

Cours Scintillateurs

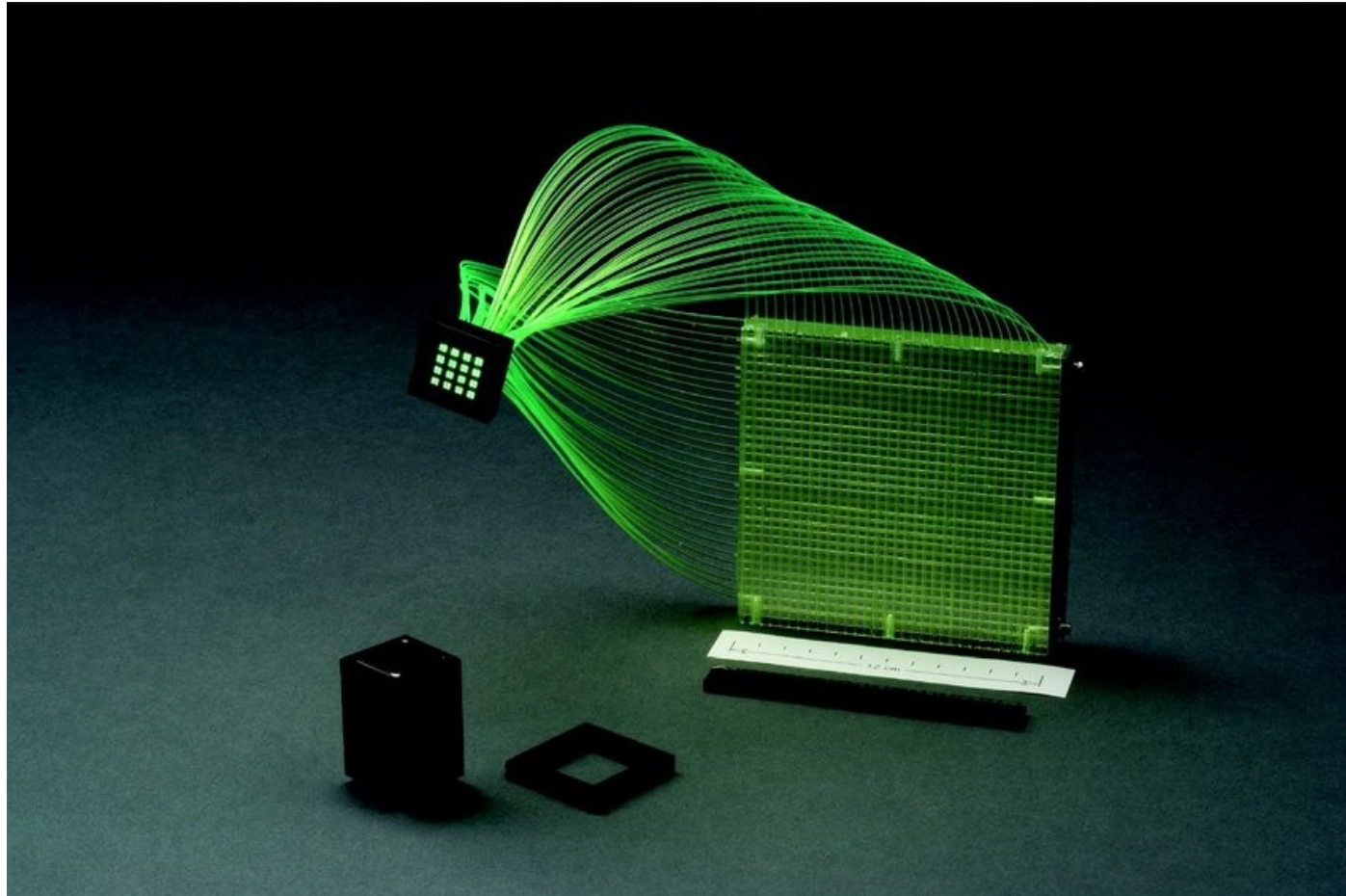
Pour l'ANF Techniques de Base des Détecteurs

