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Monolithic Active Pixel Sensors: designs for science at CCLRC

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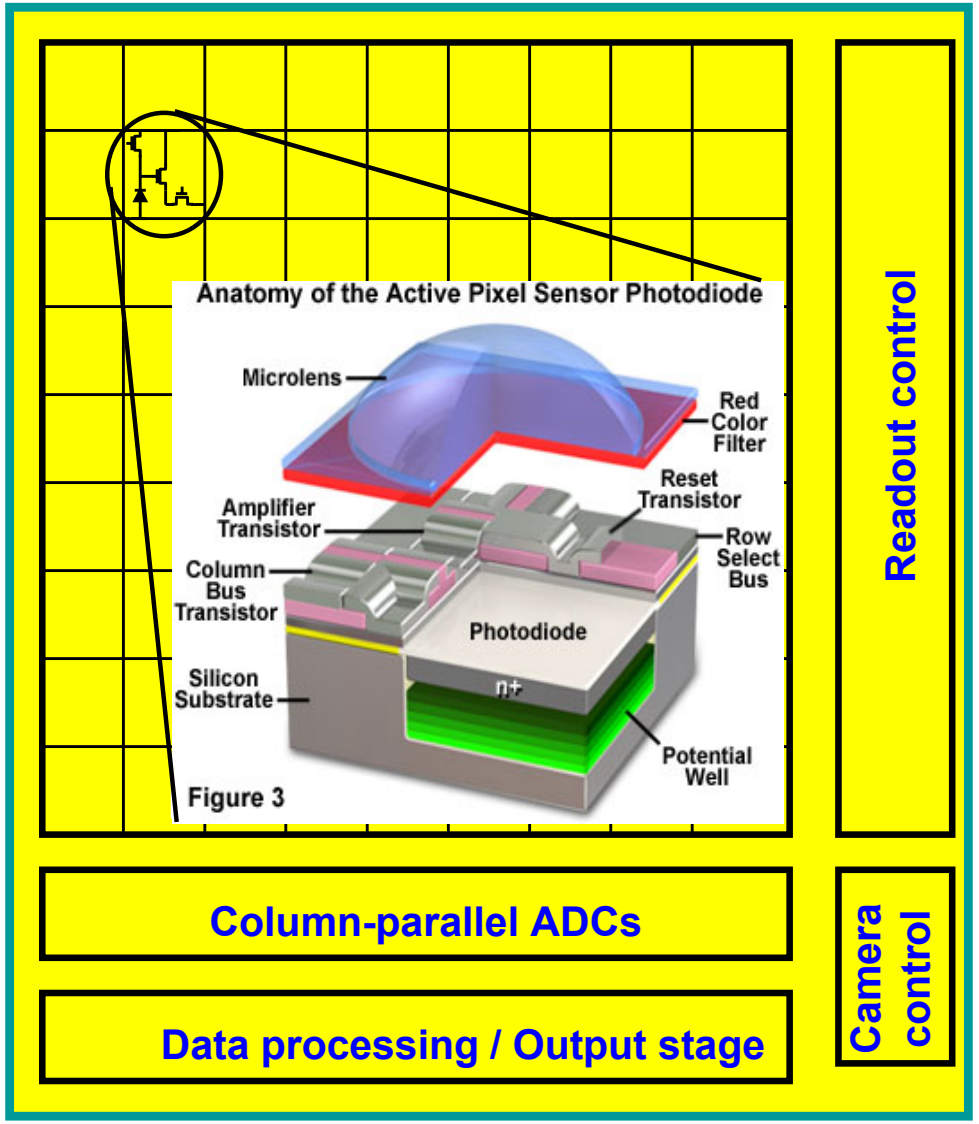
The advantages of CMOS Monolithic Active Pixel Sensors

- Function integration.
- Flexibility.
- Compactness.
- Ease of use for end-users.
- Random access.
- Power consumption.
- Readout speed.
- Radiation tolerance.



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CMOS Monolithic Active Pixel Sensors at RAL.

A brief history

1999 Design of first test structures in 0.5 and 0.7 μm CMOS.

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Established collaboration with E2V (Formerly Marconi and EEV).

2001 Fabrication of 512 x 512 camera-on-a-chip sensor.
Fabrication of test structure for particle detection in 0.25 μm CMOS.

