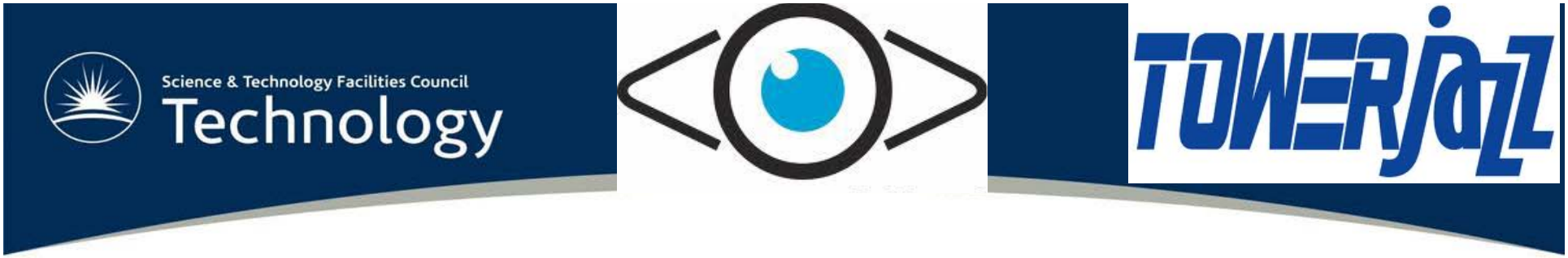


Ultra-high speed imaging at megaframes per second with a megapixel CMOS image sensor

J. Crooks, B. Marsh, R. Turchetta, *STFC-Rutherford* Appleton Laboratory, UK
K. Taylor, W. Chan, *Specialised Imaging, UK*
A. Lahav, A. Fenigstein, *TowerJazz Semiconductor Ltd, Israel*

Science & Technology Facilities Council
Technology

(Ultra)-High speed imaging. Applications

High-speed: 1k to 100kfps
Ultra-high speed: >~ 1M fps

- Combustion Research
- Biological/Microscopy
- Ballistics
- Mechanics
- Cavitation
- Material Research
- Aerospace
- Digital Image Correlation
- PIV

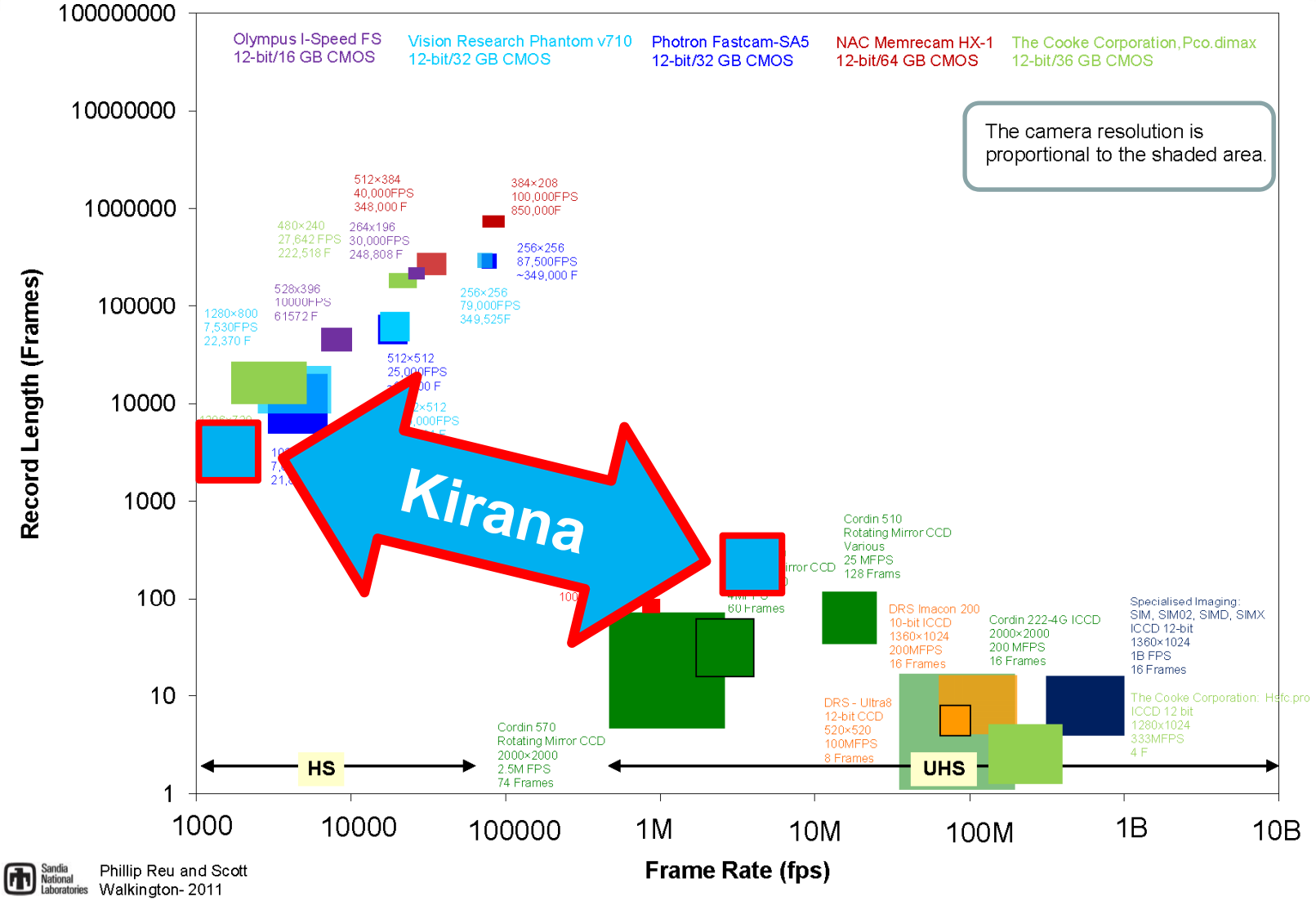
Science & Technology Facilities Council
Technology