2024

Gabriel Charles





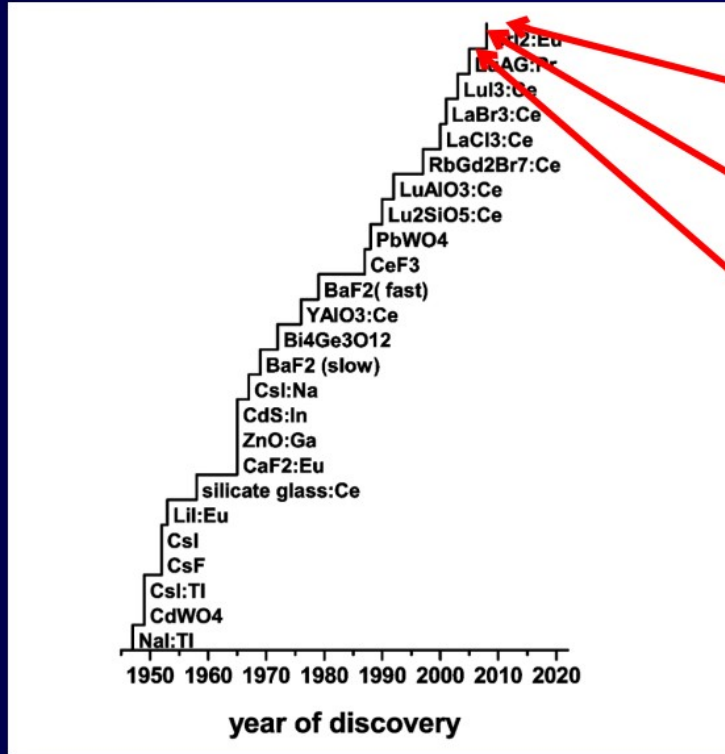


Source : Design and Testing of a Position-Sensitive Plastic Scintillator Detector for Fast Neutron Imaging, Bravar et al., 2006, IEEE TRANSACTIONS ON NUCLEAR SCIENCE

	Nal:Tl	Csl:Tl	Csl:Na	BGO	BaF ₂	PbWO ₄	LYSO:Ce
Light Yield (ph/MeV)	38000	54000	41000	10000	1800 - 10000	100	32000
Decay Constant (ns)	250	1000	630	300	<1 - 630	15	41
Wavelength of emission (nm)	415	550	420	480	220 - 310	440 - 530	420
Refraction index (at λ_{\max})	1.85	1.79	1.84	2.15	1.52	2.16	1.81
Density (g/cm ³)	3.67	4.51	4.51	7.13	4.88	8.28	7.1
Hygroscopicity	yes	slightly	yes	no	slightly	no	no
Main Characteristic	Most used scintillator	Good w/ photodiodes		High stopping power	Very fast	High radiation hardness	For PET

Source : présentation de Giulia Hull pour NDIP2017

Continuous effort to search for new luminescent materials since the introduction of Anthracene and NaI:Tl in 1948



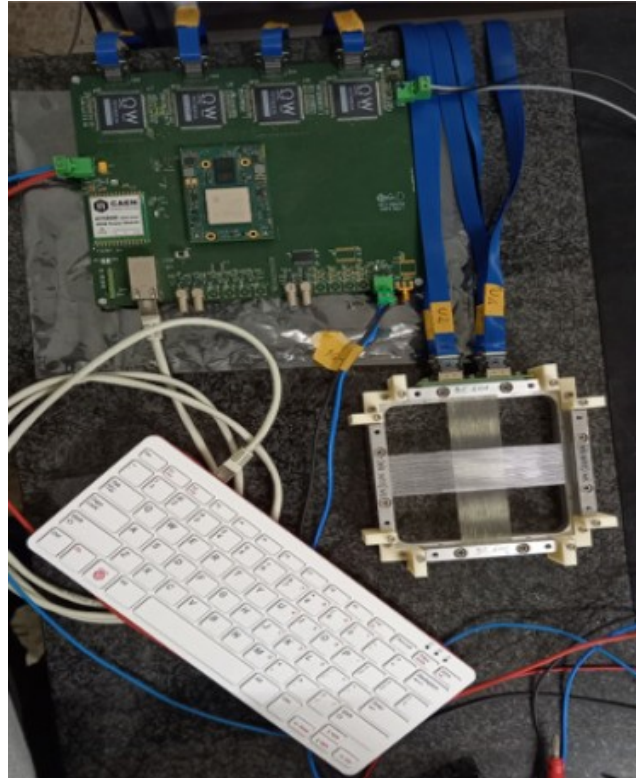
Co-doped LaBr₃:Ce (2013)