2002 Design of 12M-pixel APS, 4k linear APS, parametric test sensor (Flexible APS) in 0.25 μm CMOS.

2003 Manufacturing of 12M-pixel APS, 4k Linear APS, parametric test sensor (Flexible APS) in 0.25 μm CMOS.

2004 Rad-hard parametric test sensor in 0.25 μm CMOS

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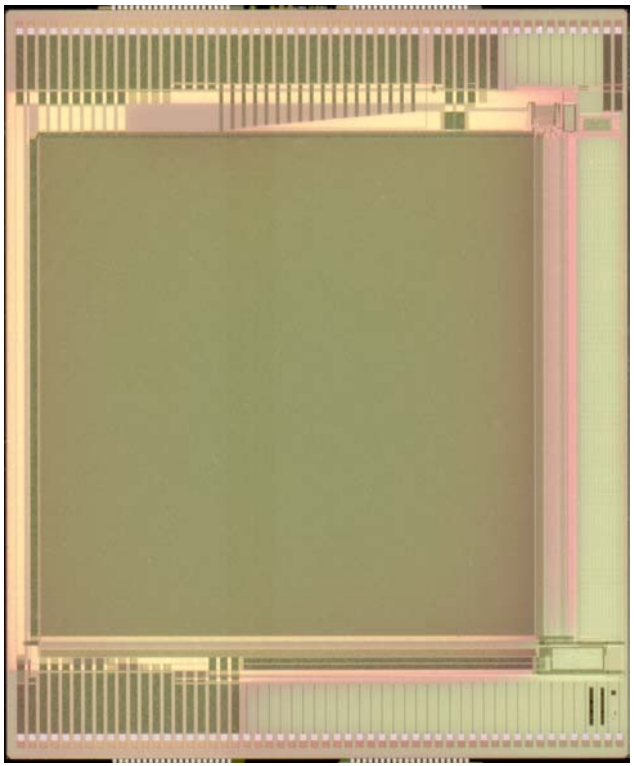
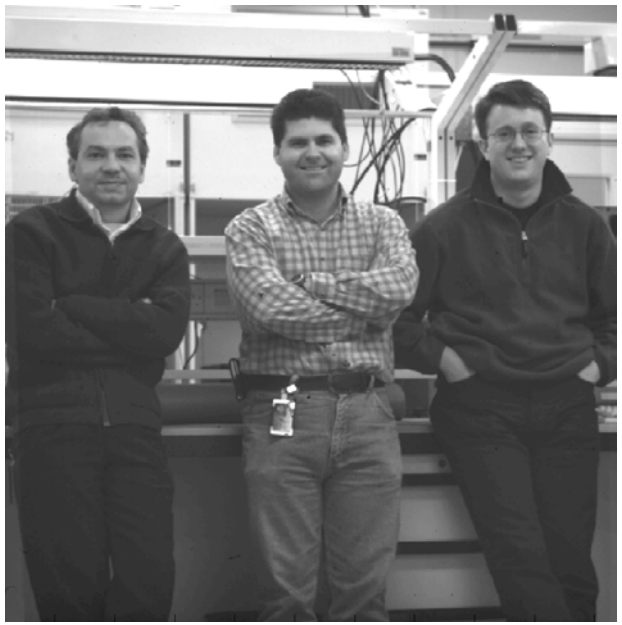
A 512 x 512 camera-on-a-chip

Designed in a 0.5μm CMOS.

