Performance of ultra-small Silicon Photomultiplier array with active area of 0.12mm×0.12mm

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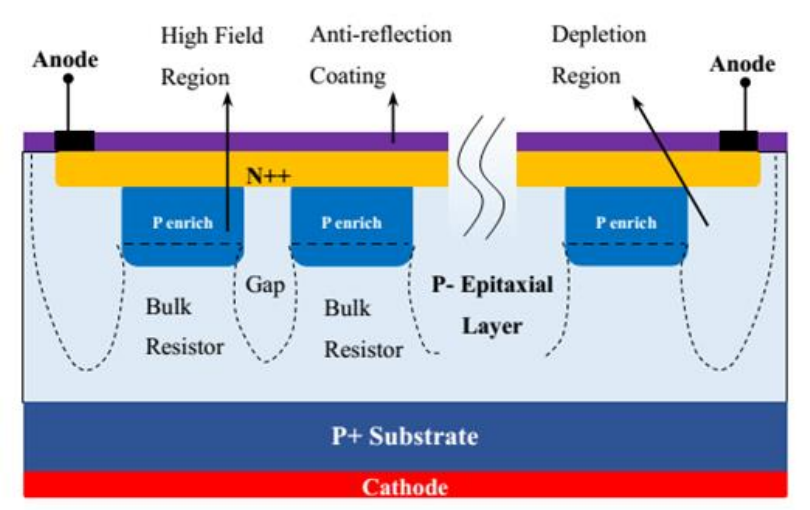
Outline

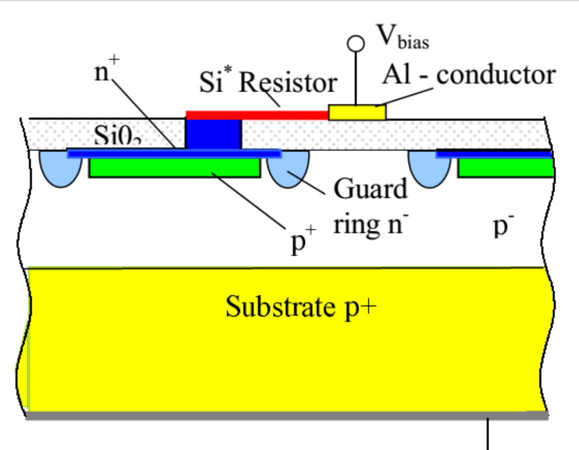
- **Motivation**
- **Experiment and Results**
- **Conclusion**

Motivation

- smaller element means better space resolution for pixel type position sensitive detector in CT, SPECT, ……
- SiPM with bulk quenching resistors, is easier to achieve small micro cells with high cell density, thus small element of array while retaining enough micro cells and adequate large fill factor than other SiPMs.
- Significant progresses have been made for SiPM fabricated at NDL since NDIP2011, 0.5mm×0.5mm → 1mm×1mm → 2.2mm×2.2mm → 3mm×3mm, how about inverse direction to smaller device?
- There are users to request such high resolved pixel SiPM array.

