e2v CCD and CMOS sensors and systems designed for astronomical applications

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e2v

SPIE, Edinburgh, 26 June 2016, Conf. 9915-3

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Contents-1

An update of recent sensors and systems

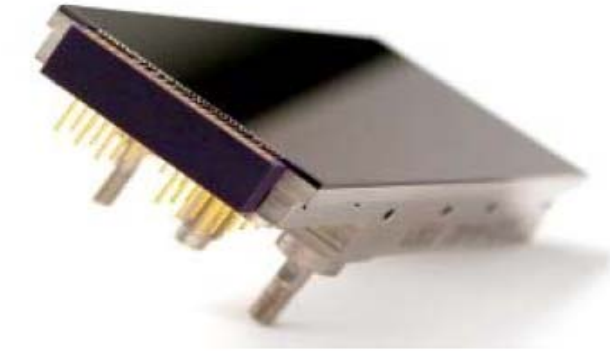
e2v designs and manufactures an increasing suite of CMOS imagers for high performance use

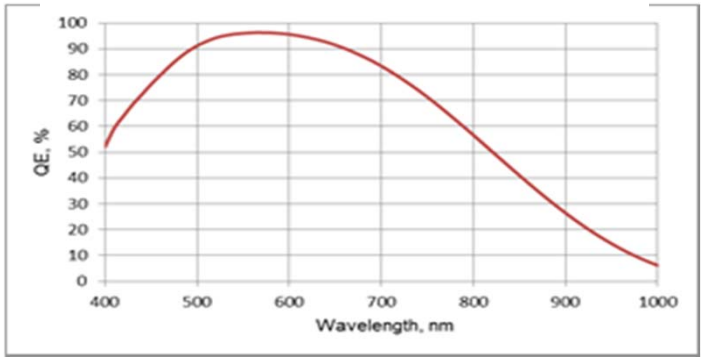
CMOS detectors-1

CIS113 (Vega)

Developed for the TAOS-II project.

Development complete; production of 40-off in progress





Paper by Jérôme Pratlong, 9915, Tues am, S8

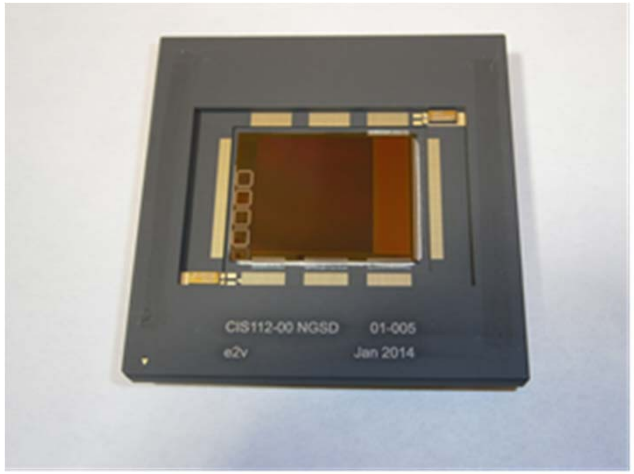
Number of pixels	**1920 (H) × 4608 (V)**
Pixel size	16.0 µm square
Image area	73.73m × 30.72 mm
Output ports	8 (REF and SIG each)
Package size	82.39 mm × 31.7 mm
Package format	76 pin ceramic PGA attached to invar block
Focal plane height	14.0 mm
Flatness	< 30 µm (peak - valley)
Conversion gain	75 µV/e^-
Readout noise	3 e^- at 2 MP/s per ch.
Maximum pixel rate	2 MP/s per channel
Maximum charge	22,000 e^- per pixel
Dark signal	70 e^-/pixel/s (at 21 °C)
Frame rate	2 fps (full frame mode) 20 fps (multiple ROI's)

CMOS detectors-2

CIS112 (NGSD)

Developed for Adaptive Optics on large telescopes.