Elpasolites for n detection (<2010)

CeBr₃ (2005)

[P. Dorenbos, IEEE - TNS, Vol. 57 N. 3 (2010) 1162-1167]

Source : présentation de Giulia Hull pour NDIP2017



Pas les premiers, juste un parmi d'autres

Source : Mazziotta et al, NIM A, A light tracker based on scintillating fibers with SiPM readout, 2022

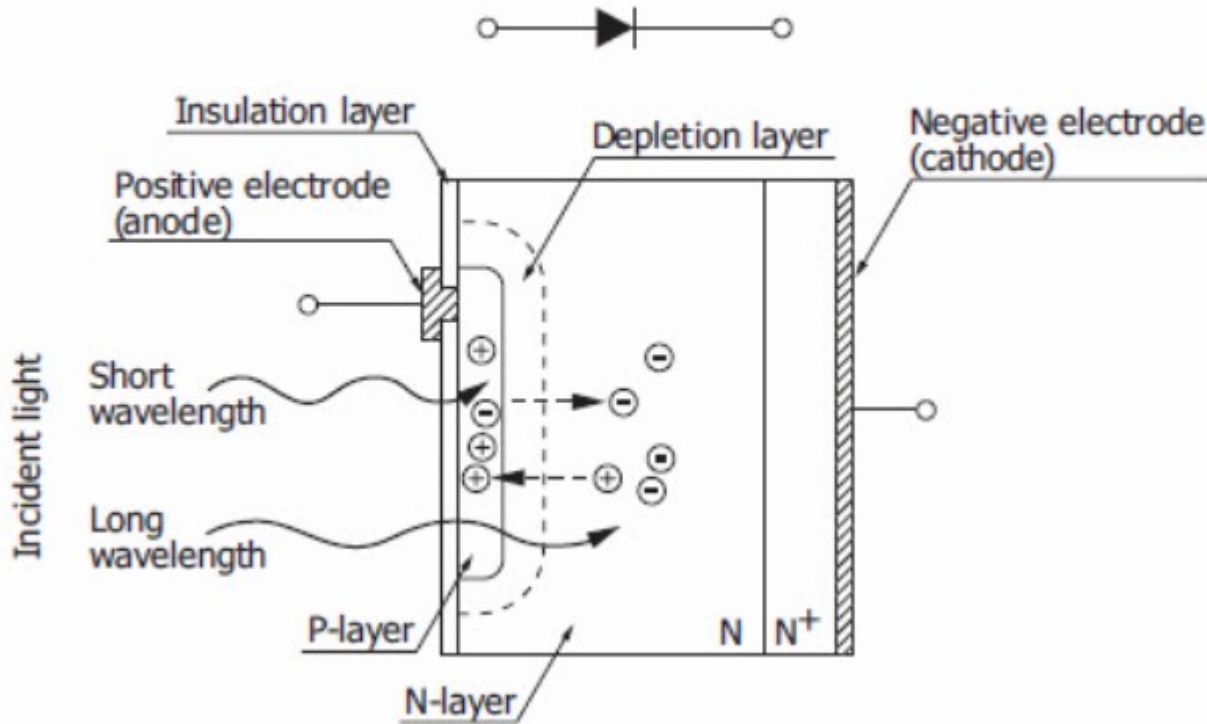
		Technologie du vide			Technologie semi-conducteurs		
		PMT	HPD	MC-PMT	PN, PIN	APD	SiPM
Efficacité de détection	bleu	20%	20%	20%	60%	50%	40%
	vert-jaune	40%	40%	40%	80-90%	60-70%	25%
	rouge	<6%	<6%	<6%	90-100%	80%	10%
Résolution temporelle /10pe		100ps	100ps	10ps	10 ^{eme} de ns	quelques ns	quelques ps
Gain		10 ⁶	3-8.10 ³	10 ⁶ -10 ⁷	1	200	10 ⁶
Tension d'alimentation		1kV	20kV	3kV	10-100V	100-500V	<100V
Utilisation dans un champ magnétique		<10 ⁻³ T	champ axiale 4T	champ axiale 2T	insensible	insensible	insensible
Niveau de signal détectable		1 p.e.	1 p.e.	1 p.e.	100 p.e.	10 p.e.	1 p.e.
Caractéristiques mécaniques		fragile, encombrant		compacte	compacte et robuste		

Source : thèse de Nicolas Hudin, Développement de nouvelles sondes per-opératoires positon pour guider la chirurgie des tumeurs solides (2013).