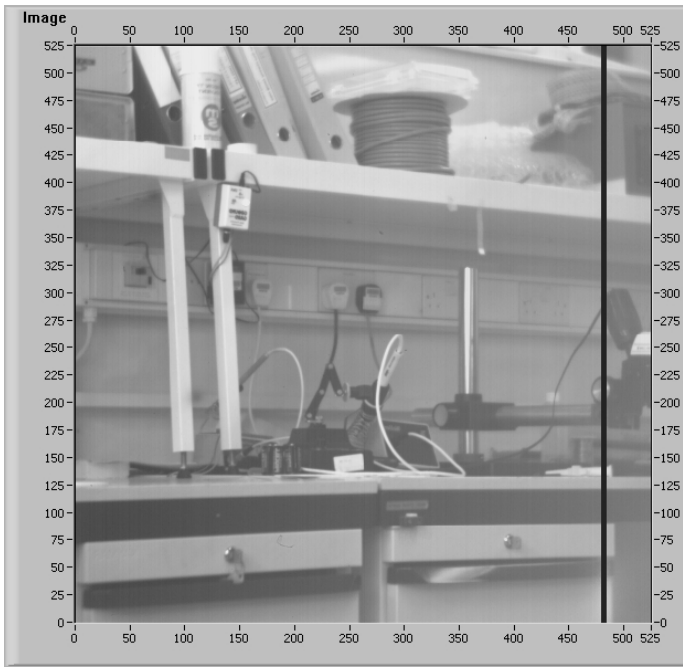
Originally for a Star-Tracker application.
It has been evaluated in many other applications including detection of UV and of low (5 keV) energy electrons.



Photograph of the sensor



Snapshot taken with a front-illuminated sensor



Snapshot taken with a back-illuminated sensor

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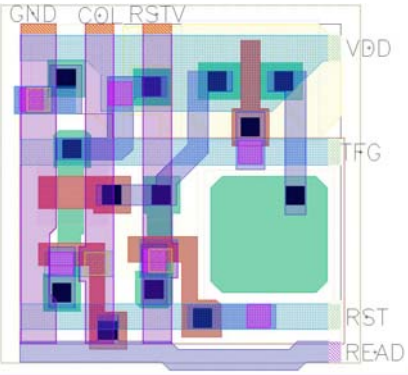
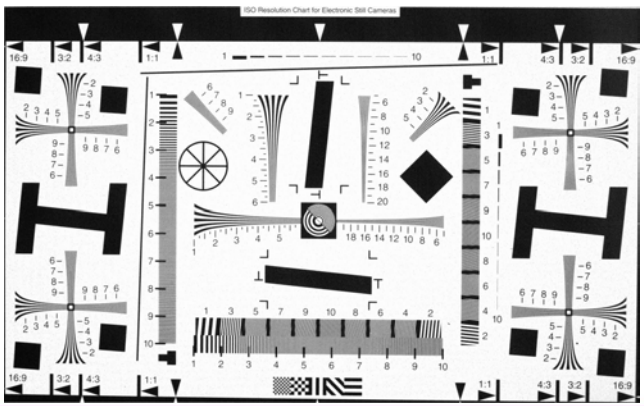
12-Megapixel Sensor

0.25μm CMOS.

Specifically designed for Solar Orbiter (an ESA mission) aimed at observing the Sun in the EUV band.

Each pixel is 5μm in size and consists of one diode and 4 transistors to permit Correlated Double Sampling.





4,096 by 2,880 array of 5μm pixels

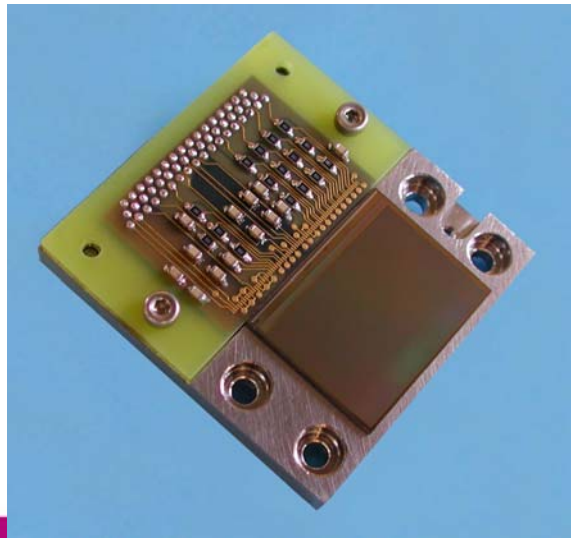
Science grade noise and dynamic range requirements

3.3V Operation

Readout speed: 1 Msamples/s

Differential analogue output

Optimised for optical wavelengths and thinning (for back illumination)



