

# Fotorivelatori al Silicio

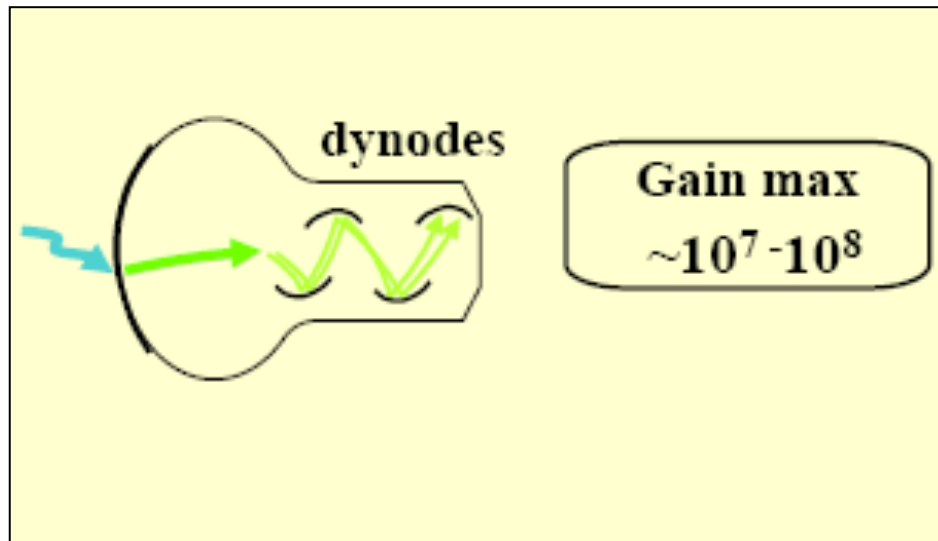
## SiPM

# SiPM

Perché lasciare i vecchi PMT e passare al silicio?

- Alta efficienza quantica
- Alto guadagno
- Alta efficienza a bassi livelli di luce
- Conteggio di fotoni
- Alta linearita'
- Ottima risoluzione temporale
- Basso consumo (senza divisore di tensione)
- Robusto, stabile, compatto
- Insensibile a campi magnetici
- Basso costo

# SiPM

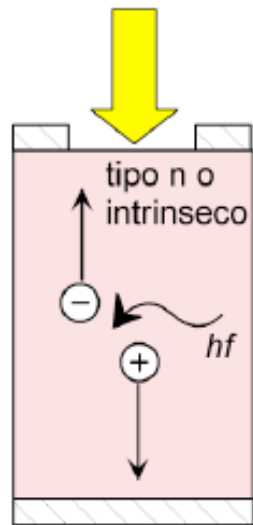


- **Sruttura complessa**
- **Alto costo**
- **Integrale dei fotoni**
- **TTS alto (ns)**
- **Consumo del divisore**
- **Fluttuazioni primo dinodo**  
 $1/\delta$
- **Linearita' critica**

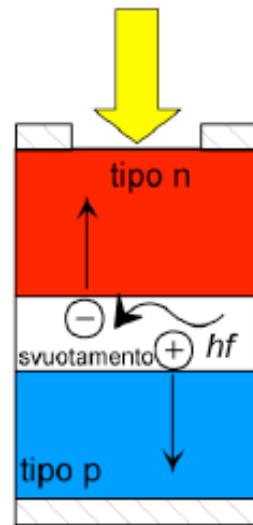
Fotomoltiplicatore a vuoto: nasce nel 1913 ed e' commerciale RCA nel 1936

La ricerca di nuovi fotorivelatori porta inevitabilmente ai dispositivi al silicio