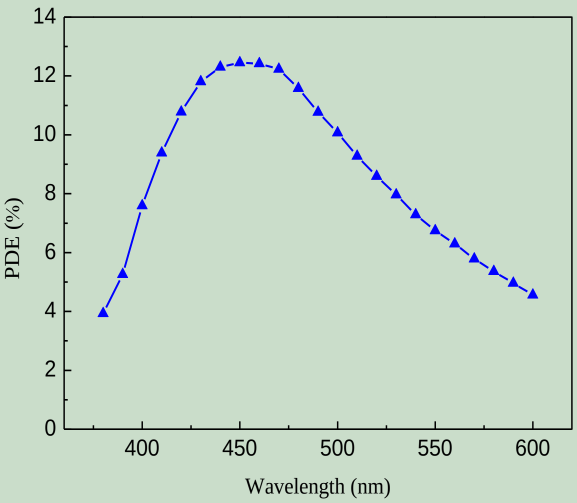


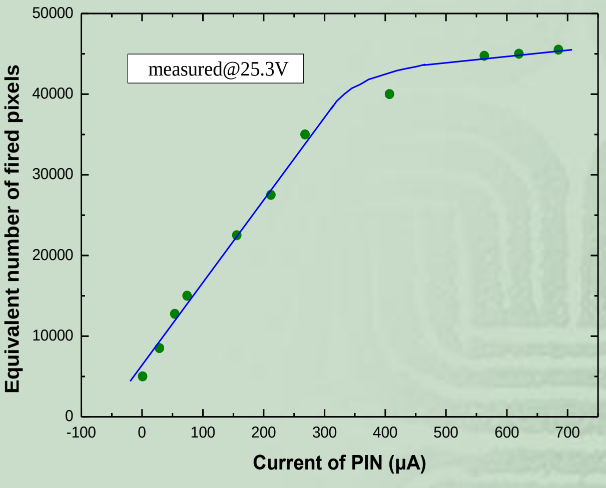
VS

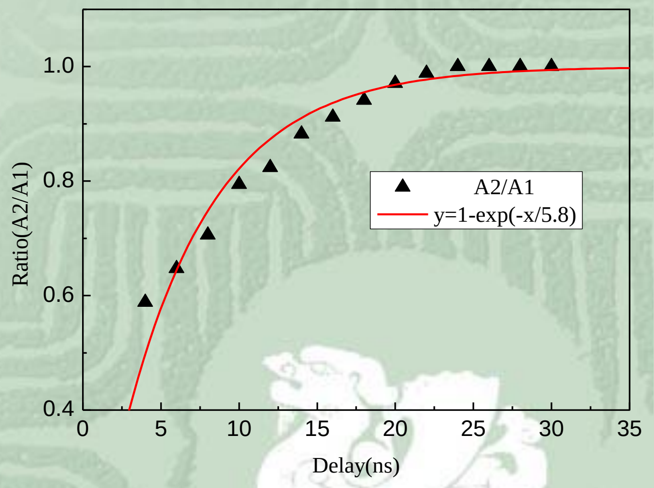


P. Buzhan, ICFA , 2001

intrinsic continuous and uniform cap resistive layer!