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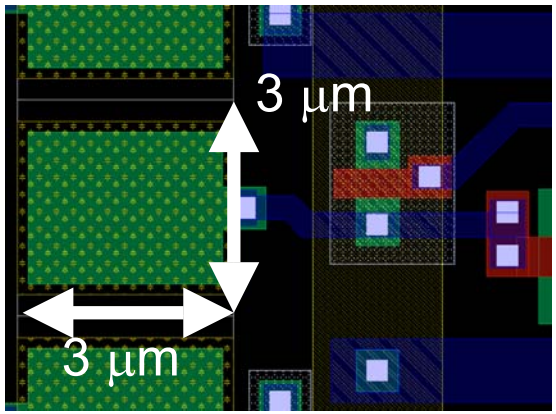
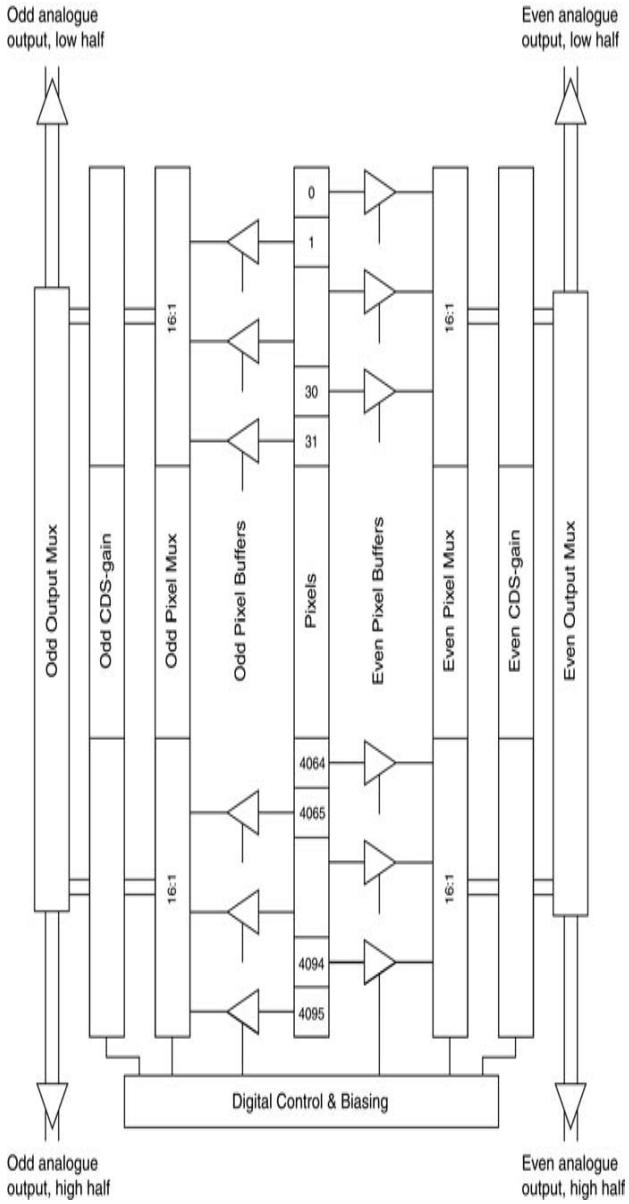
4,096-pixel Linear Sensor

0.25μm CMOS.

This prototype device demonstrates the use of APS in ultra fine resolution linear imaging.

In this case the pixel pitch of 3μm will allow a compact Earth observation camera systems to achieve a ground resolution of 1 meter.