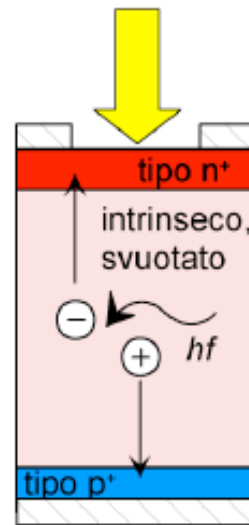
## Giunzioni p-n



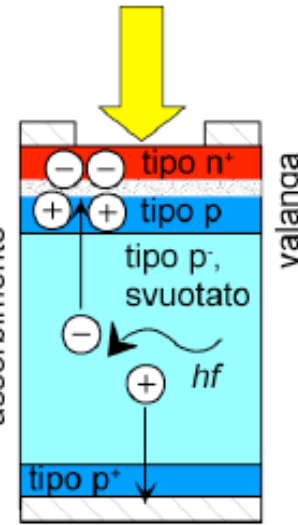
Fotoconduttore



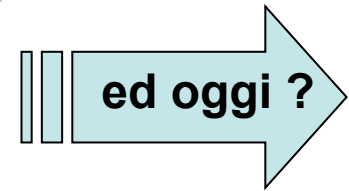
Fotodiodo pn



Fotodiodo pin



Fotodiodo a valanga



**G=1**

**APD**  
**G=50-100**

= gas

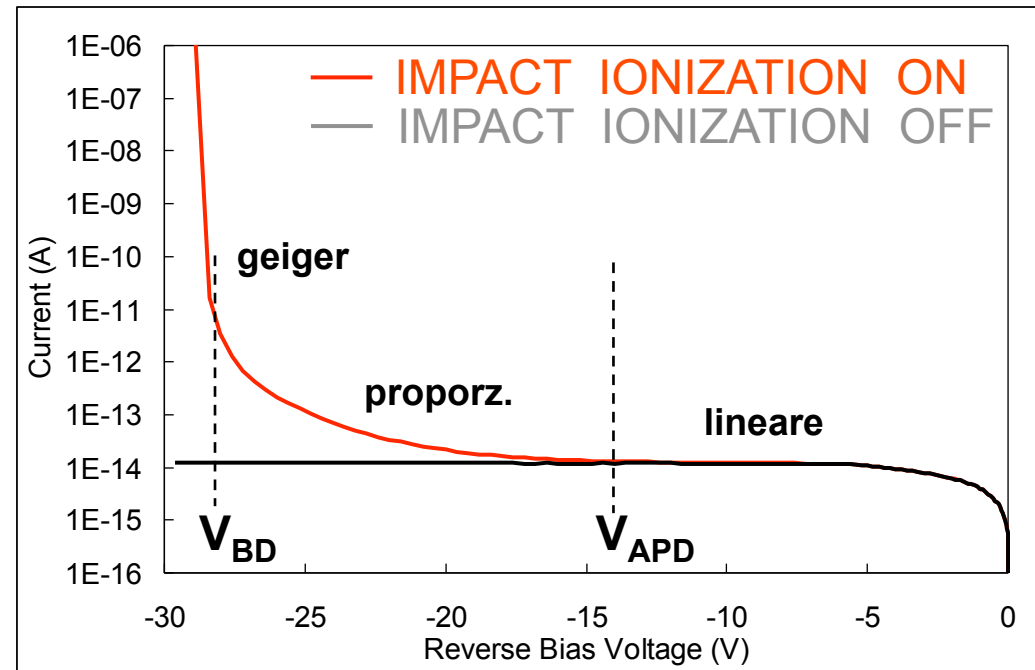
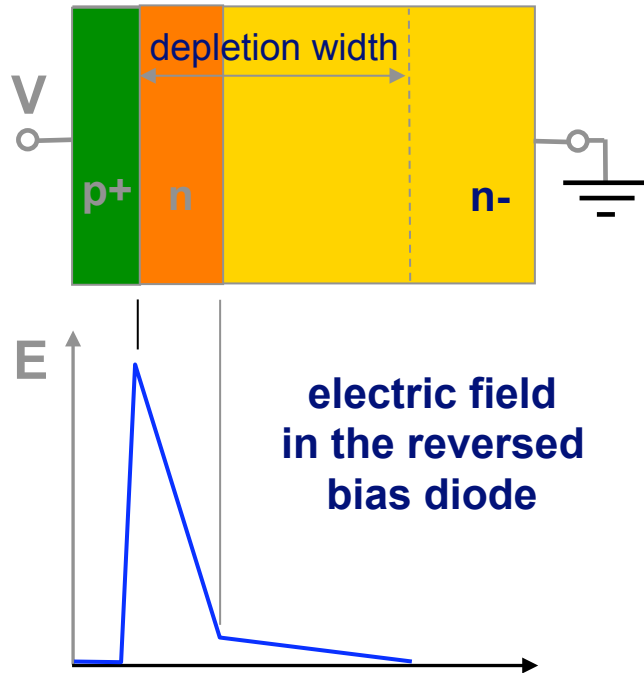
Camere a ionizzazione