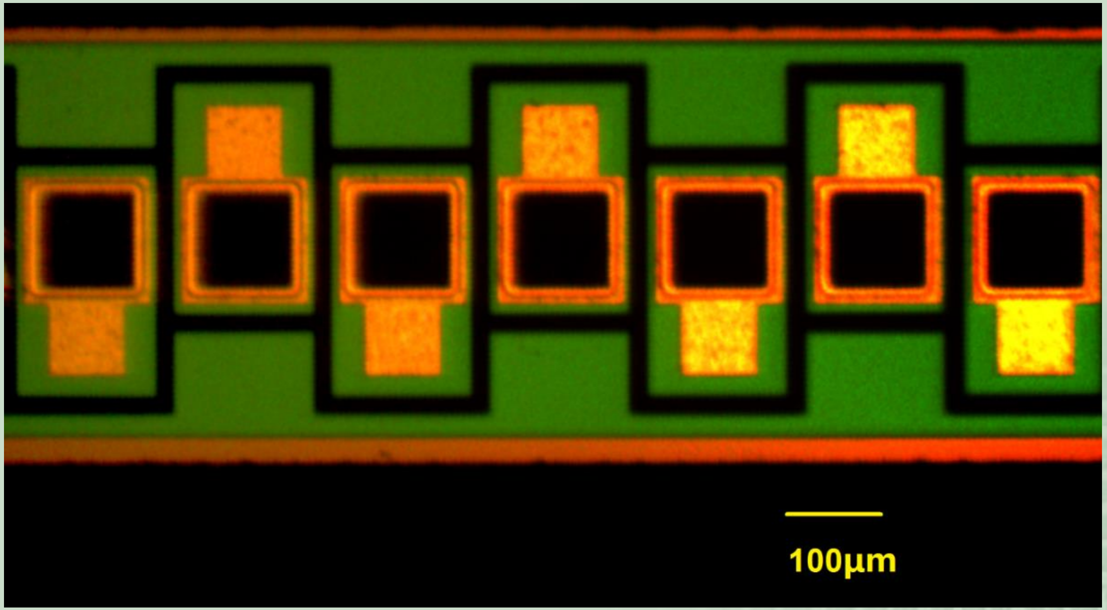




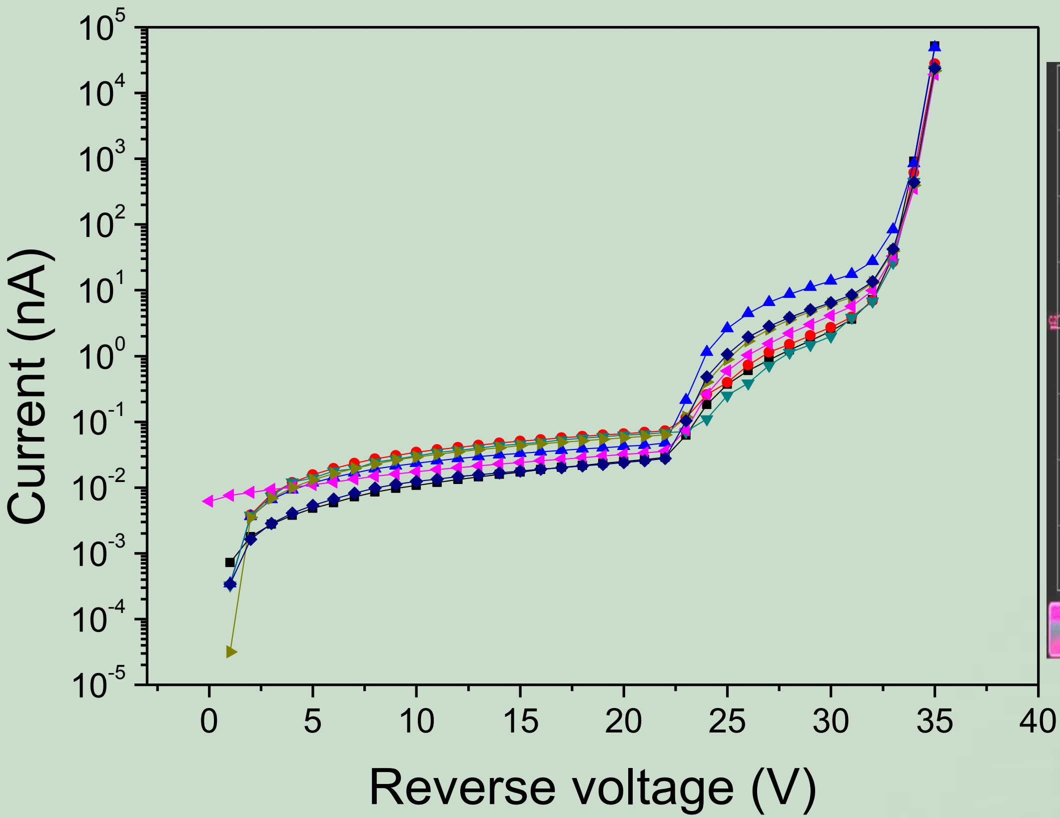


PDE=12.4%, recovery time=5.8ns, pitch≈≈10μm for NDL 2.2mm×2.2mm device with ≈44000 micro cells *(IEEE NSS 2013)*