Specifications drivers

- High resolution (~Megapixel)
- Ultra-high speed (>1MHz) with high frame depth (~200 cells)
- High-speed (~kfps) for continuous readout
- 10 bit resolution
- Flexible trigger (pre/post/center)
- 35mm format

Science & Technology Facilities Council
Technology

(Ultra)-High speed imaging review



Sandia National Laboratories

Phillip Reu and Scott Walkington- 2011

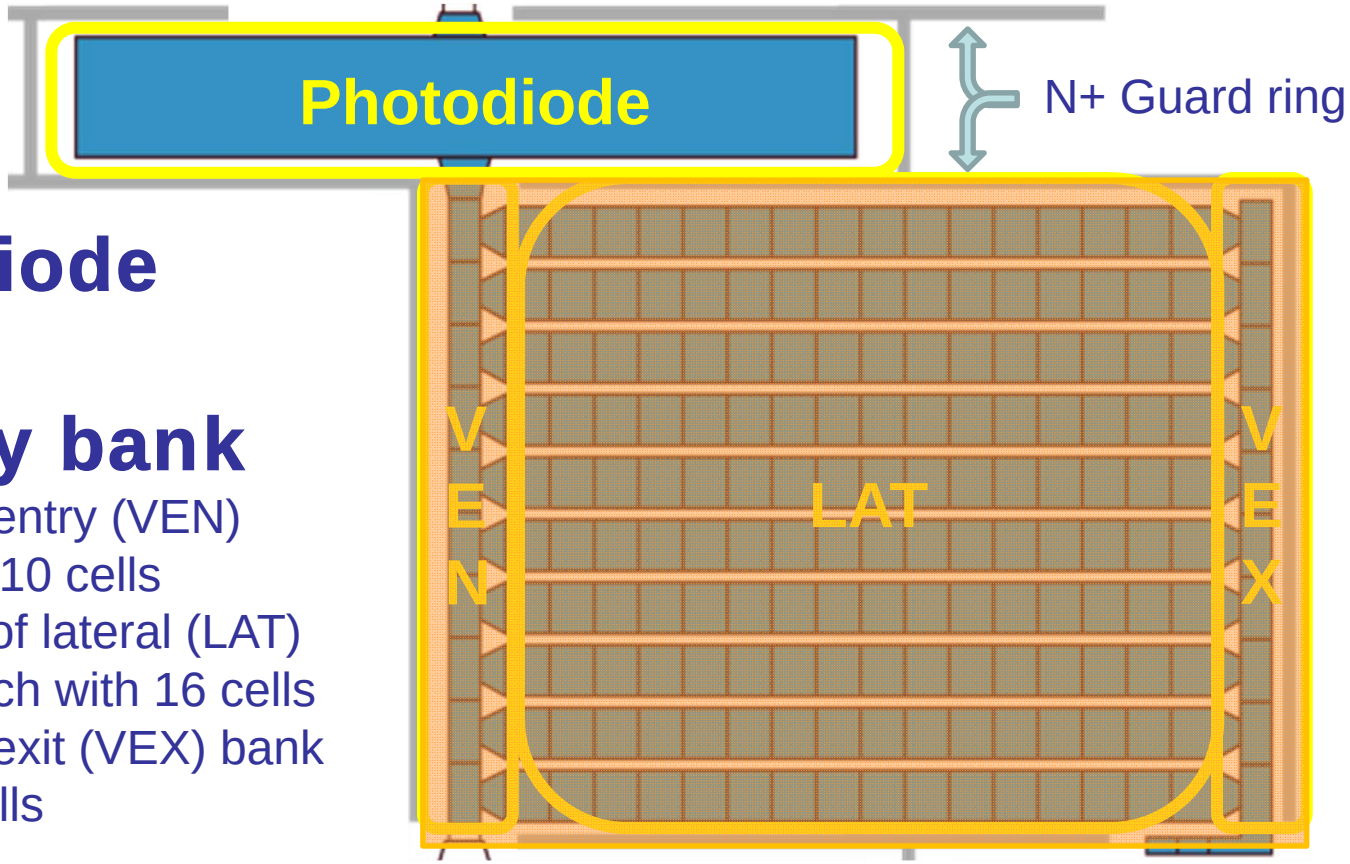
Science & Technology Facilities Council
Technology