camere proporzionali

tubi a streamer/RPC

# Regime Geiger Limitato in Si

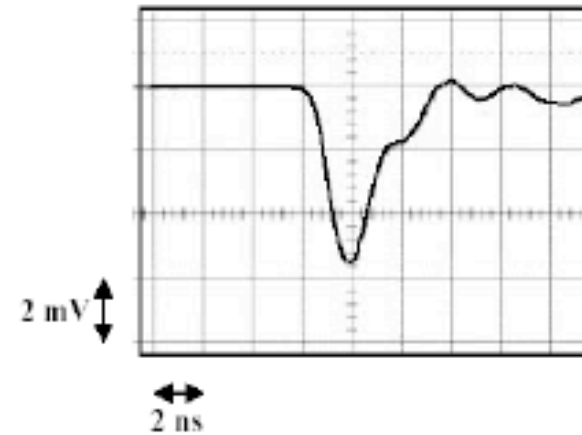
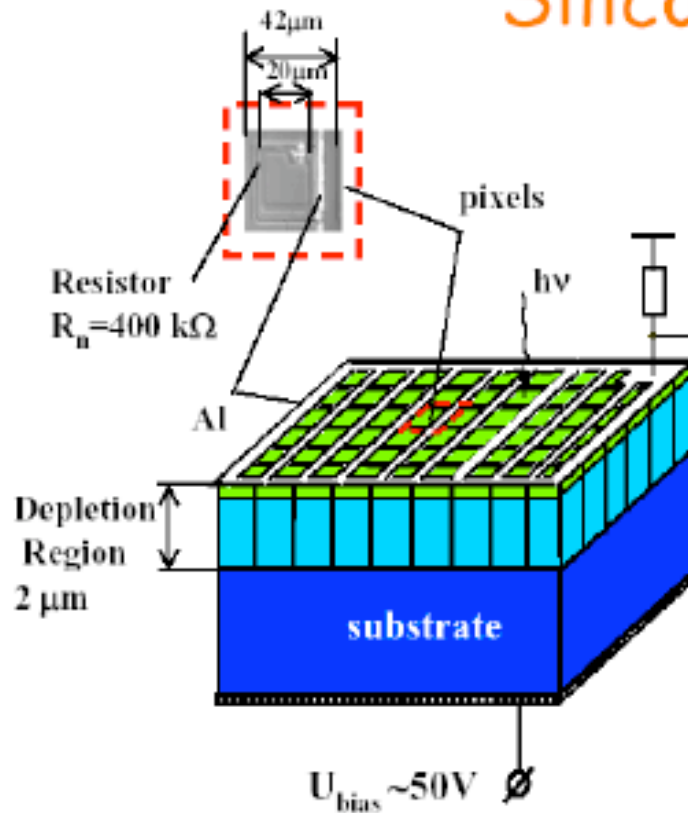
diode structure



$V < V_{APD} \Rightarrow$  **fotodiode**  
 $V_{APD} < V < V_{BD} \Rightarrow$  **APD**  
 $V > V_{BD} \Rightarrow$  **Geiger-mode APD**

**coppie raccolte/coppie generate = 1**  
**coppie raccolte/coppie generate = M**  
**collected pairs/generated pair = ind.**

# Silicon photomultiplier (SiPM)



## SiPM main features:

- Sensitive size  $1 \times 1 \text{ mm}^2$  on chip  $1.5 \times 1.5 \text{ mm}^2$
- Gain  $2 \cdot 10^6$
- $U_{\text{bias}} \sim 50\text{V}$
- Recovery time  $\sim 100 \text{ ns/pixel}$
- Number of pixels: 576
- Nuclear counter effect: negligible (due to Geiger mode)
- Insensitive to magnetic field
- Dynamic range  $\sim 10^3/\text{mm}^2$

