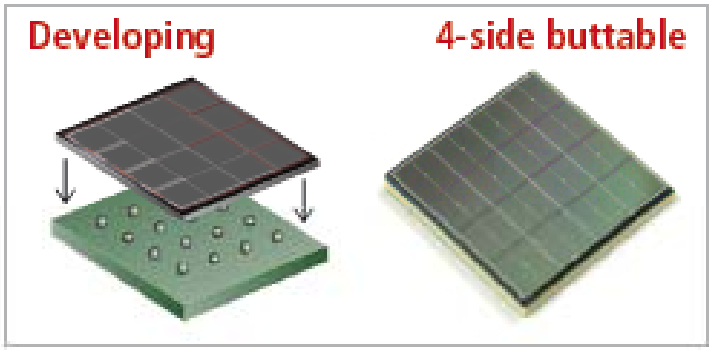
MPPC: What comes next



3 x 3 mm – 4 x 4 ch.
monolithic array with wire bonding



3 x 3 mm – 4 x 4 ch.
monolithic array with silicon through vias

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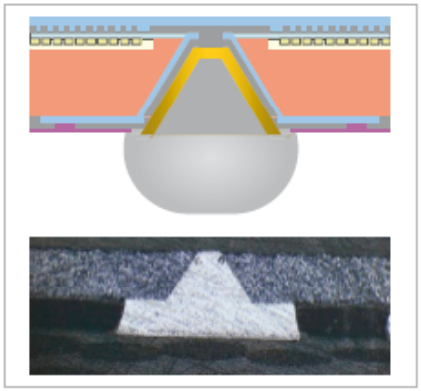
MPPC: What comes next

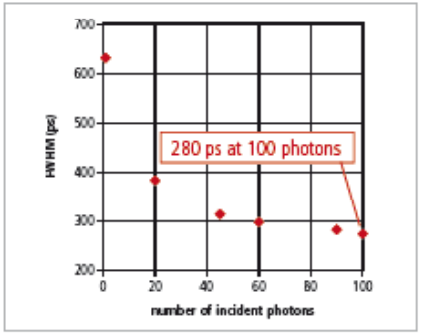
2 Through Silicon Via (TSV)



Cross section of TSV

4-side buttable packaging

Large area monolithic arrays have been developed for TOF-PET. These have wire bonding pads at the edge of the chip only allowing a 3-side buttable assembly limiting the total size.
We have designed a monolithic array with through vias in which each channel has a bump pad and is connected by the shortest distance possible to the substrate. This 4-side buttable structure minimizes dead space and opens up new possibilities with its unlimited total size.



FWHM time resolution of 3 x 3 mm MPPC with TSV

Time resolution improvement

The large area monolithic array has long signal metal traces to the bonding pads which add additional parasitic resistance and capacitance.
This causes a problem to obtain fast and uniform time response characteristics. The monolithic array with TSV has no traces and therefore it is possible to minimize the parasitic resistance and capacitance.
The time resolution measurement was done with a picosecond light pulser. Timing of 280 ps was obtained with 3 x 3 mm single channel with an input of 100 photons. The TSV technology has advantages but needs further improvements to optimize the design and the process conditions to get best performance and total reliability.

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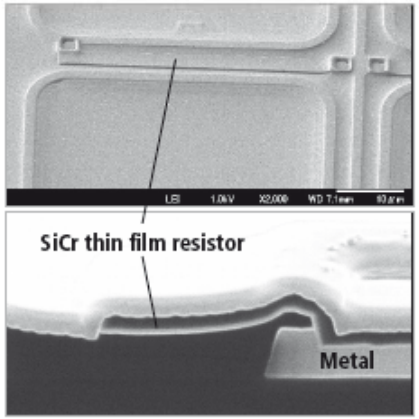
MPPC: What comes next