Kirana pixel. 1

Photodiode

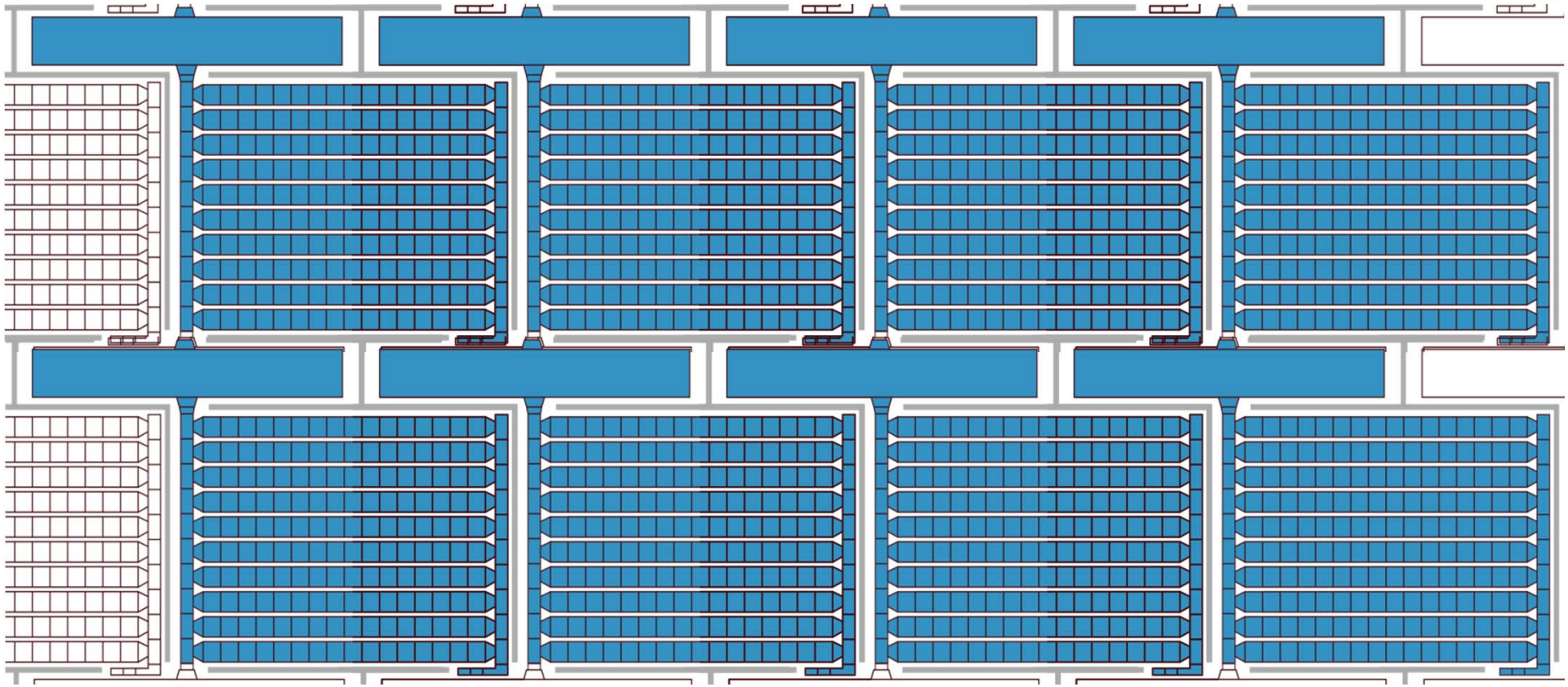
Memory bank

- A vertical entry (VEN) bank with 10 cells
- Ten rows of lateral (LAT) banks, each with 16 cells
- A vertical exit (VEX) bank with 10 cells