Experiment and Results

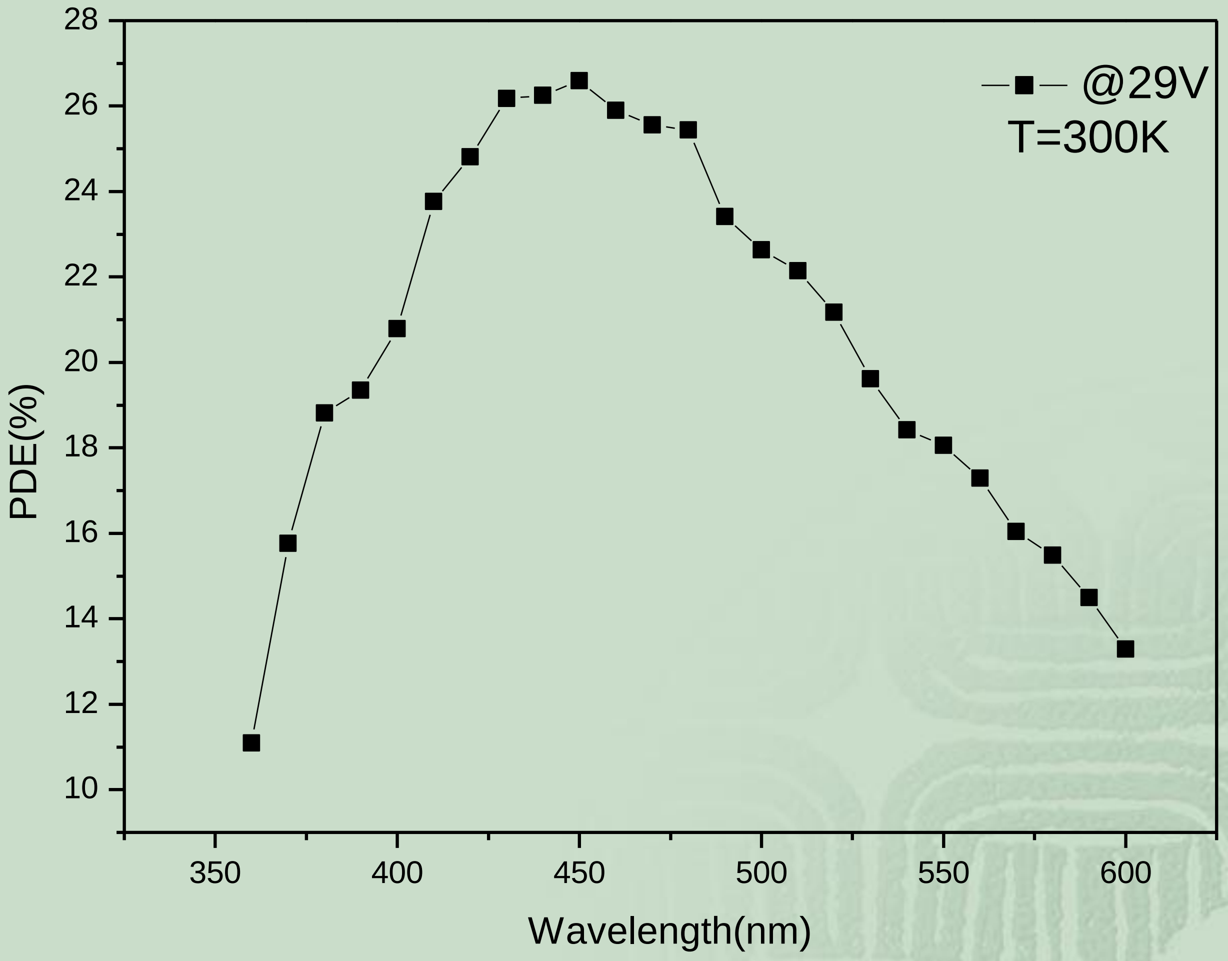


Micrograph of a 1×7 array of 120μm×120μm SiPMs, one element contains 120 micro cells, geometrical fill factor is 41%, pitch of micro cell is about 10 μm, pitch of element is 200μm.