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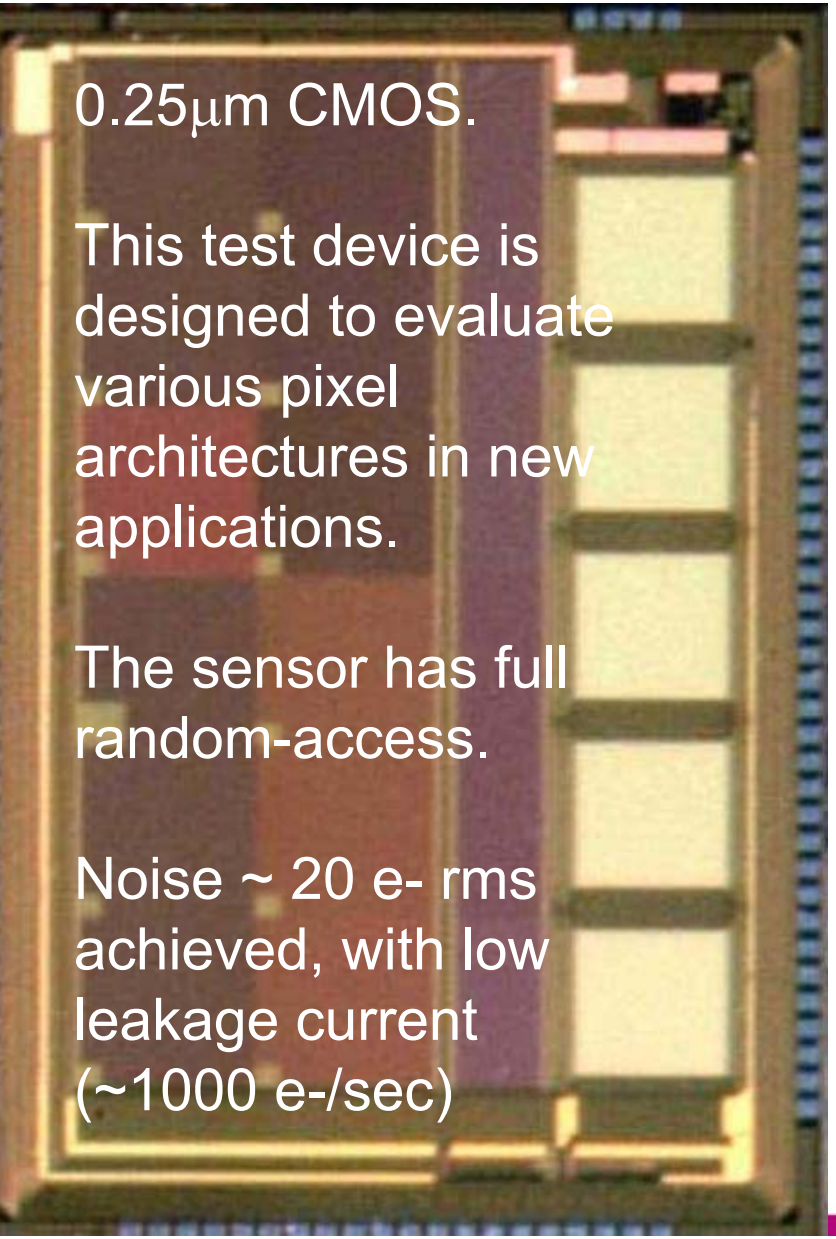
A Random Access Low-Noise Parametric Test Sensor



0.25μm CMOS.

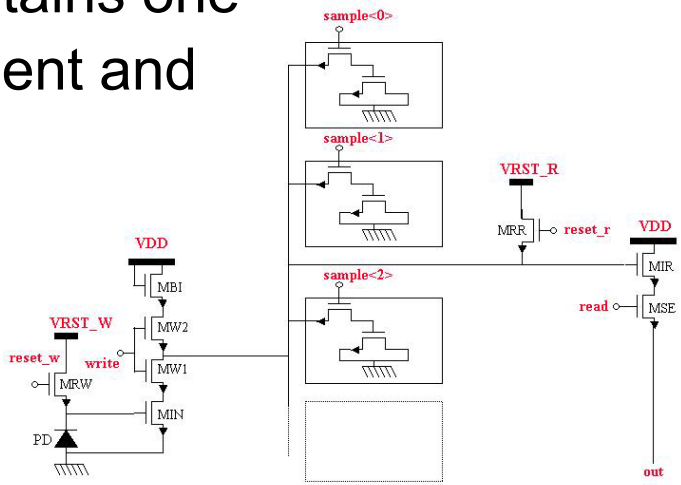
This test device is designed to evaluate various pixel architectures in new applications.

The sensor has full random-access.

Noise ~ 20 e- rms achieved, with low leakage current (~1000 e-/sec)

The most complex architecture is the Flexible Active Pixel Sensor (FAPS). Its driving requirement is the vertex detector for the future Linear Collider in Particle Physics.

In the FAPS pixels, ten frames can be recorded at over 1 MHz sampling rate. Each pixel contains one detection element and 28 transistors.