Science & Technology Facilities Council
Technology

Kirana pixel. 2

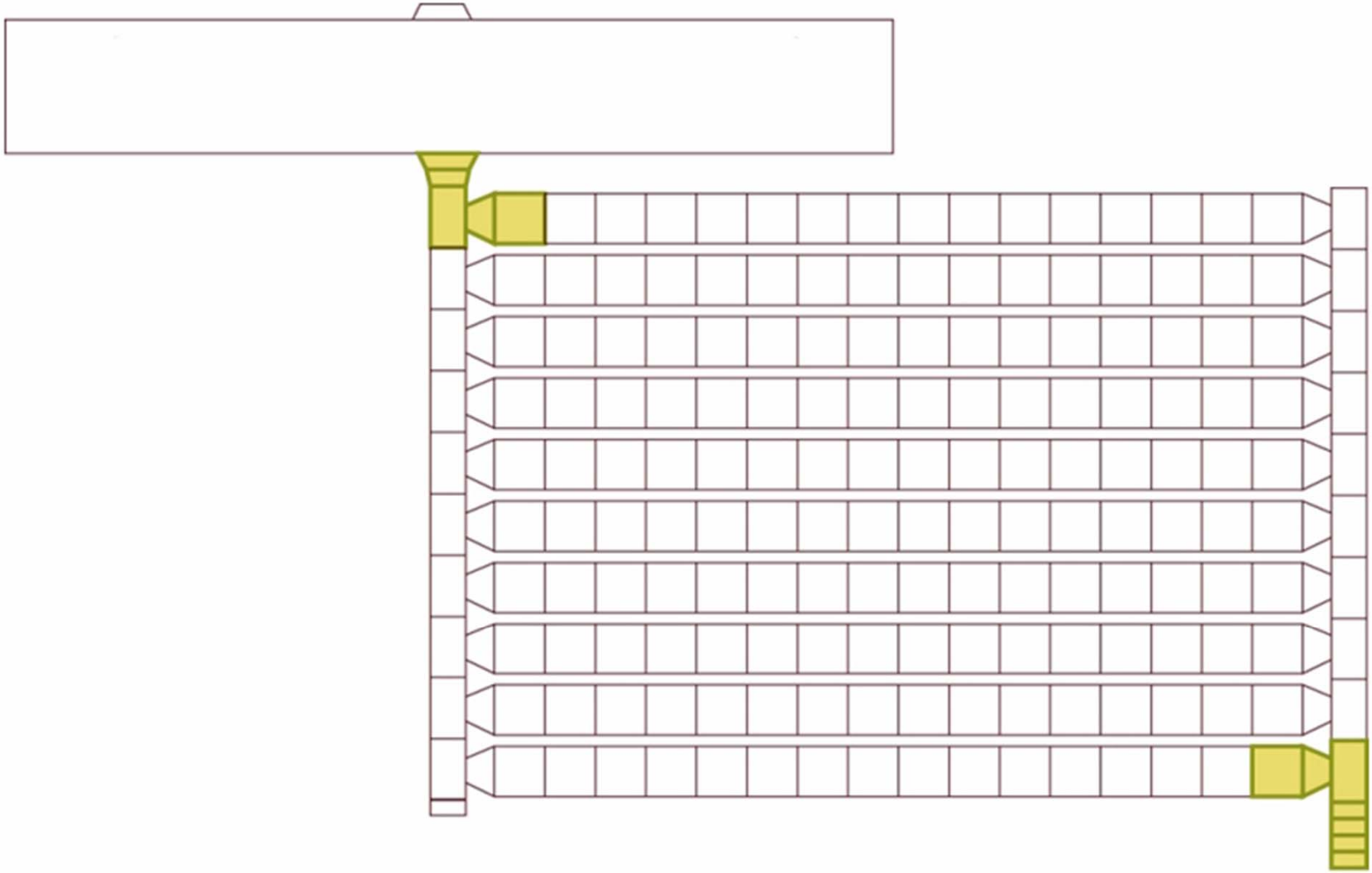


Highly scalable architecture:

- **Number of memory cells**
- **Number of pixels**

Science & Technology Facilities Council
Technology

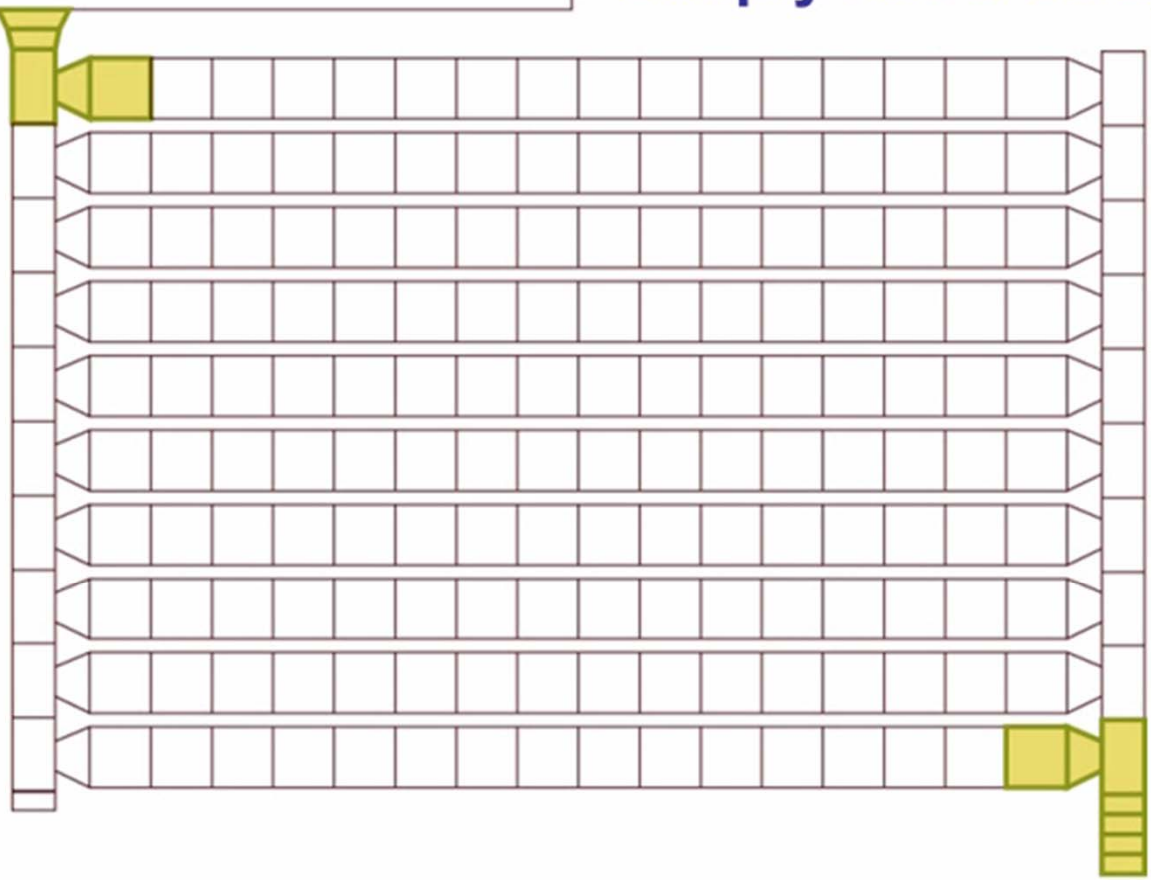
Kirana. Burst mode



Science & Technology Facilities Council
Technology

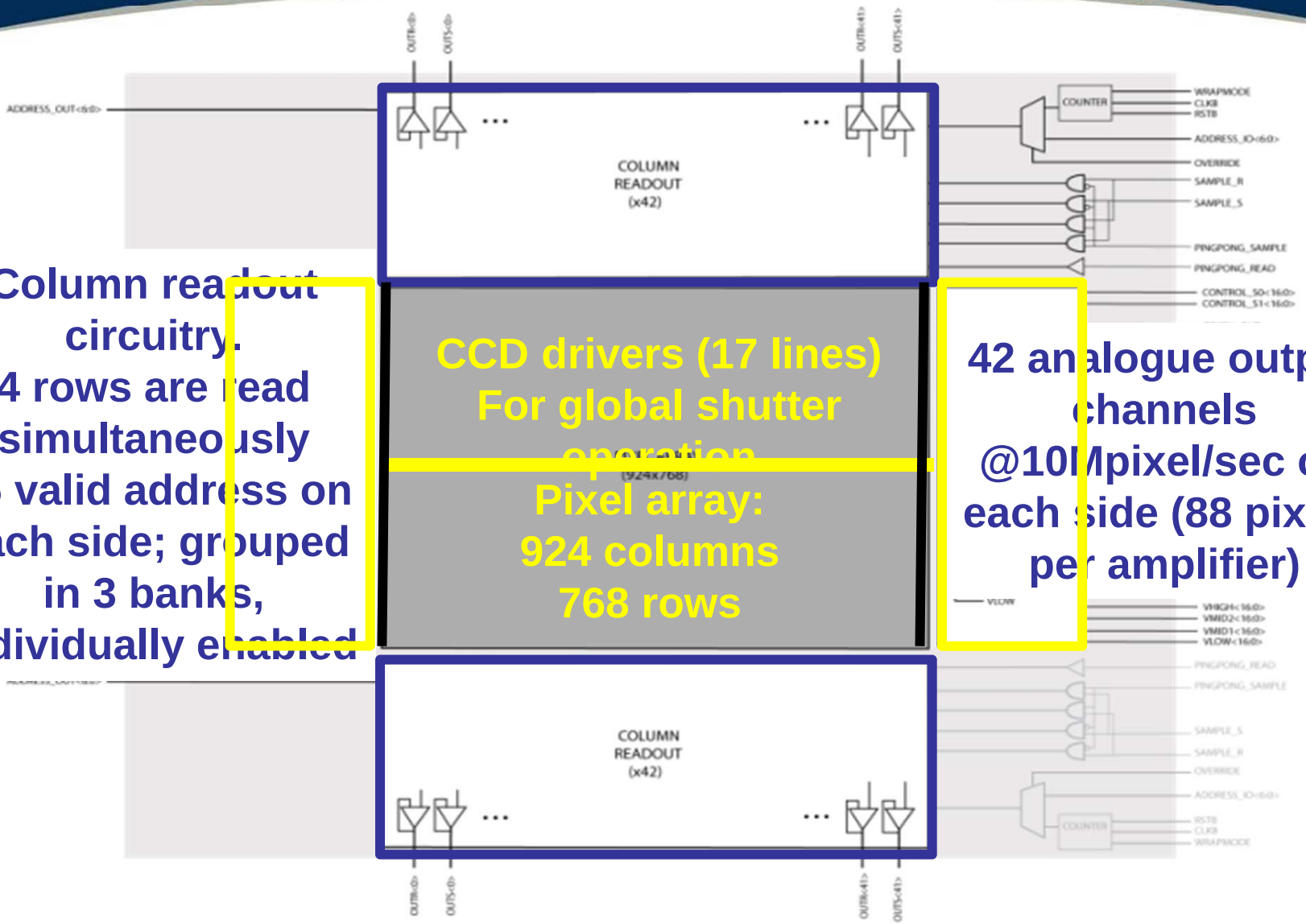
Kirana. Continuous mode

Memory bank acting simply like a delay line



