Review of Solidstate Photomultiplier

Developments by CPTA & Photonique SA

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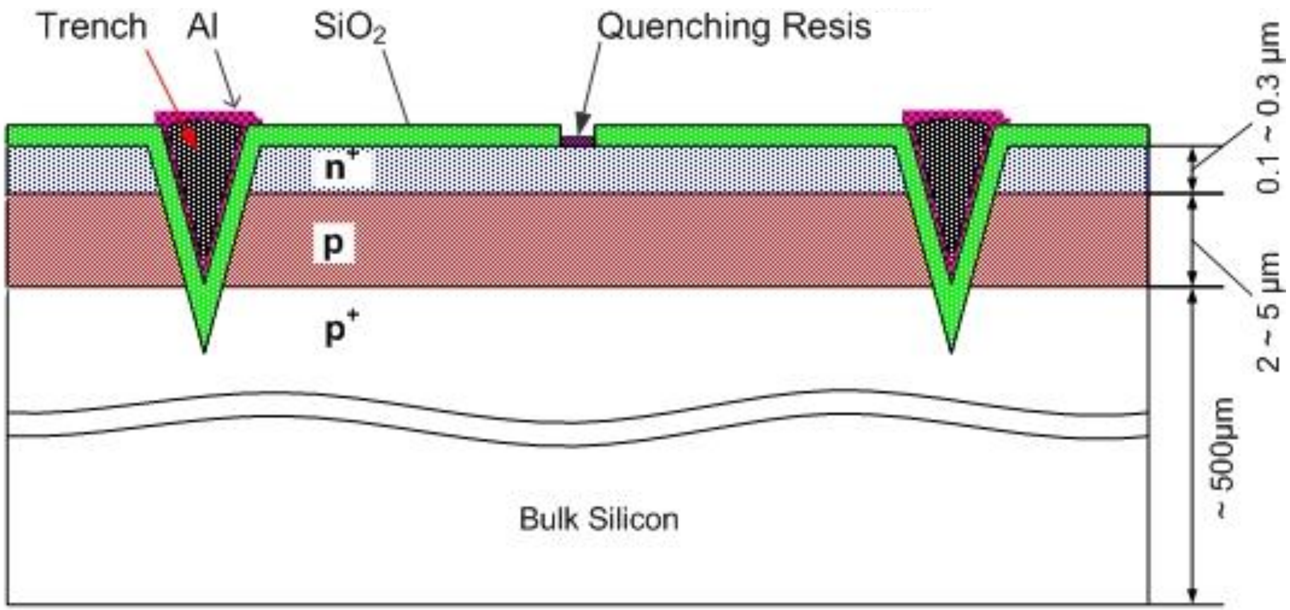
Overview

- SSPMs development & status
- Support electronics
- Outlook

n^+ p p^+ Structure for Visible Light Applications

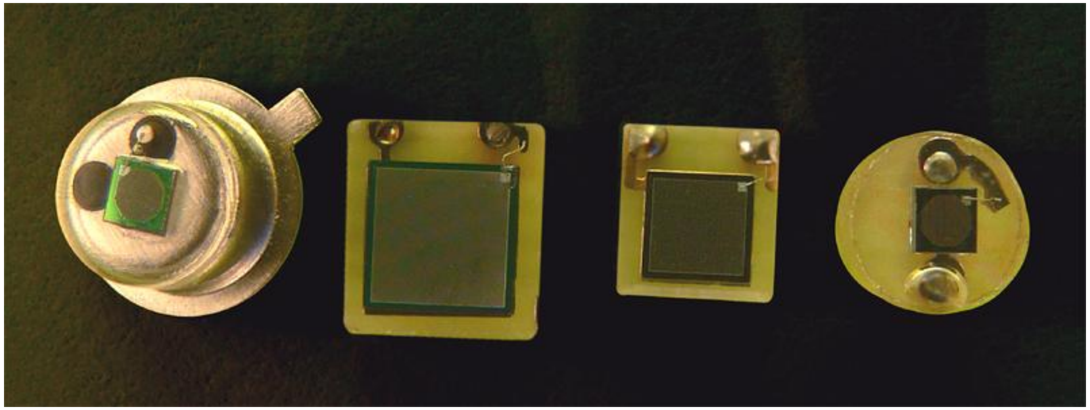


Trench Architecture

→ **High fill / geometric factor**
→ **Low optical cross talk**
→ **Low excess noise**
→ **Uniform Electric field**