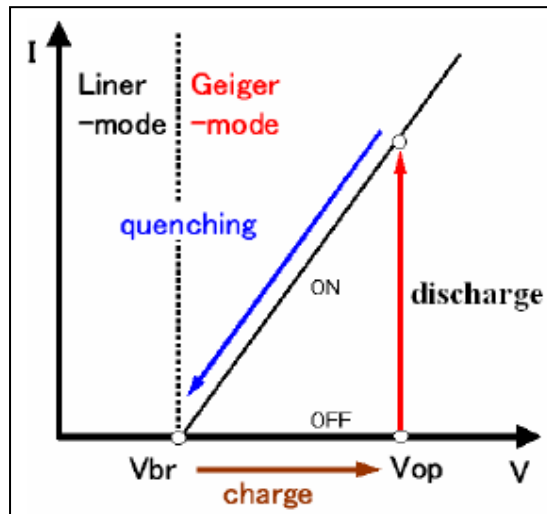
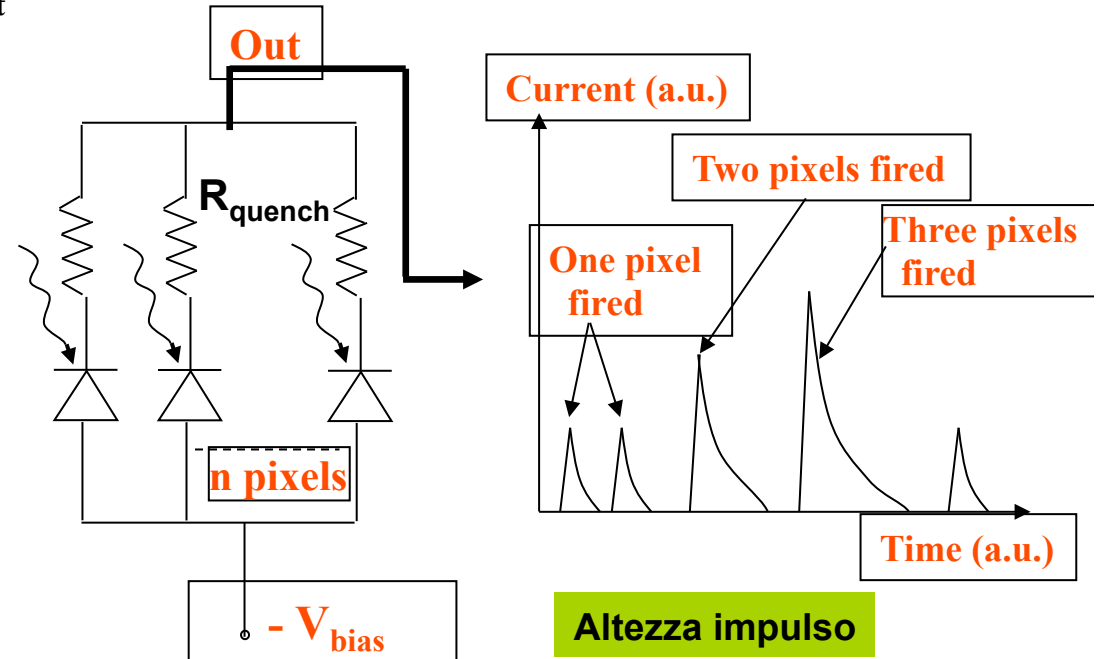
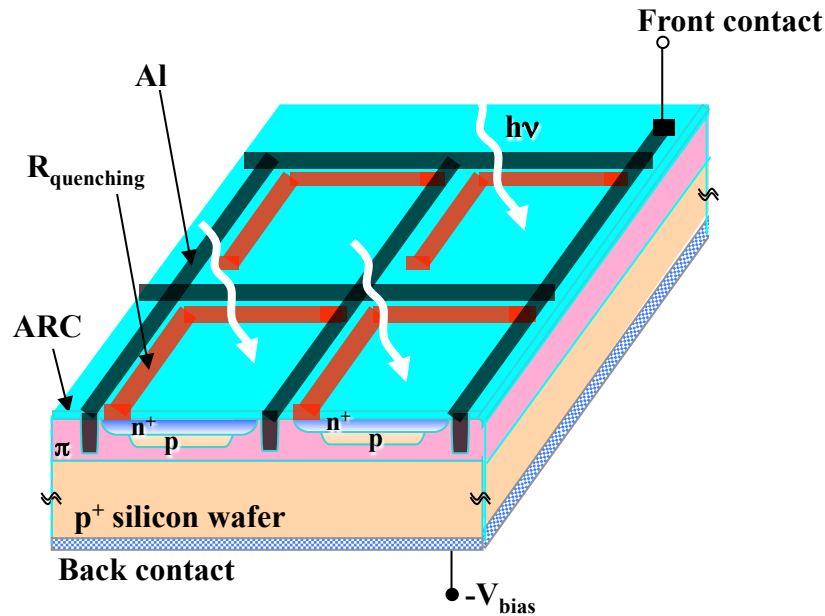
- matrici di microcelle in parallelo
  - ogni microcella: GM-APD +  $R_{\text{quenching}}$
- V. M. Golovin and A. Sadygov*