Characteristic	PMT	PD	APD	SiPM
Spectral coverage [nm]	115-1,700	190-13,000	190-1,700	320-900
Peak QE (η) [%]	< 40	< 90	< 90	< 40 (<i>PDE</i>)
Active area [mm ²]	< 12,000	< 100	< 100	< 10
Gain (μ)	10^5 - 10^6	1	< 100	10^5 - 10^6
NEP [W/ $\sqrt{\text{Hz}}$]	> 2×10^{-17}	> 6×10^{-16}	> 1×10^{-15}	> 6×10^{-16}
Rise time [ns]	> 0.15	> 0.23	> 0.35	> 1
Bandwidth [Hz]	< 2×10^9	< 1.5×10^9	< 1×10^9	NA
Time jitter [ns]	> 0.05	NA	> 0.2	> 0.2

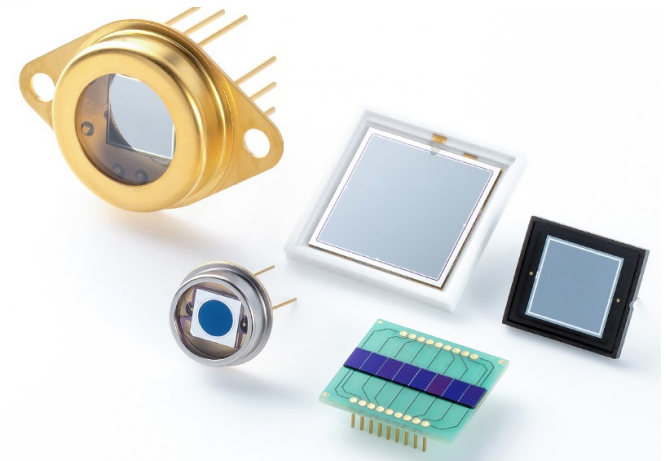
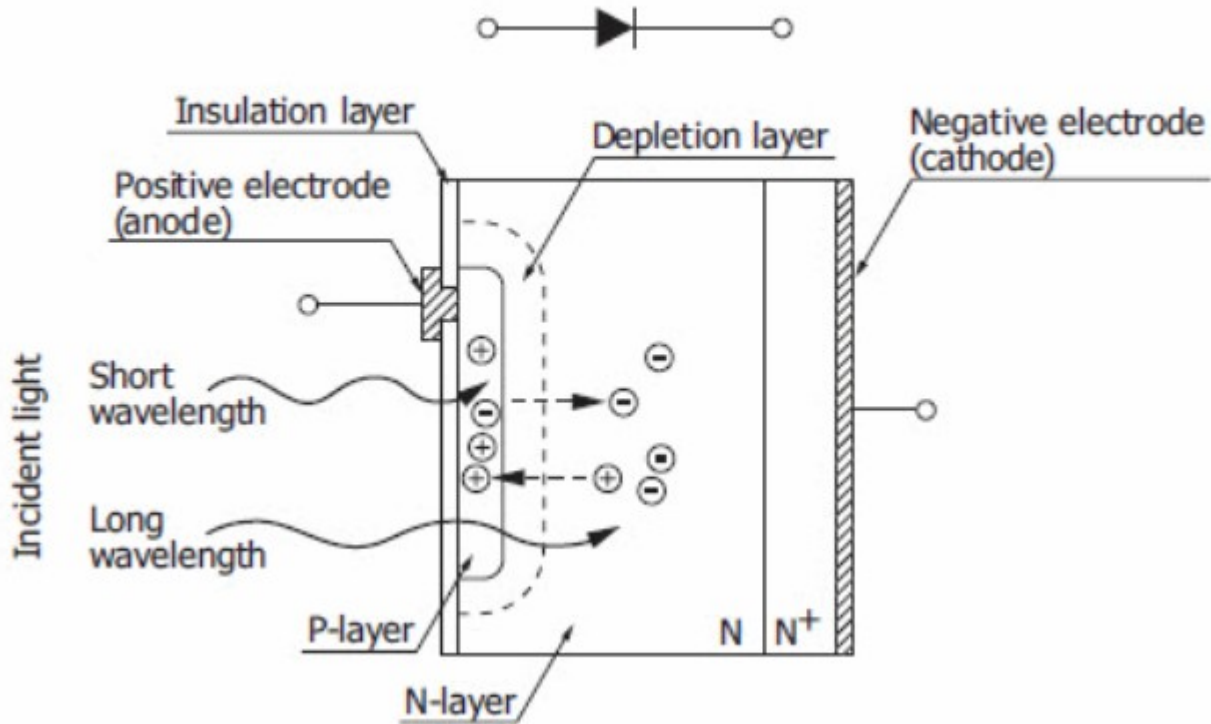
Source : Hamamatsu.com