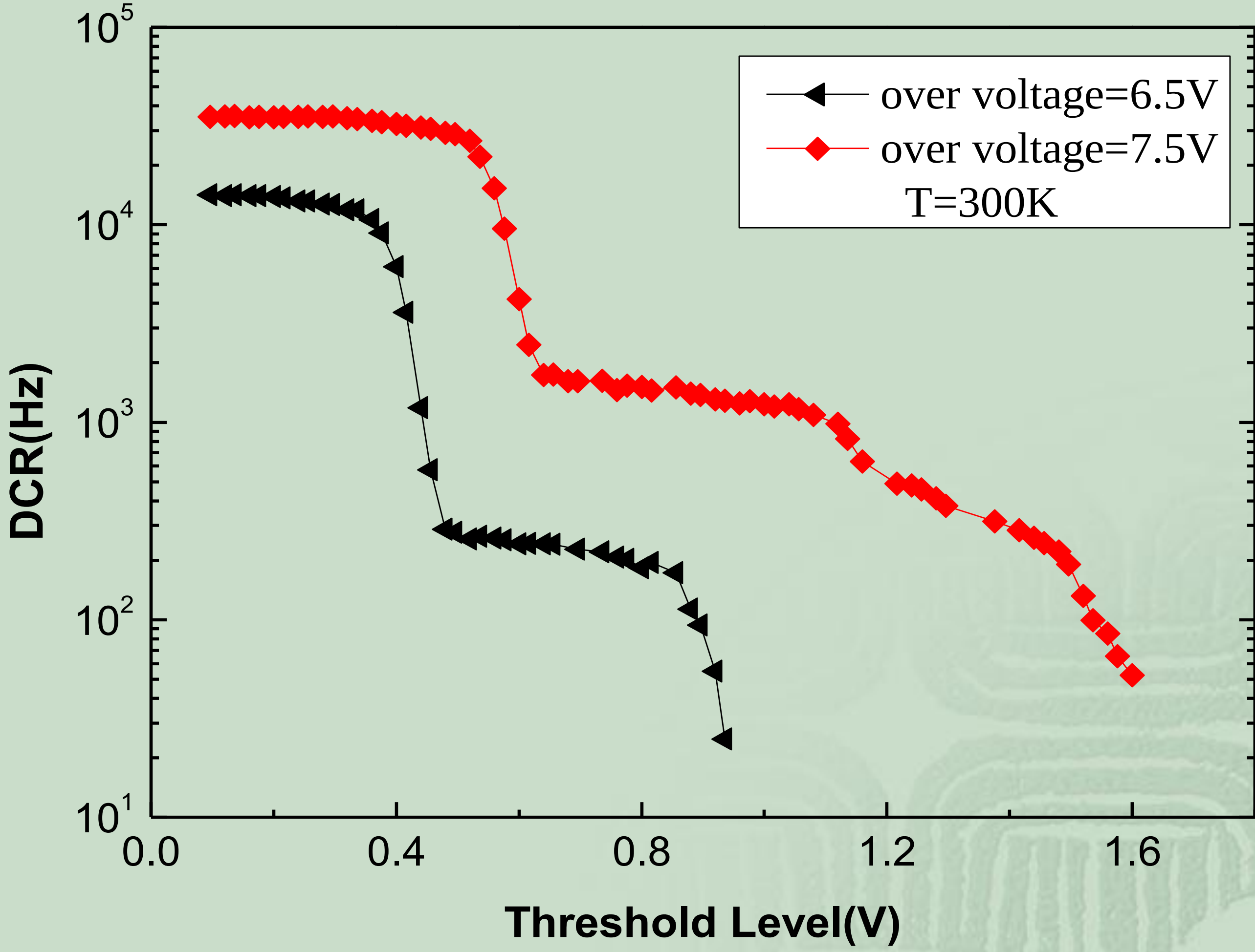


The I-V curve of the 7 element SiPMs at room temperature, all the breakdown voltages (V_b) are 22.9V.

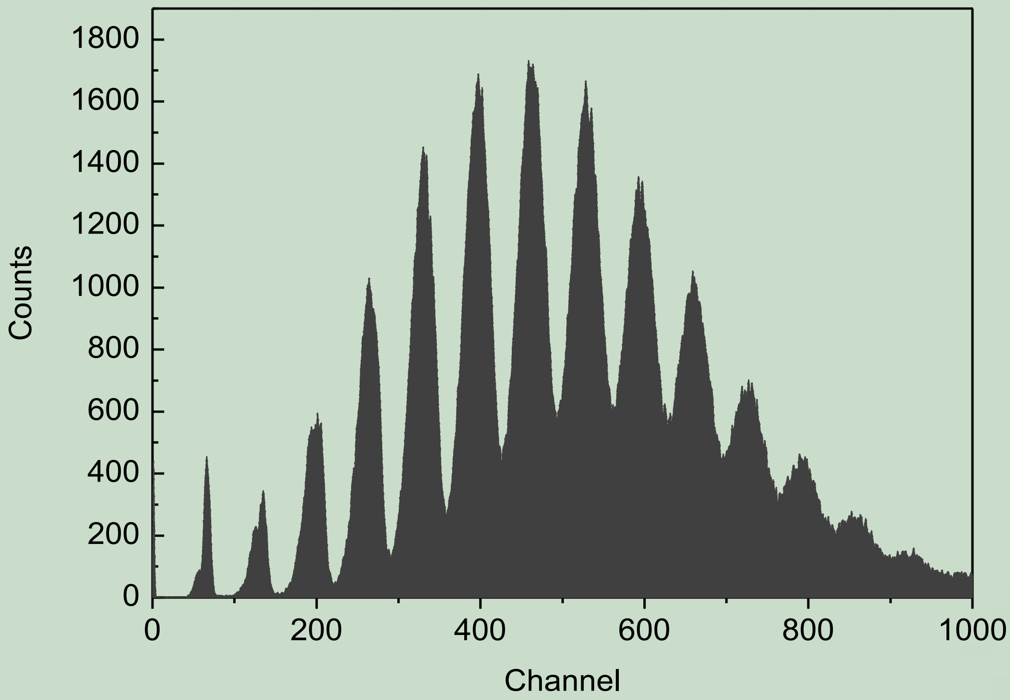
Dark pulse signal of one SiPM element. The FWHM of the pulse is about 3ns, dark count rate is 28.7kHz (@29V, with Preamplifier)