*MEPHI*



**ITC-irst programma MEMS  
Hamamtsu.....**

# SiPM / G-APD / MPPC



- **microcontatori** indipendenti in regime **geiger limitato**
- Geiger spento dalla **caduta** del campo e **resistenza di quenching R**.
- Segnale in uscita **somma segnali** singoli geiger
- **V Geiger** 10-20% sopra la tensione di brekdown 25-60 V

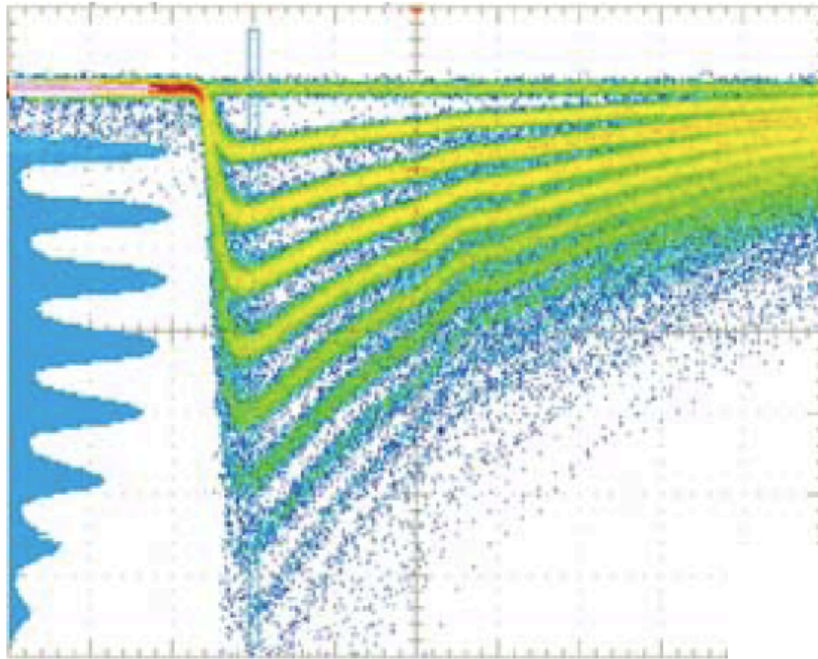