- **High frame rate and very low noise**
- **Backthinned and red sensitive**
- **Precursor of 1600 X 1600 sensor**



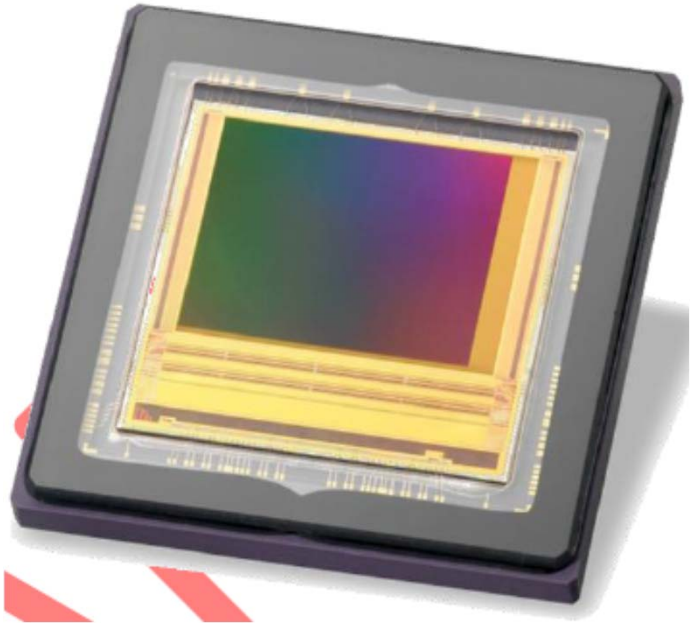
Number of pixels	**880 X 840**
Pixel size	24.0 µm square
Image area	21.12 mm × 20.16 mm
Output	Digital; multiple parallel ADCs
Package format	Ceramic PGA
Readout noise	< 3 e^-
Variants	> 85% at 589 nm
Maximum charge per pixel	4,000 e^-
Frame rate	> 700 fps

See paper by Mark Downing, 9915, Tues am, S8

CMOS detectors-3

Onyx EV76C664

- Standard product with low noise
- Fully digital sensor with multiple modes
- Frontside illuminated with micro-lens



Key Features

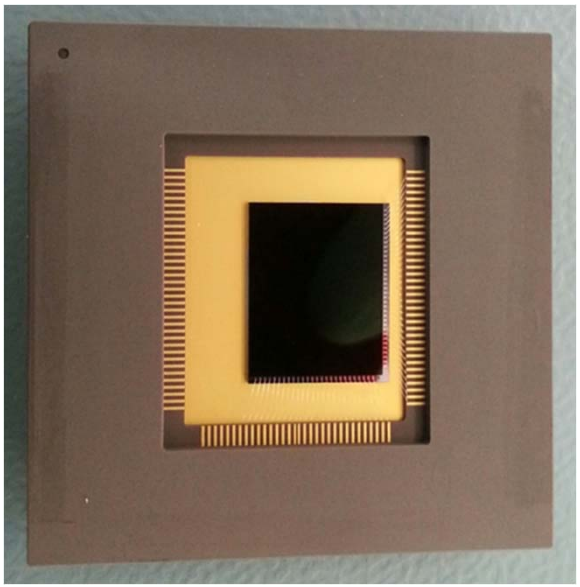
Number of pixels	**1280 X 1024 (1.3 Megapixel)**
Pixel size	10.0 µm square
Shutter modes	Global and Rolling
Output	8, 10, 12, 14 bit LVDS
Package format	Ceramic 67-pin PGA
Readout noise	6 e^- (min, depending on mode)
Quantum Efficiency	Monochrome or sparse colour (with microlens)
Maximum charge	16,000 e^- per pixel

See e2v.com for datasheet

CMOS detectors-4

CIS115 (Sirius)

- Backthinned sensor with low read-noise
- Designed for space applications
- Planned for JANUS (Juice) ESA mission
- Being qualified for space use by end-2016
- Samples available; FMs to follow