Visible Light Sensor Line-Up (2008)

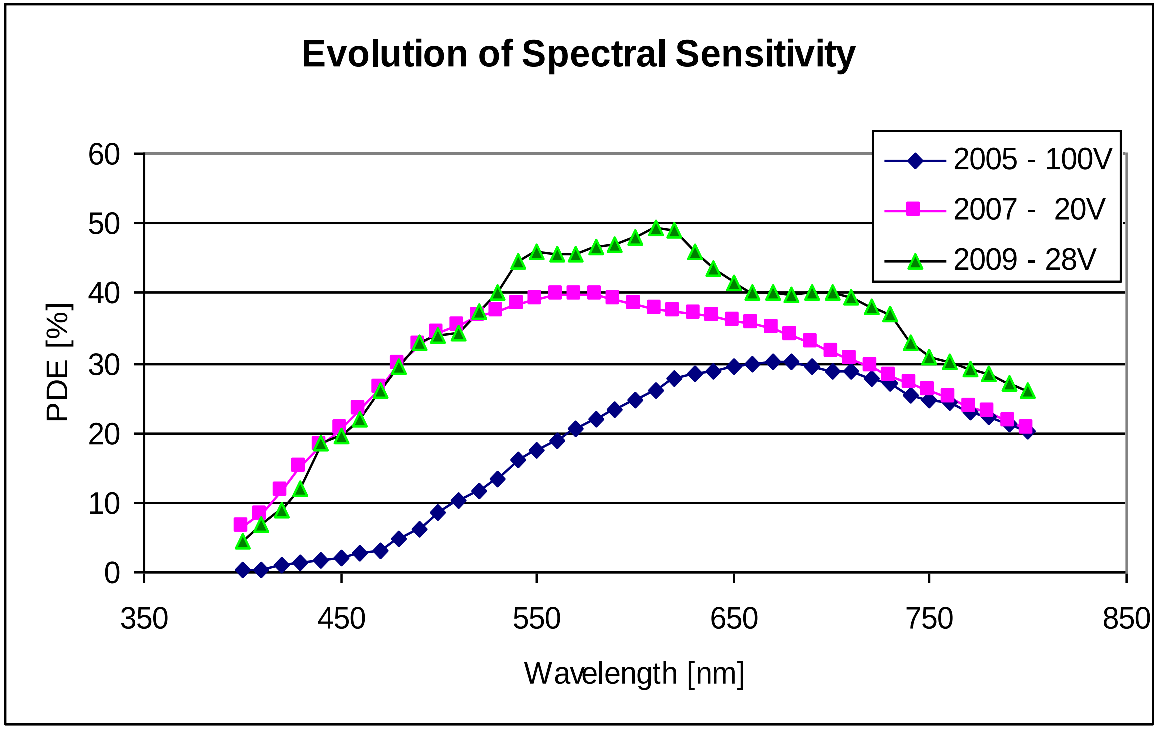
Sensor Area	Micro-cell size	Micro-cell count	Geometric Factor
1mm^2	43µm	556	~60%
4.4mm^2	50µm	1764	>70%
9.0mm^2	33µm	8100	>60%



NEW 2009: 2.5 x 2.5 mm 43µm cell size ~70%

Performance Evolution 2005 - 2009

- **Opt. doping concentrations**
- **Opt. n+ layer thickness**
- **Impr. n+ p junction**
- **Impr. trench geometry**
- **Better field uniformity**