Photodiode structure

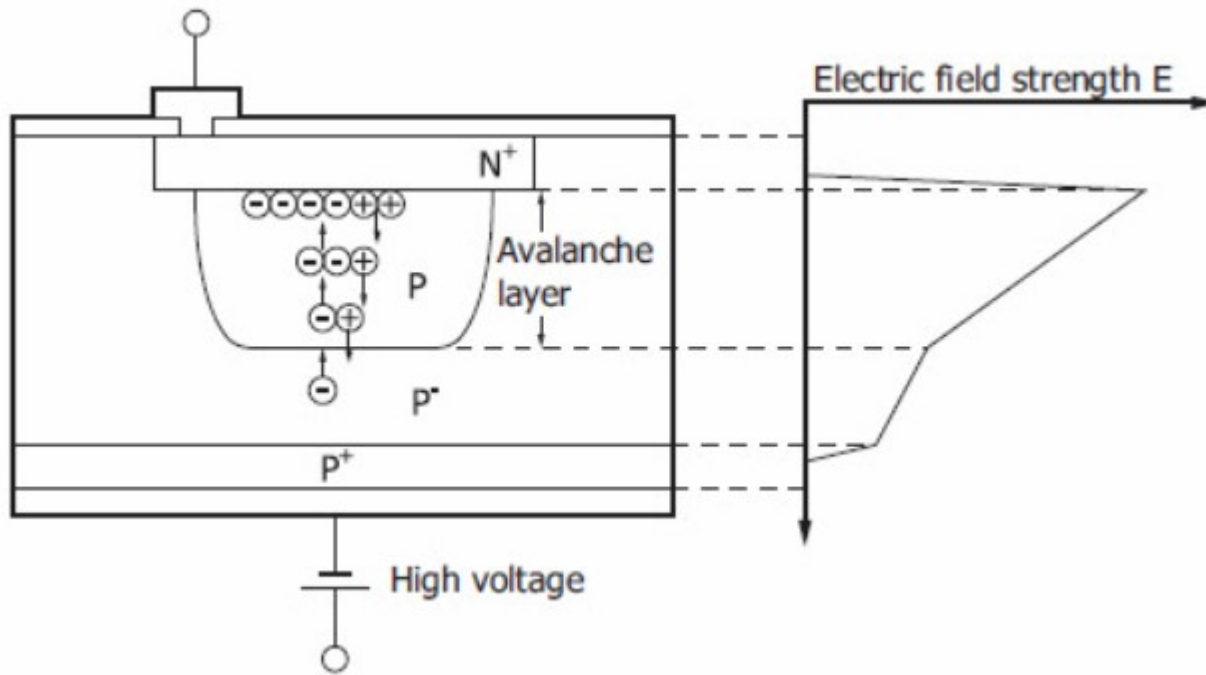


Source : Hamamatsu.com

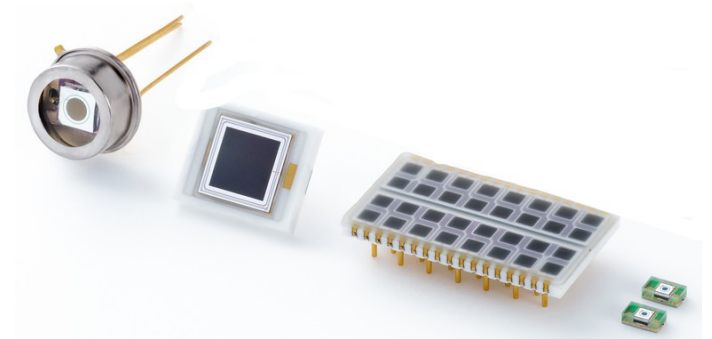
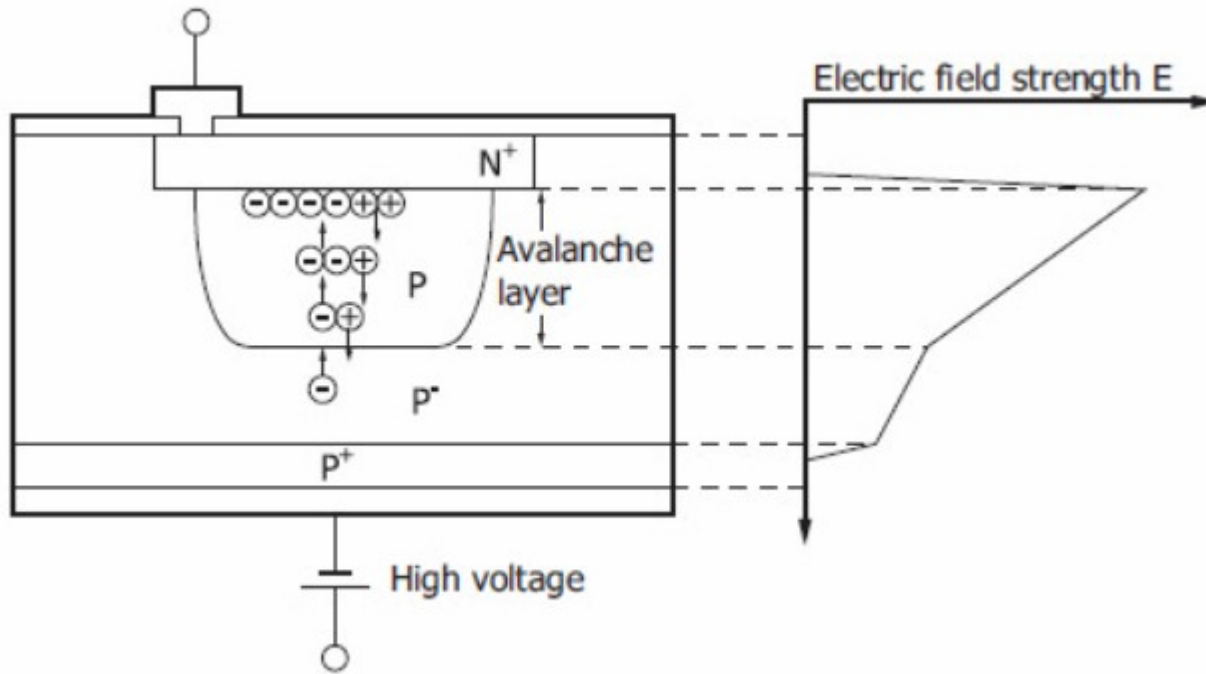
Photodiode structure