3 Thin metal film quenching resistor

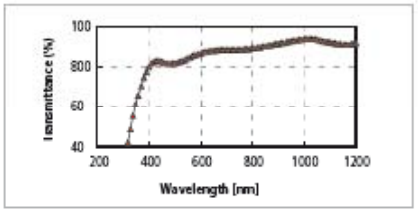


Applying SiCr thin film

High energy physics (HEP) calorimetry applications require photo sensors with high dynamic range and high QE. MPPC dynamic range depends on the pixel density. However smaller pixels have lower fill factor because of the space taken up by the quenching resistors.
We have studied the use of SiCr thin film resistors instead of poly-Si. It has higher sheet resistance, a lower temperature coefficient and higher resistance uniformity which allows for a more narrow pattern.

Material	TCR	Size	σ(Rs)
Poly-Si	-2.4 k Ω/°C	W=2 μm	20 %
		W=1 μm	39 %
SiCr thin film	-0.5 k Ω/°C	W=2 μm	9 %
		W=1 μm	11 %

This table provides a comparison of measurement data between poly-Si and SiCr resistors. The sheet resistance is 10 k Ohm/sq and the length is 60 mm. Temperature coefficient of resistance (TCR) and variation of resistance (s) in the wafer were drastically improved.



High transmittance

The area lost to the poly-Si quenching resistors formed around the active region limits the fill factor and QE. The transmittance of SiCr thin film is more than 80 % in the range above 400 nm wavelength. It is possible to form the SiCr thin film resistor on top of the active area with minimal loss of sensitivity.

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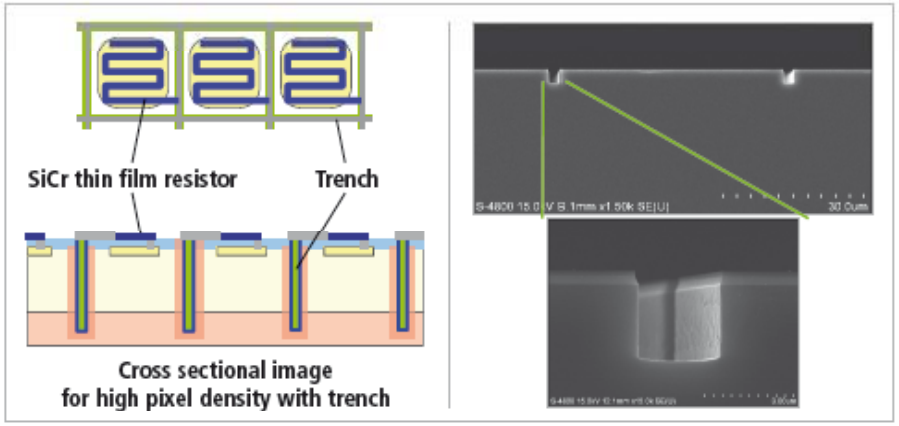
4 "All in one MPPCs"

Decreasing optical cross talk has been one of the challenges for the MPPC. It is known that trenches formed around each elementary cell prevent stray photons from generating photoelectrons in neighboring cells. We are now processing 2 mm trenches (both width and depth) using a reactive ion-etching (RIE) machine.
We have designed "All in one MPPCs" with these improved methods which include TSV, SiCr thin film resistors, trench among others. One example is a large scale monolithic array MPPC in which the pixel pitch is 50 mm for TOF-PET applications. Another is a high pixel density MPPC with pixel pitches less than 15 mm for HEP applications. These experimental samples are in processing and initial characteristics will be obtained in a few months.