2005: V_b = ~100V; V_{ov} = $V_{bias} - V_b$ up to 4V or 4% of V_b

2007: V_b = ~ 17V; V_{ov} = up to 8V or 45% of V_b

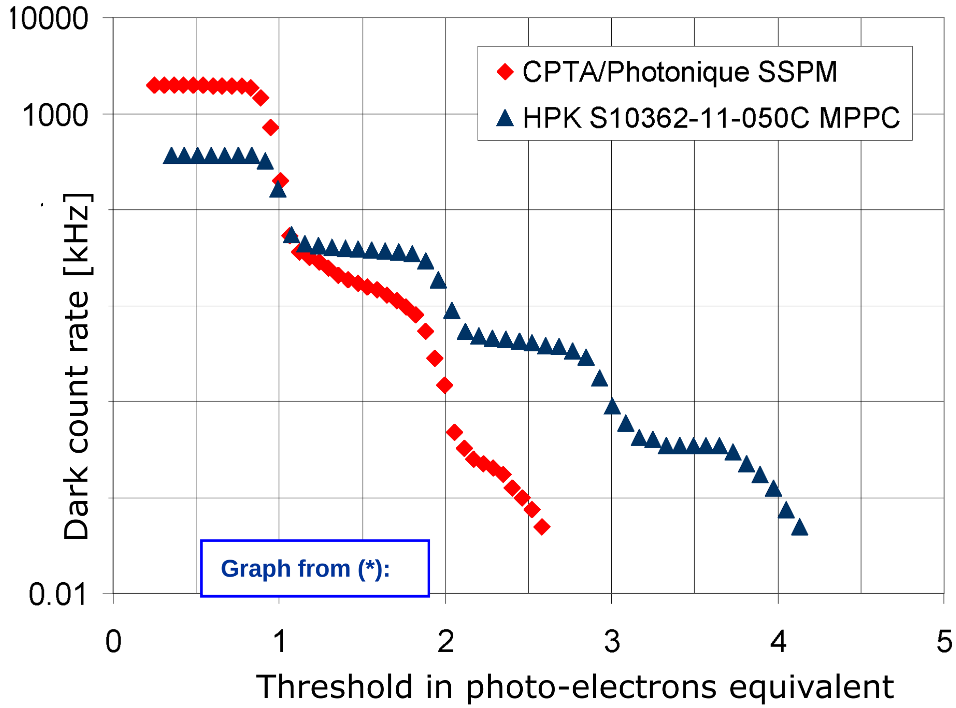
2009: V_b = ~ 28V; V_{ov} = >10V and Gain ~1.4 x 10^6 in 50ns gate

Optical Cross-Talk

Trench architecture significantly reduces optical cross talk and allows for improved tuning of readout threshold

- **No Trench**:
  Crosstalk: **20% … 30%**

- **With Trench**:
  Crosstalk: **1% … 3%**



(*) Y. Musienko – Advances in multipixel Geiger-mode avalanche photodiodes (silicon photomultipliers); to be published in NIM A (08)

Quenching Resistor

Affects: Cell Recovery Time & After pulsing

Can tune micro-cell quenching resistor value from

0.7MΩ **to** **100**MΩ

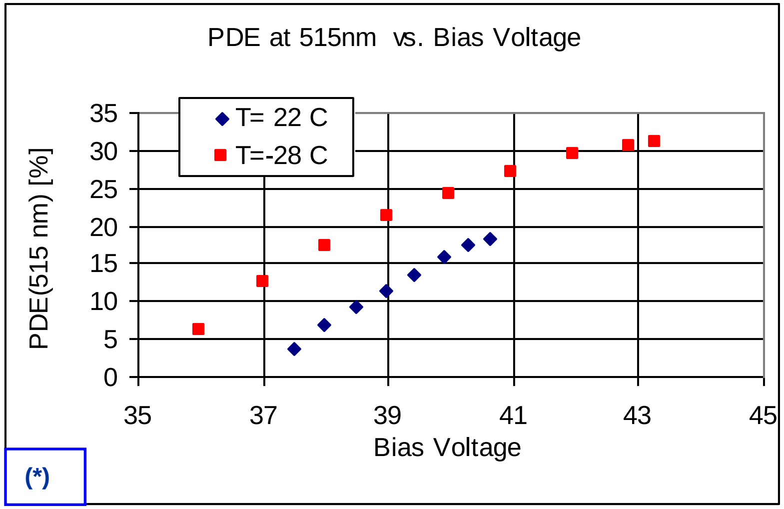
Fast recovery **~70ns**
Modest afterpulsing:
<10% in 100ns gate