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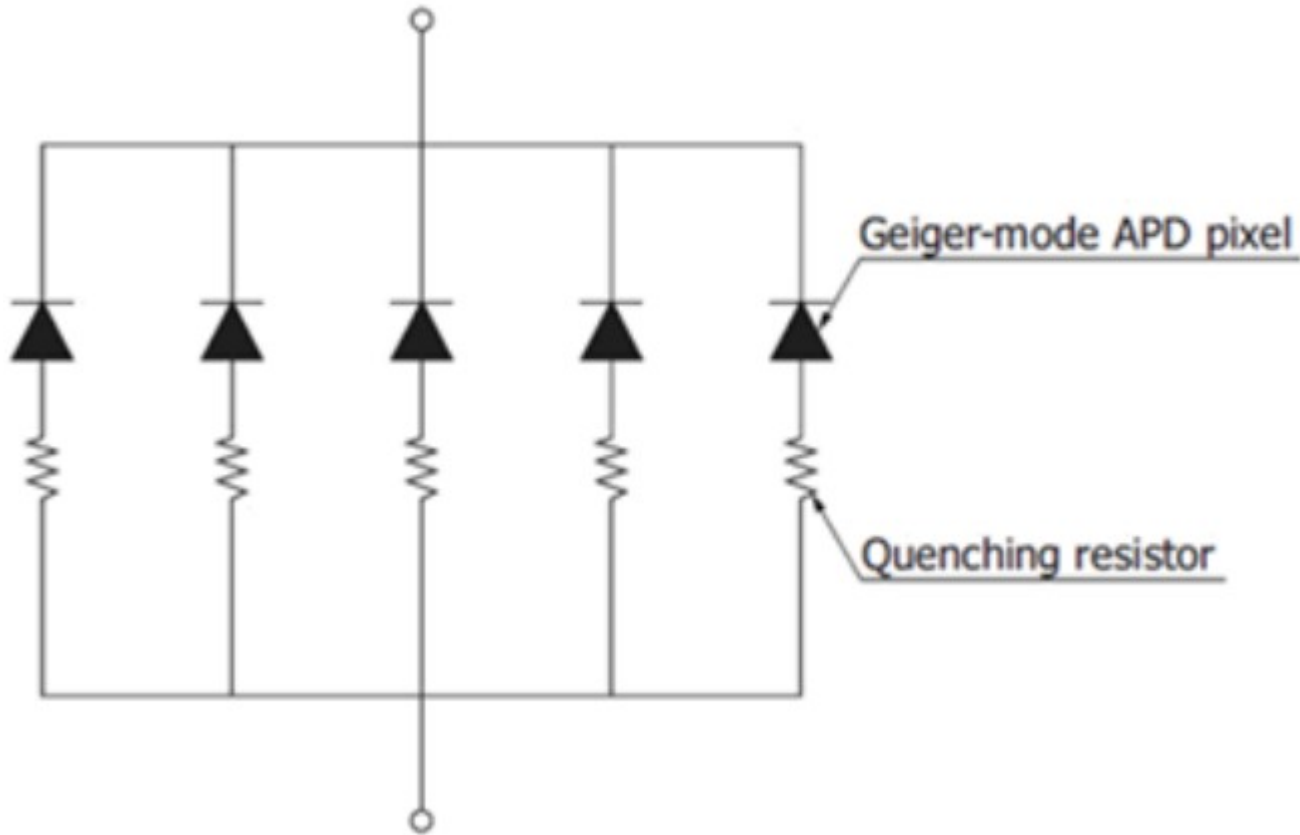


Source : Hamamatsu.com