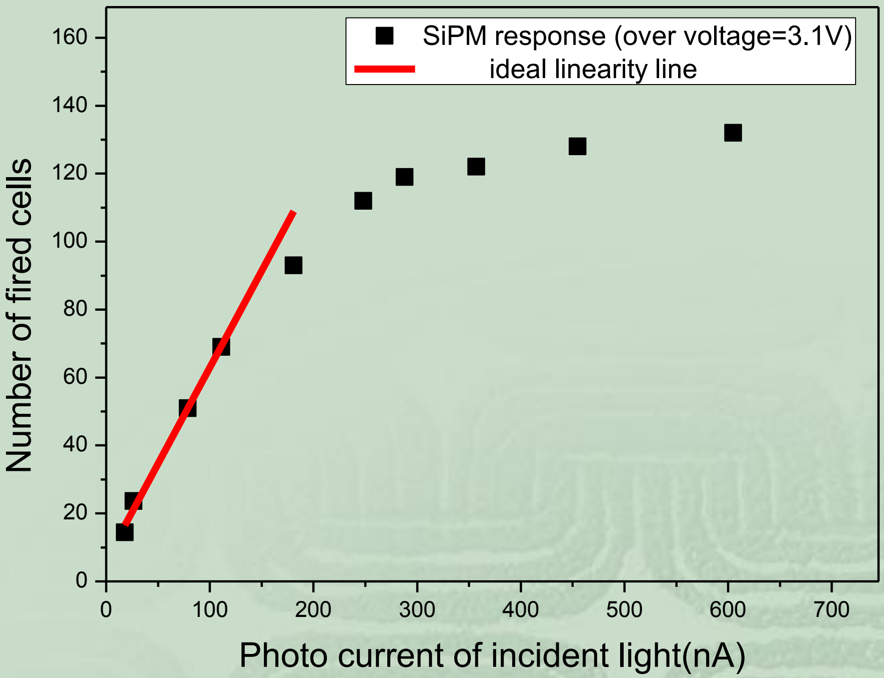
Photon detection efficiency of the 0.12mm SiPM element when operating at 29V and room temperature



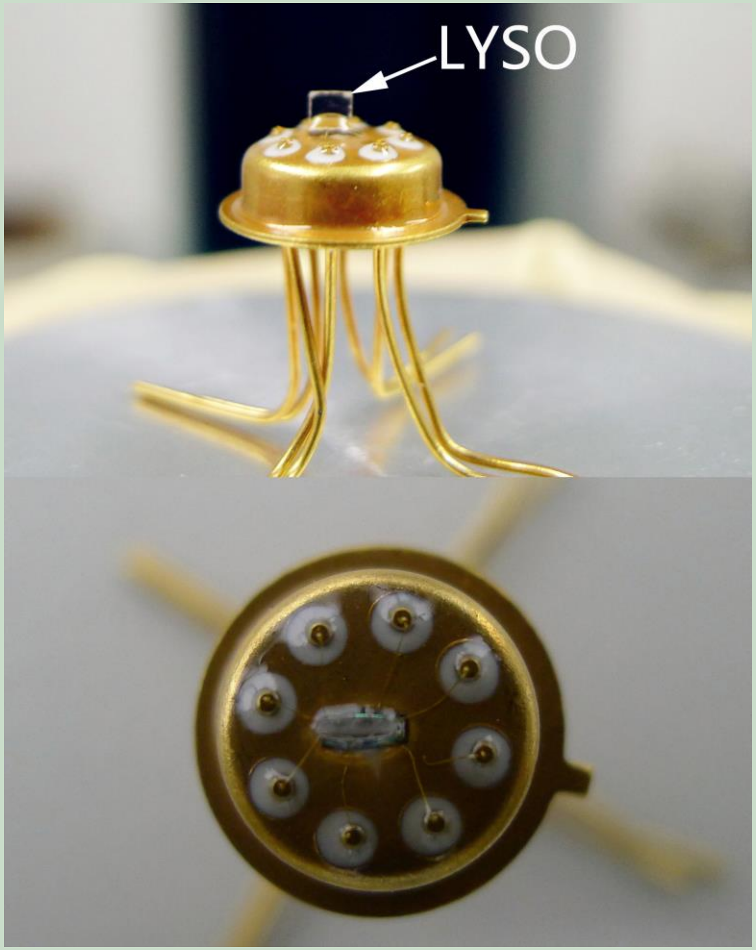
The dark count rate at different threshold levels. The cross talk is 2.0% at ΔV=6.5V and 4.1% at ΔV=7.5V