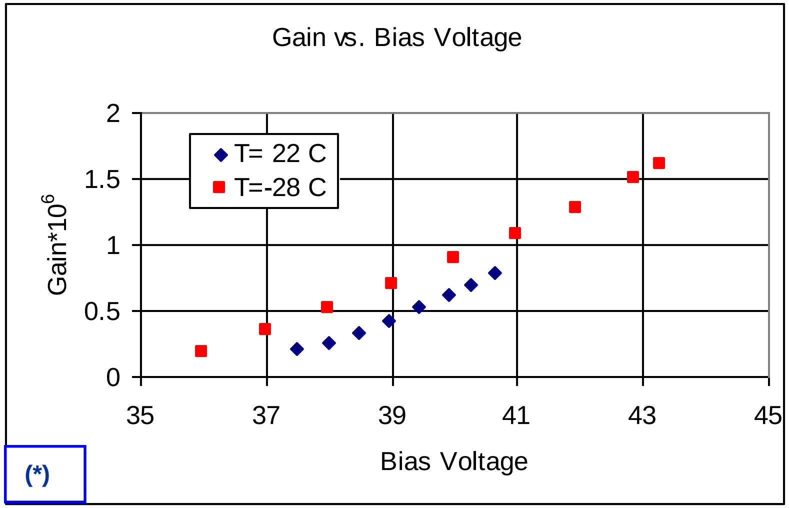
Slower recovery **~10µsec**
Low afterpulsing
~1-3% in 100ns gate

Note: Micro-cell capacitance **~100fF ;** **"Optimal" value for off-the-shelf: ~1MΩ**

Temperature Stability of Signal Amplitude (I)

$$\mathbf{Amplitude_{Signal} = N_{Photons} \times PDE(T) \times Gain(T)}$$





T = - 28Cº **T = + 22Cº**

Wide V_{op} range results in reduced slope in the ***PDE vs. Bias*** and ***Gain vs. Bias*** curves.

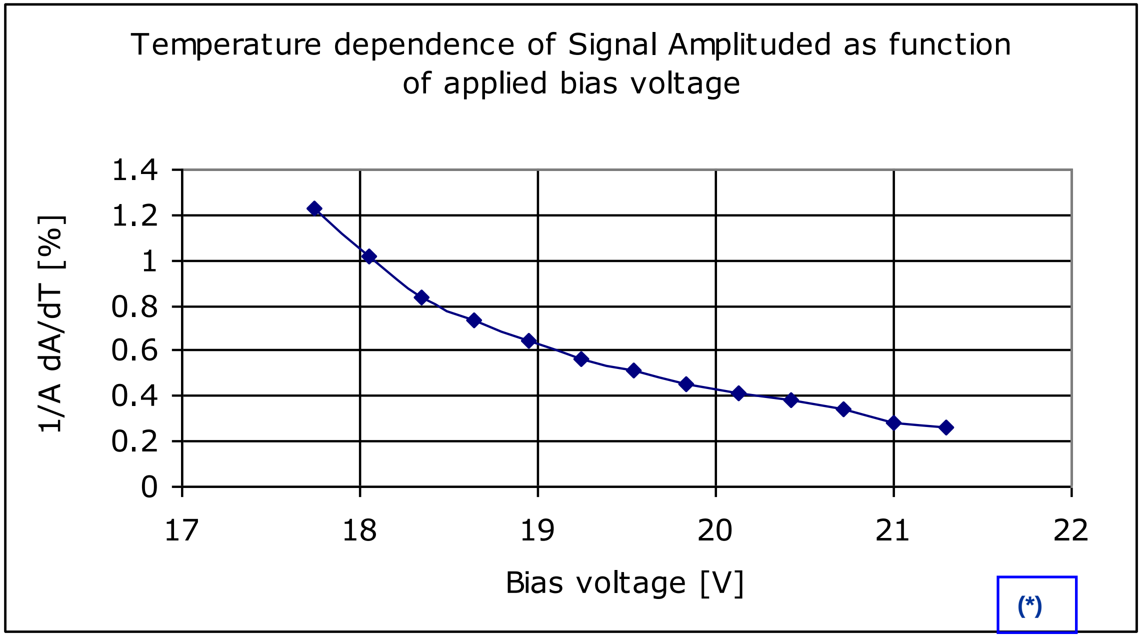
(*): **SSPM_050701GR**

Temperature Stability of Signal Amplitude (II)

A wide V_{op} range over V_b reduces temperature dependence of signal amplitude

Amplitude – Temperature correlation is **<1%/C°** for bulk of operating range.