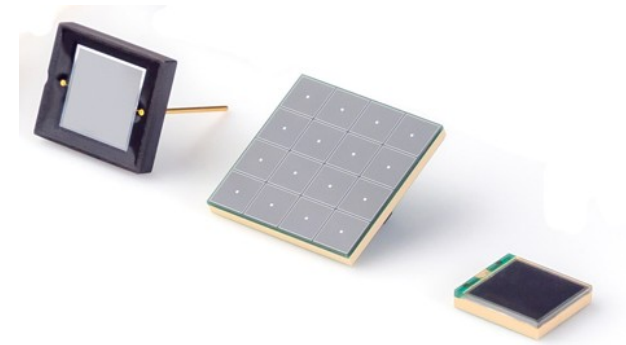
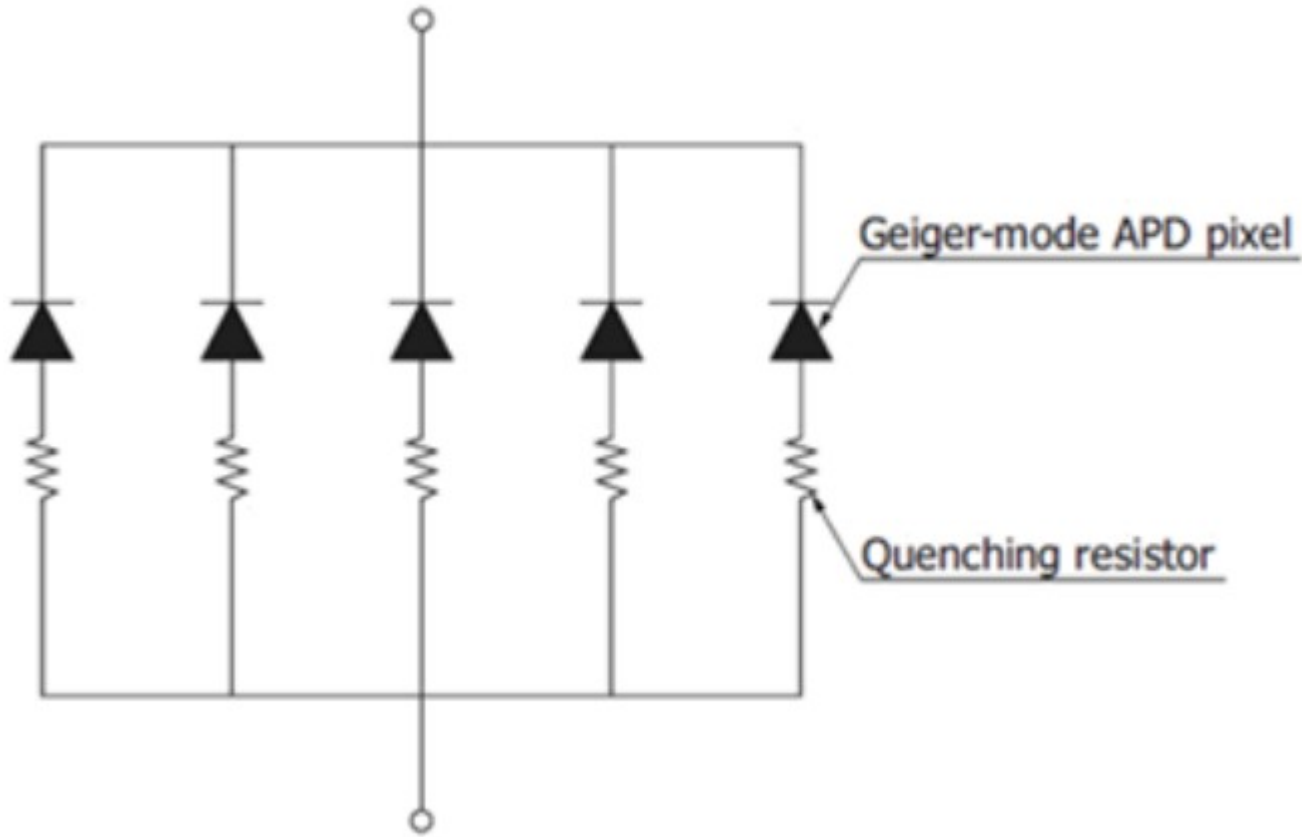
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SiPM structure