Cross sectional image
for high pixel density with trench

MPPC modules

standard

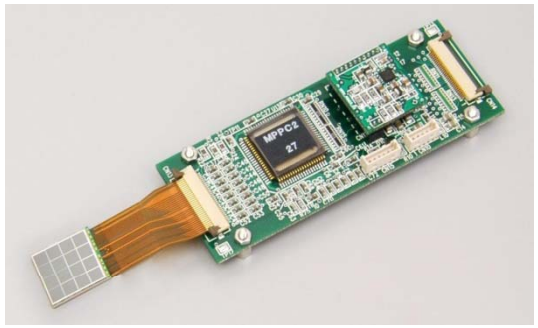
1ch type

C10507 series

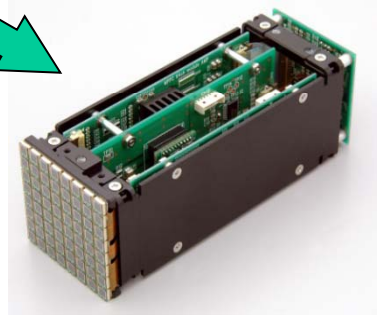
TE Type

C11208 series

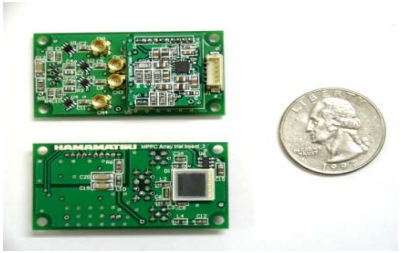
Module 4x4 monolithic



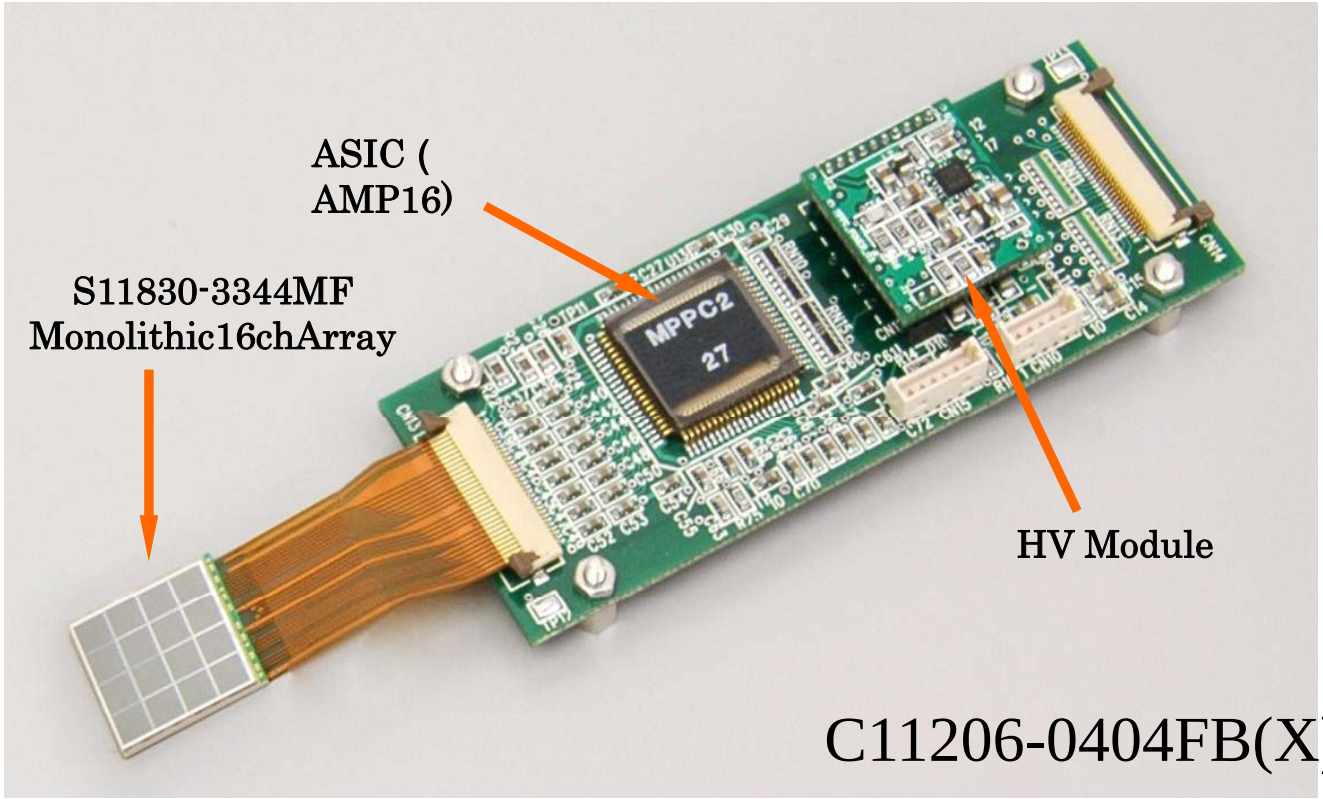
Module 8 x 8 discre



Module 2 x 2 ; high speed type



MPPC module for 4x4 array



Including preamp and bias circuit for MPPC array

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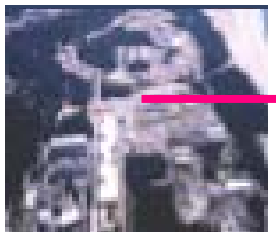
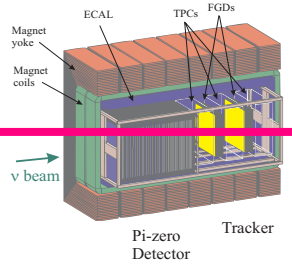