Science & Technology Facilities Council
Technology

Sensor floorplan

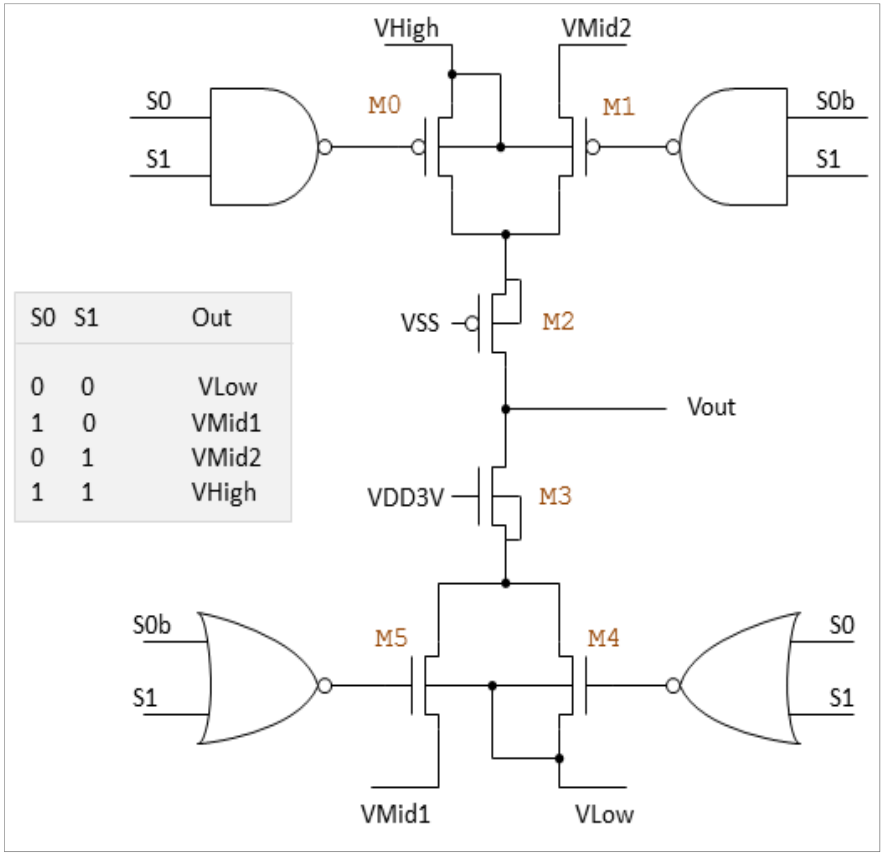


Column readout circuitry.
4 rows are read simultaneously
96 valid address on each side; grouped in 3 banks, individually enabled

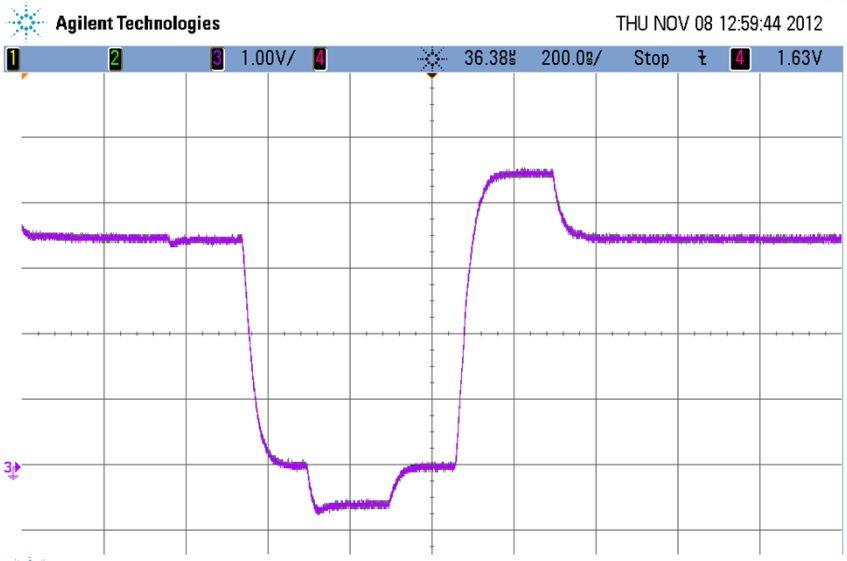
42 analogue output channels @10Mpixel/sec on each side (88 pixels per amplifier)