# SiPM: da Hamamatsu MPPC

## ■ 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 <sup>5</sup>	7.5 × 10 <sup>5</sup>	2.4 × 10 <sup>6</sup>	-



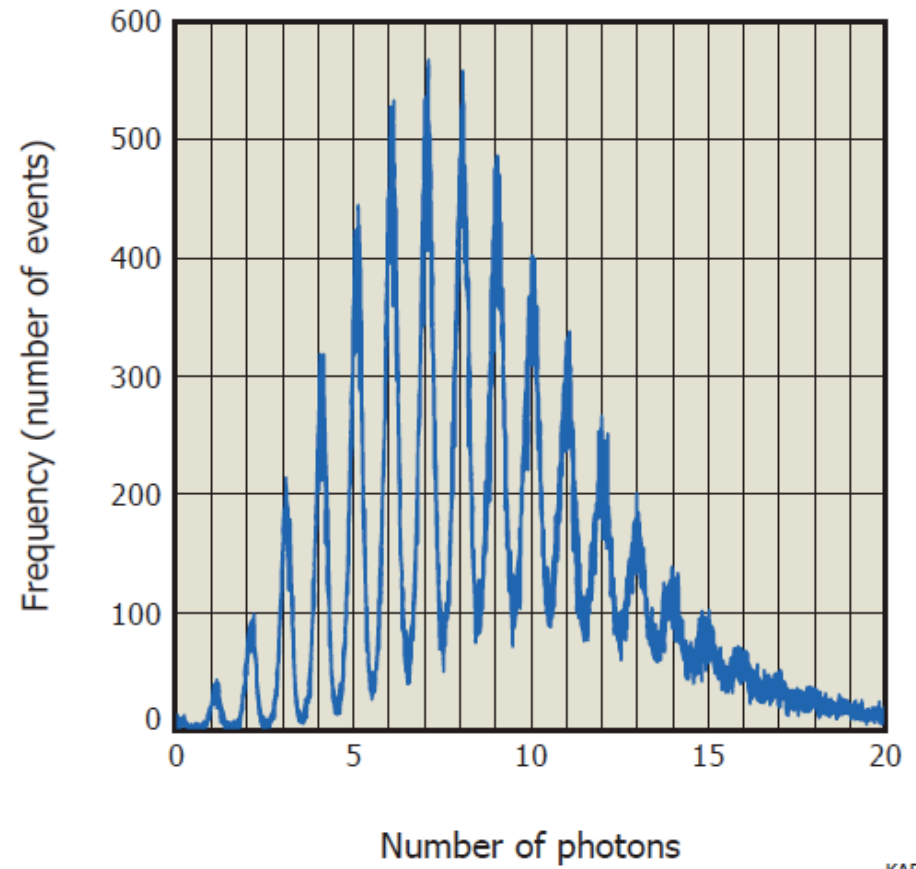
Number of photons



Time

Segnale in carica

Segnale Oscilloscopio

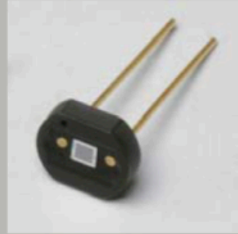


P.5

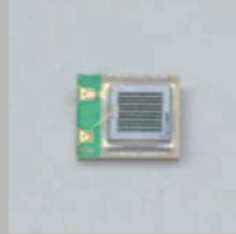
### Active area: 1 × 1 mm type



Metal type



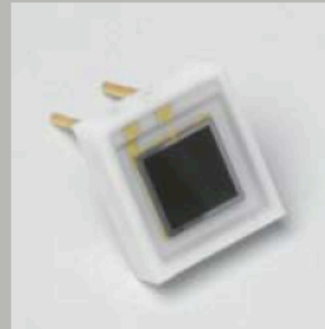