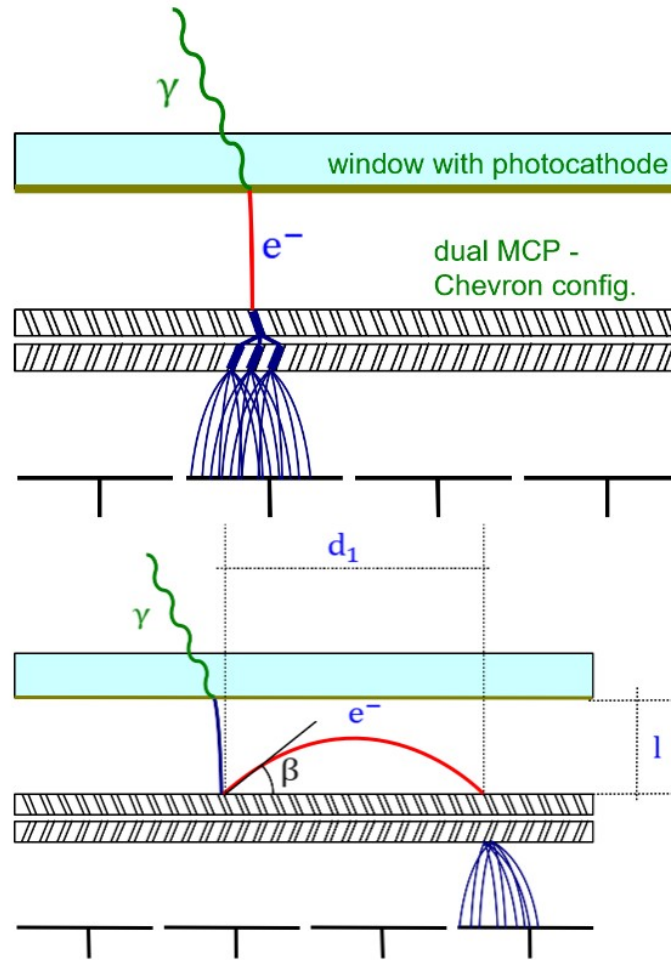


Source : Hamamatsu.com

SiPM structure



Source : Hamamatsu.com



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Scintillateurs



Un élément
scintillant

Un guide de
lumière, parfois

Un photodétecteur