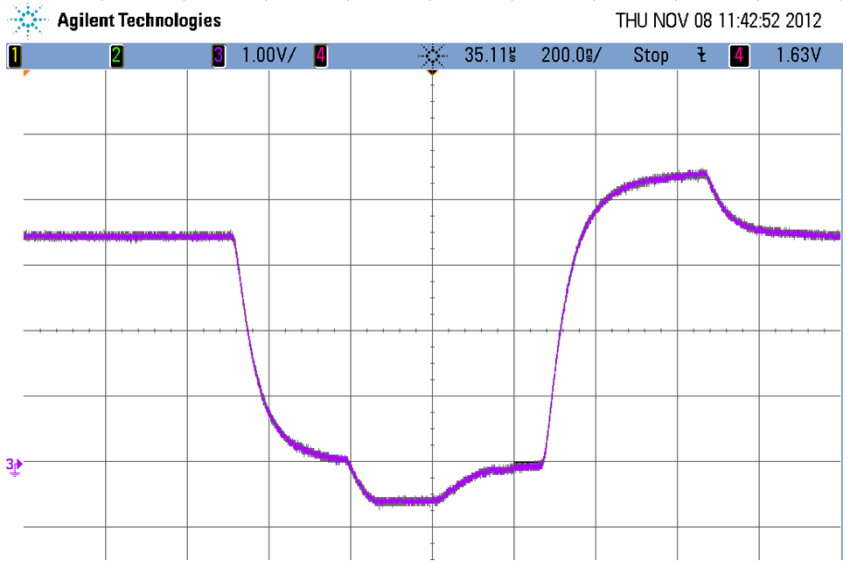
Science & Technology Facilities Council
Technology

CCD drivers



S0	S1	Out
0	0	VLow
1	0	VMid1
0	1	VMid2
1	1	VHigh

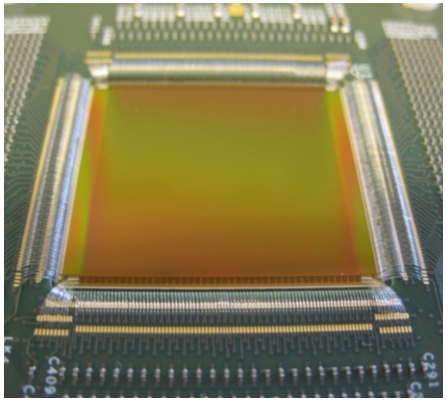




Science & Technology Facilities Council
Technology

Performance summary

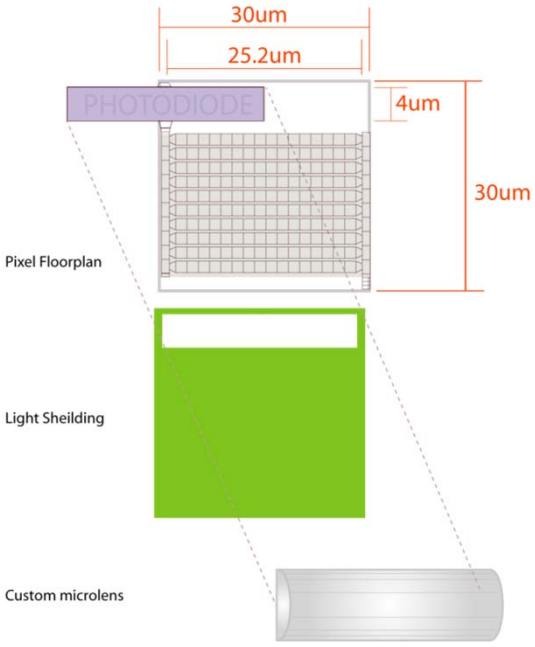
Parameter	Unit	Value
Pixel pitch (X)	um	30
Pixel pitch (Y)	um	30
Pixel format (X)		924
Pixel format (Y)		768
Number of pixels		709,632
Frame rate (burst mode)	fps	5,000,000
Frame rate (continuous mode)	fps	1,180
Pixel rate (burst mode)	Pixel/sec	3.5 T
Pixel rate (continuous mode)	Pixel/sec	0.84 G
Noise	e- rms	<10 e- rms
Full well capacity	e-	11,700
Camera gain	µV/e-	80
Dynamic range		>1,170
	dB	61.4
	bit	10.2
Fill Factor		11%