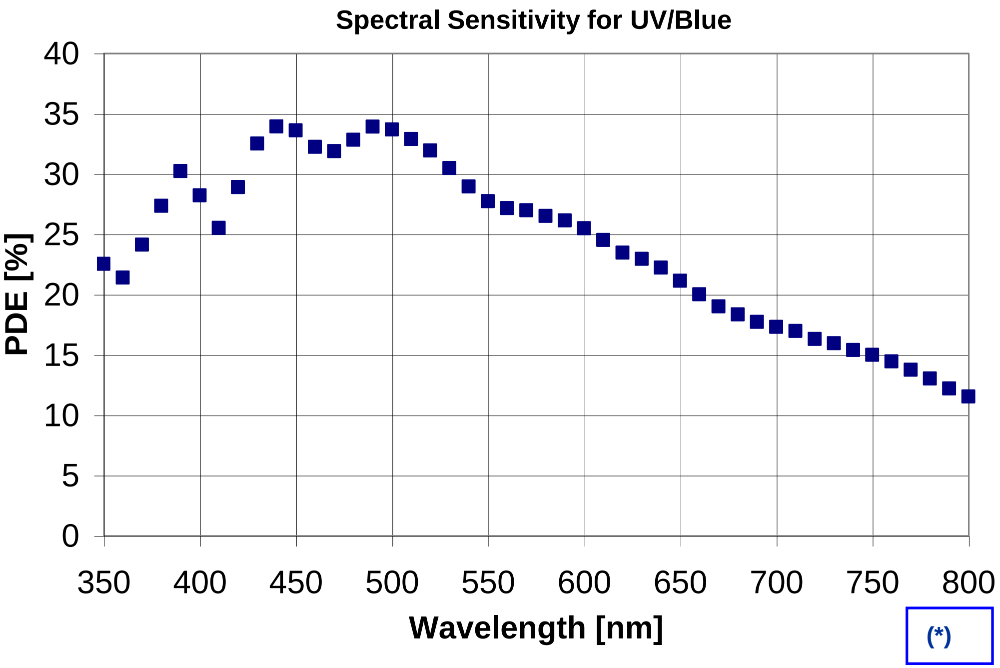
2009 < 0.5 %/C°



(*) **SSPM_0701BG**

$p^+ p n^+$ (UV/Blue): 2008

- Significantly improved implementation of this structure
- Still fighting against dark counts: 1 ~ 3 MHz / mm^2
- Working on wavelength shifter enhanced devices for deep UV applications



T-coeff. of gain	< 1% / C^o
Excess noise factor	< 1.1
Rise time	< 700ps

(*) **SSPM_0611B14MM**

Readout & Support Electronics

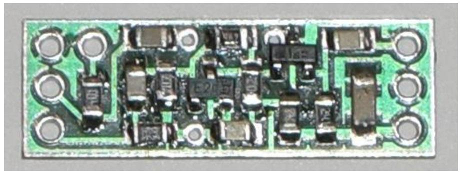
We are developing a comprehensive set of readout solutions

These are available:

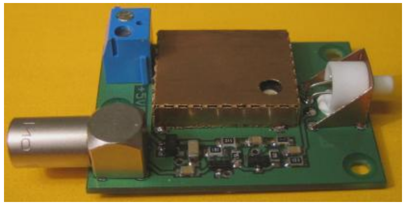
- ➔ **Turn-key**
- ➔ **Customized**
- ➔ **Under license**

Readout & Support Electronics

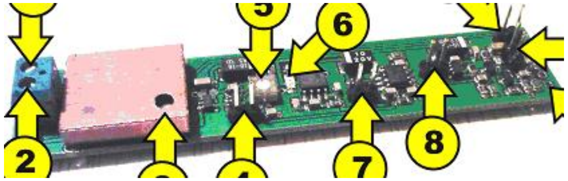
Bias circuit
⊕
Transimpedance amplifier



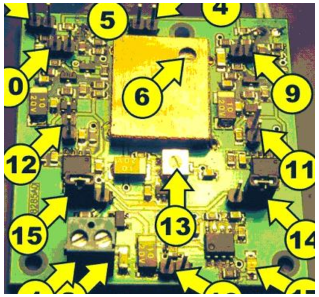
Above
⊕
Temp. Comp. Bias supply



Above
⊕
Threshold Discriminator



Above for Dual Channel
⊕
Coincidence Unit



Outlook

SSPMs - Core sensor developments:

- Higher cell density with peak PDE $\geq$ 40%
- Noise / Dark-count rate reduction
- Small area devices
- Improved sensor packages
- Peltier cooled solutions

SSPM support infrastructure:

- Modular electronics solutions
- Light concentration and focusing

Thank you for your attention

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