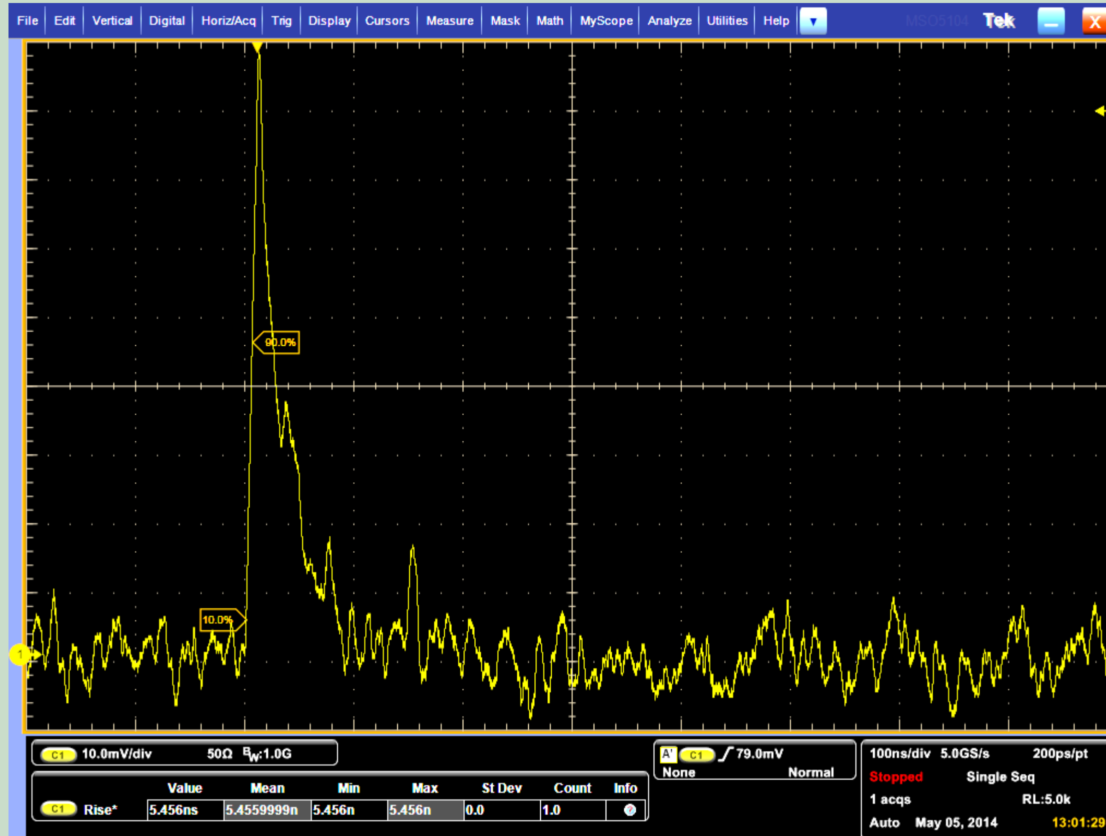


Pulse height distribution with pulsed LED illumination（λ=525nm，20ns FWHM，*f*=10 kHz）



Fired cell number versus photo current of incident light on a photodiode (Nd:YAG laser, 532nm, 7ns, 10kHz）