Ceramic type



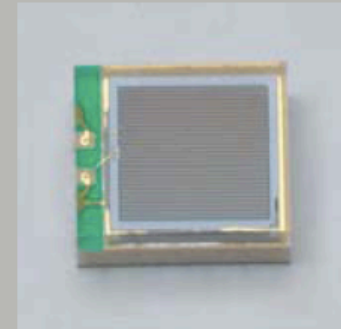
SMD type

P.7

### Active area: 3 × 3 mm type



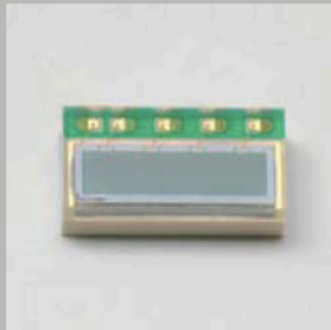
Ceramic type



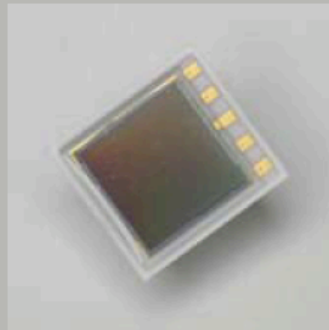
SMD type

P.9

### MPPC array

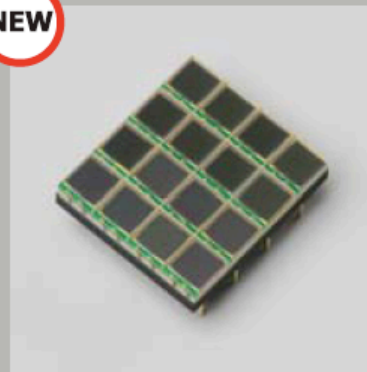


1 × 4 ch type

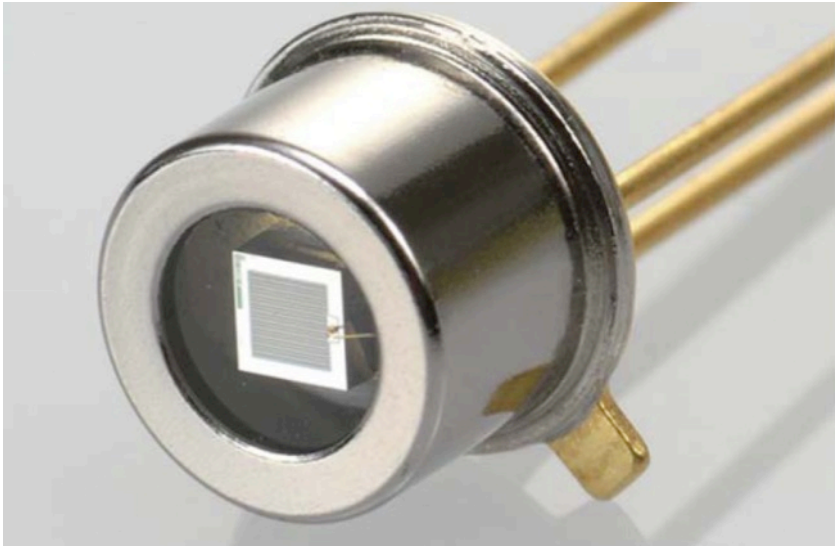
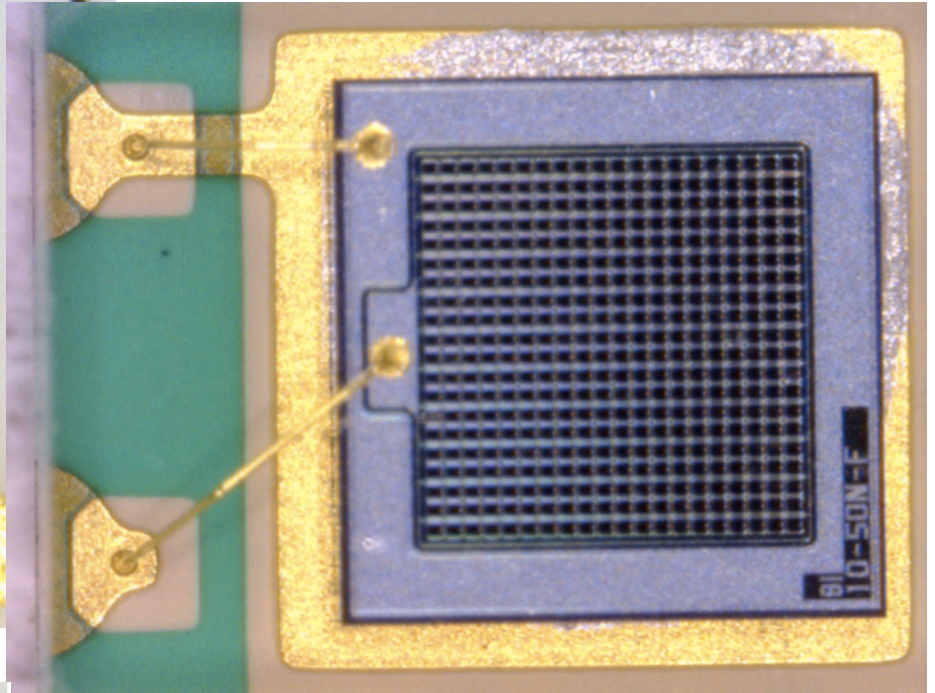
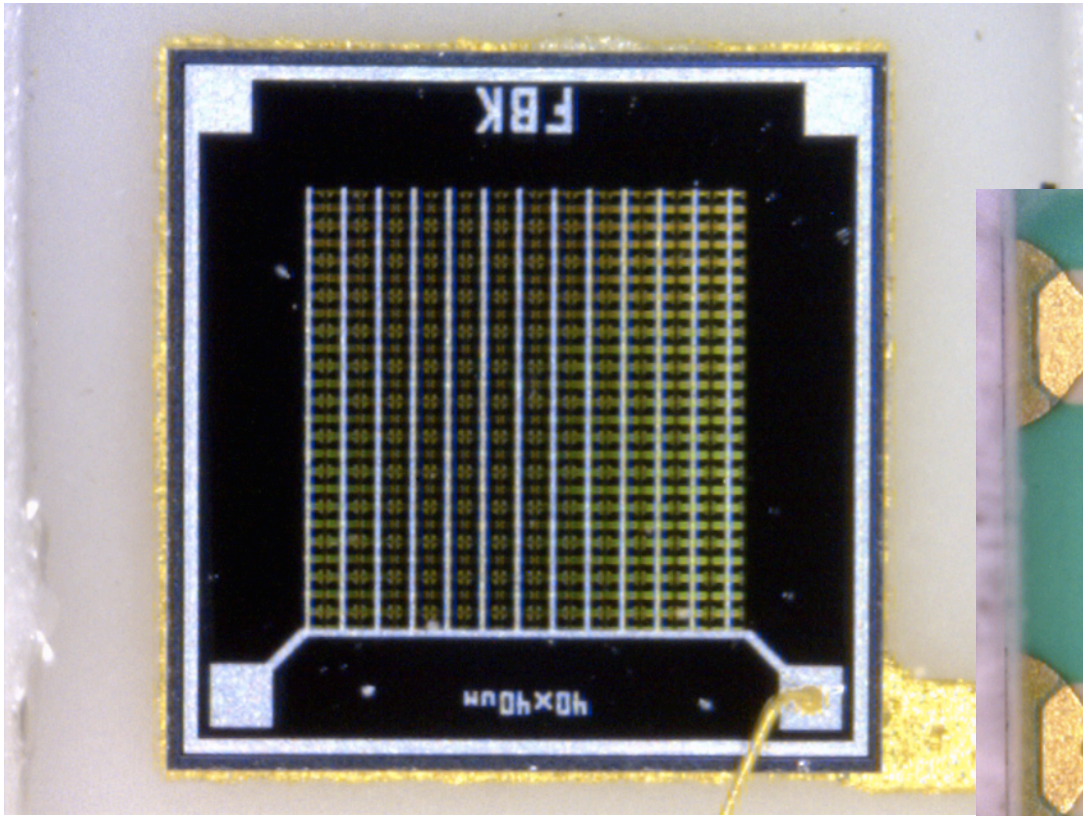