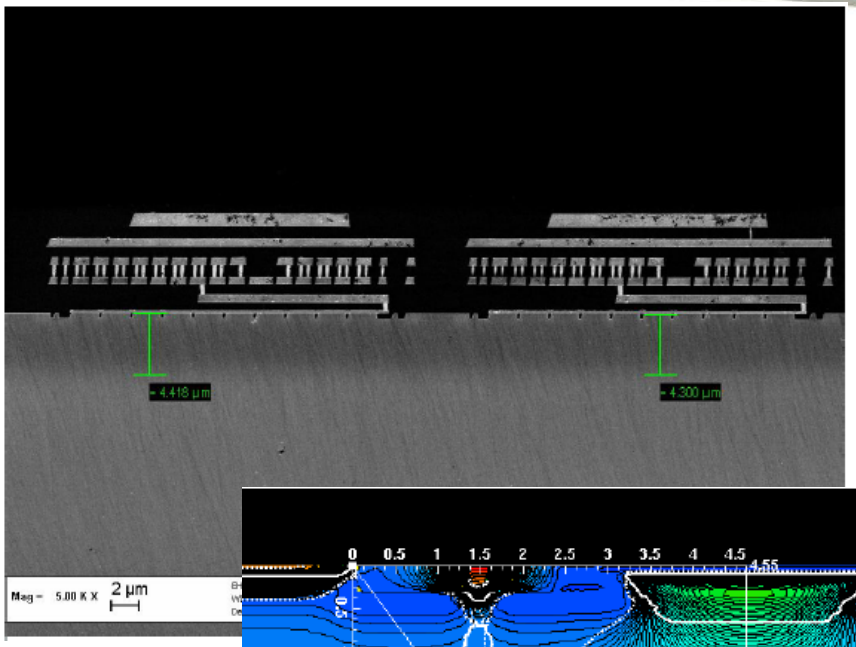


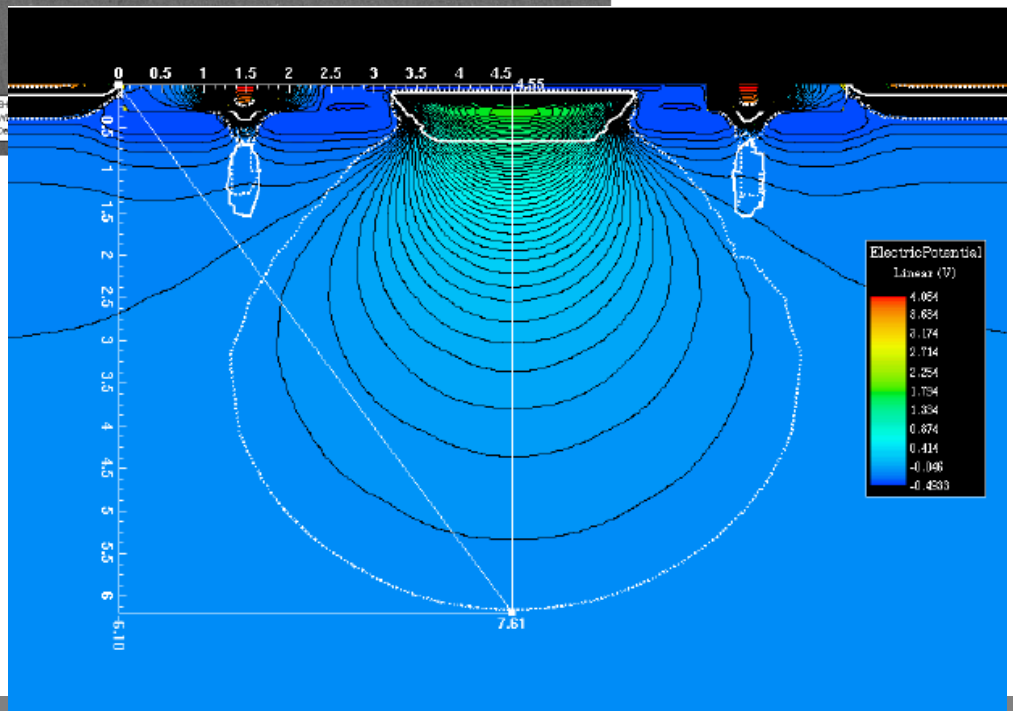
Manufactured on standard epi: 5.5 µm thickness, low resistivity

Science & Technology Facilities Council
Technology

Next steps







Science & Technology Facilities Council
Technology

Conclusions

0.7 Mpixel sensor; 30 µm pixel

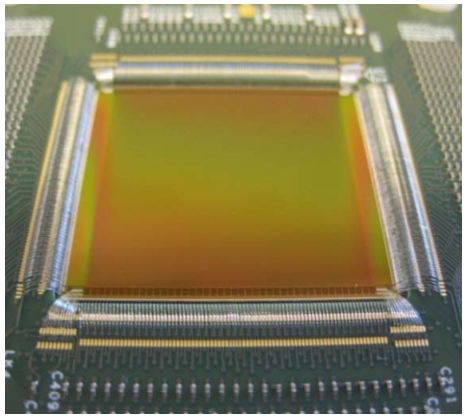
Combined high and ultra-high speed operation

Burst mode at 5Mfps with 180 memory cells → 3.5 Tpixel/sec

Continuous mode at over 1kfps

10 bit dynamic range

Next steps:
- High-res wafers
- Improved guard-ring
- Improved deep P-implant
- Optimised microlenses



Questions?

Acknowledgements:

This work was partly funded by STFC grant ST/J000760/1 and by

STFC Innovation Limited Proof of Concept funding