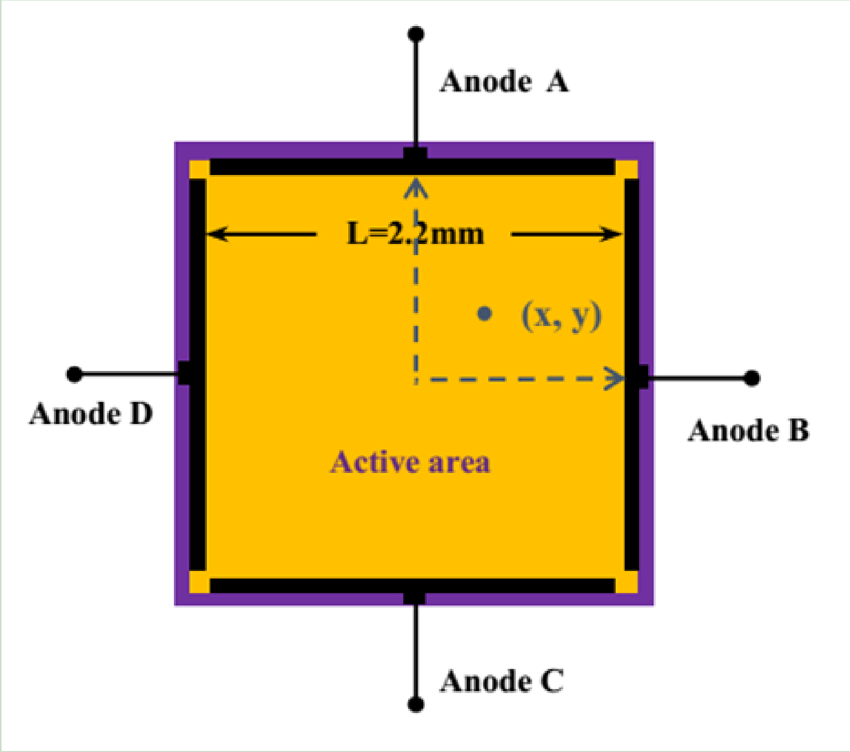


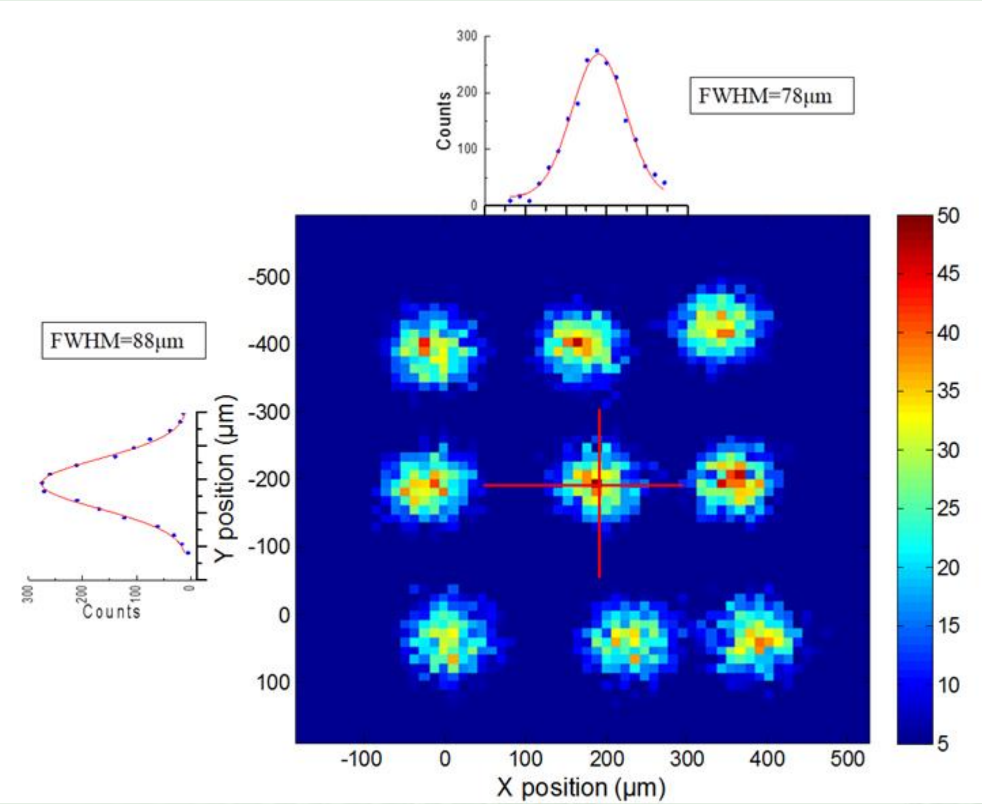
(up) Side view and (down) top view of a LYSO, 0.15mm (W)×1.6mm (L)×1.6mm (H) coupled to the 1×7 SiPMs array

Response to a 662 keV ^{137}Cs γ source for the LYSO/SiPM scintillation detector

How about Position Sensitive SiPM with Charge Division Mechanism?

- SiPM with bulk quenching resistor is easy to implement owing to the intrinsic continuous and uniform cap resistive layer
- However, limited to low flux, multiple photons





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Conclusion

- A SiPM line array, features an epitaxial bulk quenching resistor, was demonstrated with ultra-small elements of 0.12mm×0.12mm in active area, 0.2mm in pitch and 120 micro cells.
- Compared with PS-SiPM with charge division mechanism, it is a promising pixel position sensitive detector for simultaneous high space resolution and high flux, single or multiple photon detection.
- The main difficulty maybe the readout electronics since too many channels is needed as an imaging sensor. 1-D scanner as the case in CT is possible to alleviate this problem.

Thanks for Your Attentions!

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