2 × 2 ch type

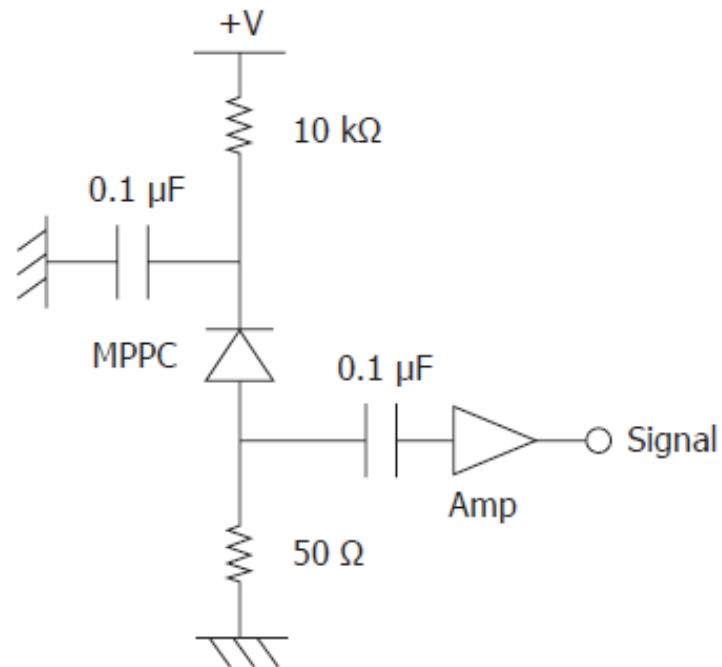
NEW



4 × 4 ch type



## Basic connection diagram for MPPC



KAPDC0024EA