9.8µm SPAD-based Analogue Single Photon Counting Pixel with Bias Controlled Sensitivity

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Neale Dutton, Lindsay Grant and Robert Henderson





CMOS SPAD Pixels 2

SPAD Only	SPAD + Minimal	1b Mem	Analogue	Digital
 SPAD SPAD + Passive Quench 	 Row and Col Select Column bus sharing 	 Time Gate 1b Memory A <i>"Jot"</i> 	 Time Gate Analogue Counter or TAC 	 Digital logic in pixel TDC or Digital Counters
Highest Fill Factor				Lowest Fill Factor
Least In- pixel Functionality	< <u> </u>			Most In-pixel Functionality



CMOS SPAD Pixels





[A] Richardson, J. et al. "A 32x32 50ps Resolution 10 bit Time to Digital Converter Array in 130nm CMOS for Time Correlated Imaging" 2009, CICC, Proc. Of,

[B] Webster et al. "A silicon photomultiplier with >30% detection efficiency from 450-750nm and 11.6µm pitch NMOS-only pixel with 21.6% fill factor in 130nm CMOS" Proc of ESSDERC, 2012

[C] Walker, R. et al. "High Fill Factor Digital Silicon Photomultiplier Structures in 130nm CMOS Imaging Technology" 2012, IEEE NSS, Proc. Of,

[D] Maruyama, Y. et al. " A Time-Gated 128X128 CMOS SPAD Array for On-Chip Fluorescence Detection" IISW 2011

Fabricated Test Array

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Pixel Schematic



Charge Transfer Amplifier Timing



CTA Operation





Pixel Characterisation

Column Output Voltage Histogram – Discretised Poisson Curve



Bias Controlled Sensitivity



Full Well Capacity 10





Pixel Response Non Uniformity 11



Input Referred Noise 12





Switched Current Source Mode 13



- CTA operated as a switched current source.
- This mode enables fast single photon detection.
- Zero, one, few photons .
- Time gated QIS pixel, *Fossum 2011 [11]*



Switched Current Source Mode 14





Switched Current Source Mode 15





Summary (1) 16





Summary (2) 17

- Two modes:
 - 'CTA' \rightarrow Analogue Counting
 - 'SCS' → 1b Memory
- Bias controlled sensitivity
- PRNU <2% for sensitivity range 5.5mV to 13.1mV/event
- Scalable pixel design with zero static bias current.







Thank You Questions?