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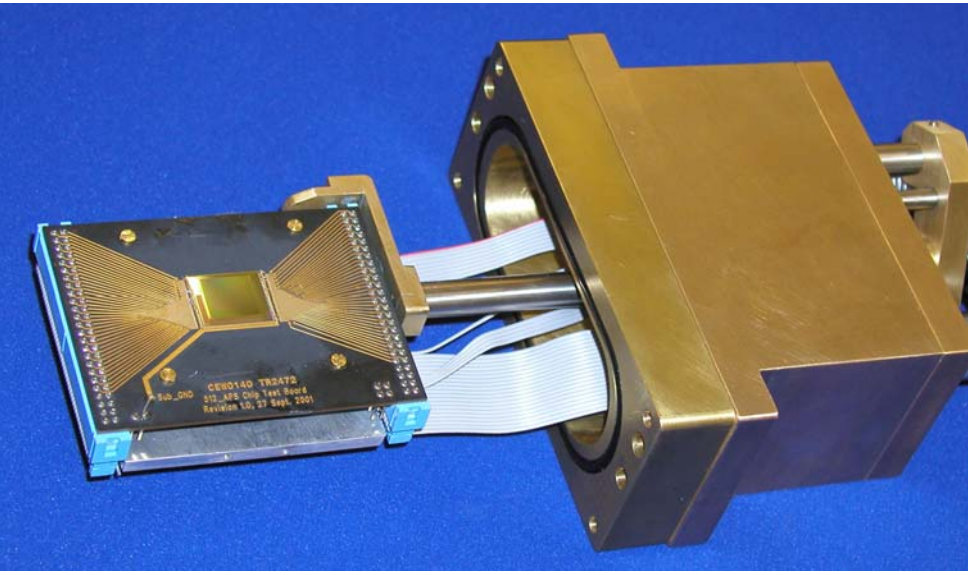
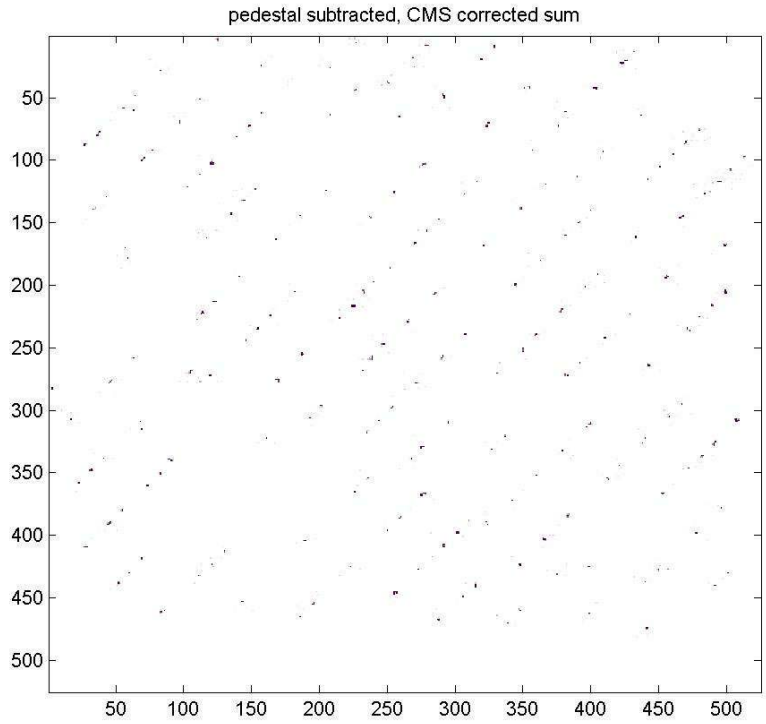
Electron detection

Collaboration with the MRC-Laboratory of Molecular Biology, Cambridge, and support from CASE fellowship with University of Liverpool.

Demonstrator tests with the 512x512 camera-on-a-chip.