In mass production since 2008

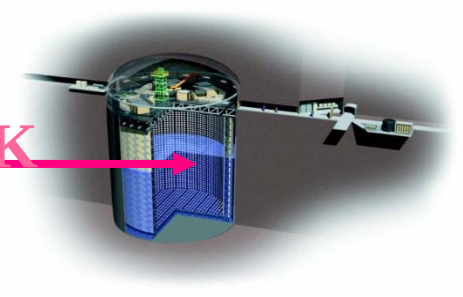


J-PARC
in Tokai-mura

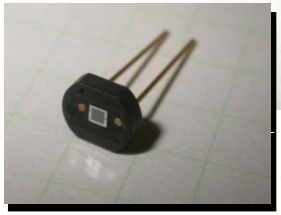


Fronting Detector
in J-PARC

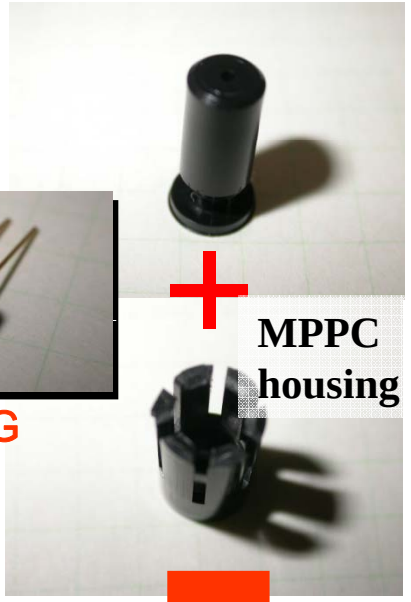
295K m



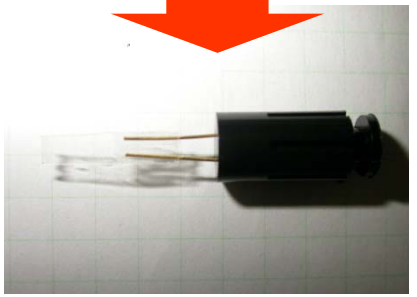
Super KAMIOKANDE



The same PKG of S10362-11-C



MPPC housing



Kyoto Univ. present

Neutrino Oscillation is measured, when neutrino made by J-PARC is irradiated to KAMIOKANDE.
Examination of Mass of Neutrino
MPPC is used in Front Detector in J-PARC
64K pcs of S10362-13-050C : delivered in 2008 to 2009

Thank you for your attention !!

www.hamamatsu.com