Raster scan with 120 keV electrons



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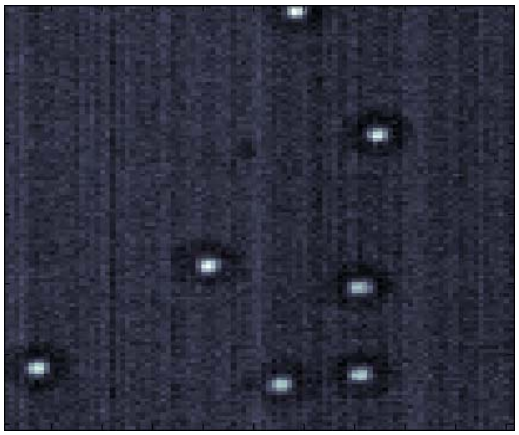
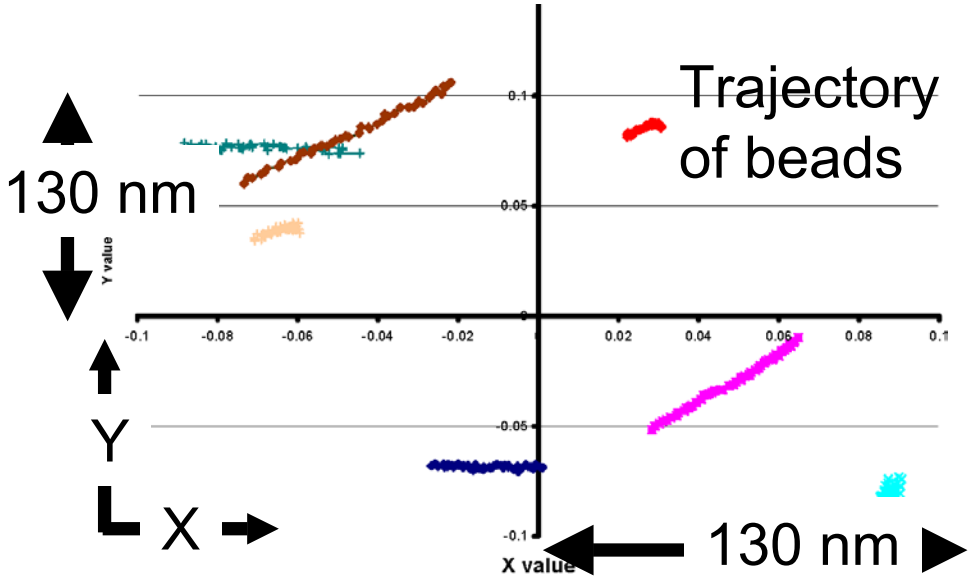
Bio-medical application

Tracking of beads in an optical tweezers experiment

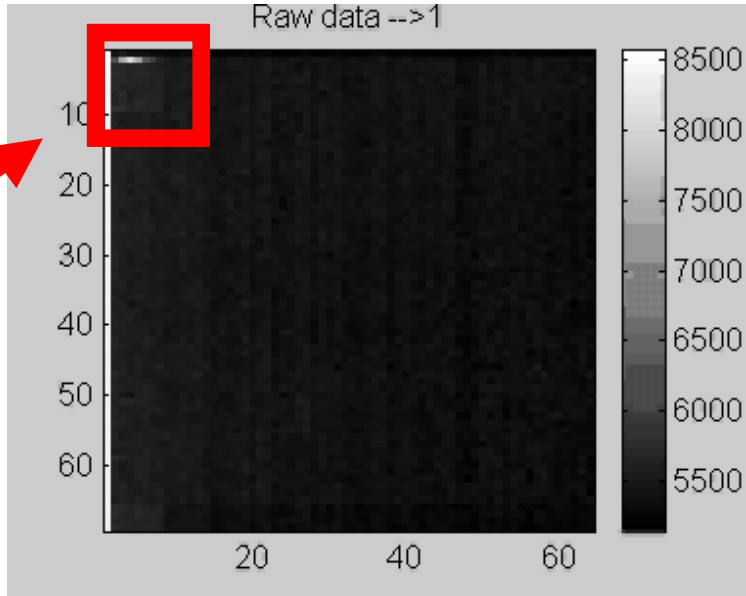




Very preliminary measurement of spatial resolution <~ 1 nm
(State of the art ~ a few nm)

'Imaging' individual neuron activity by sensing the action potential

Detection of voltage pulse in a 'blind' APS



Conclusions

- CMOS Monolithic Active Pixel Sensors in RAL: first design in 1999 for the detection of visible light for a Space Science application
- Followed by designs for charged particle detection in particle physics
- Demonstrated detection of UV, low-medium energy electrons, …
- Opening new horizons for imaging in bio-medical applications
- Complete list of contributions/collaborations in the posters (and more details on design/applications)

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