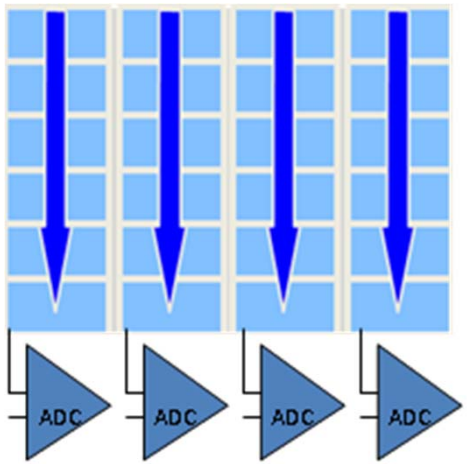
Number of pixels	**1504(H) × 2000(V)**
Pixel size	7.0 µm square
Number of output ports (reset and signal pins)	4 pairs of analogue outputs
Package size	48.26 mm square
Package format	140 pin ceramic PGA
Flatness	< 10 µm (peak to valley)
Conversion gain	35 µV/e^-
Readout noise	7 e^- (Rolling shutter)
Maximum pixel data rate	8 MP/s per channel
Maximum charge per pixel	55,000 e^-
Frame rate	Up to 10 Hz
Minimum time to read one line at 6·2 MP/s	66.25 µs
Frame rate at full resolution	Up to 7.5 fps

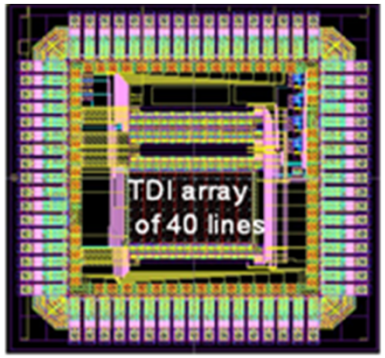
CMOS detectors-5

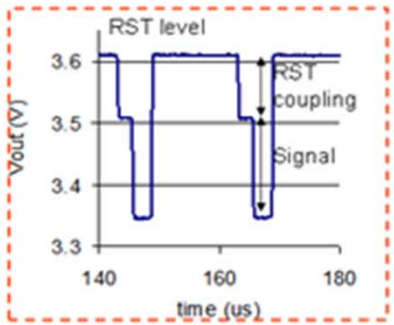
TDI CMOS development

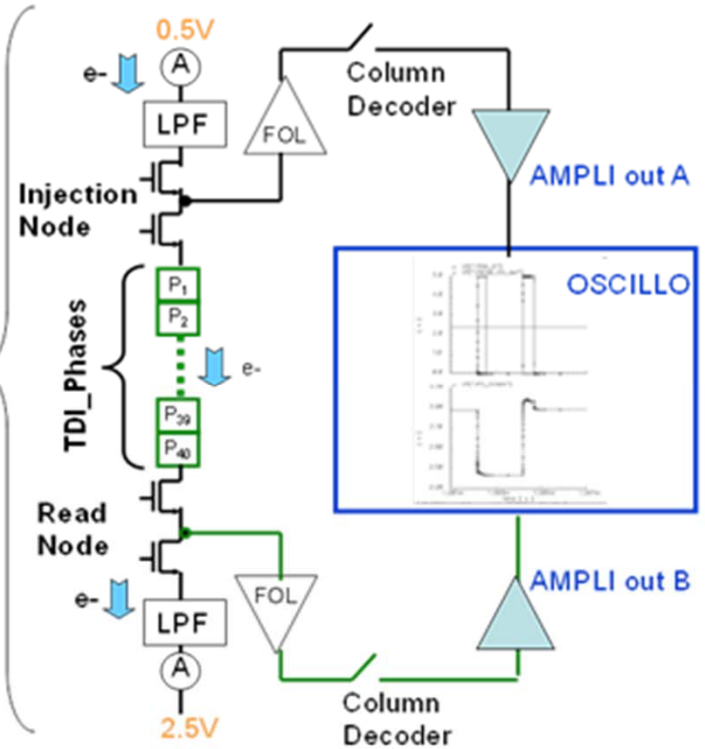
Time-Delay-Integrate used for scanning space applications; eg GAIA uses TDI CCDs

- TDI CMOS offers digital architecture & low power
- Most promising technique is a CCD-like structure-
- Charge summation along track
- Good CTE after irradiation is important
- Small test devices made & tested
- Full sized device planned







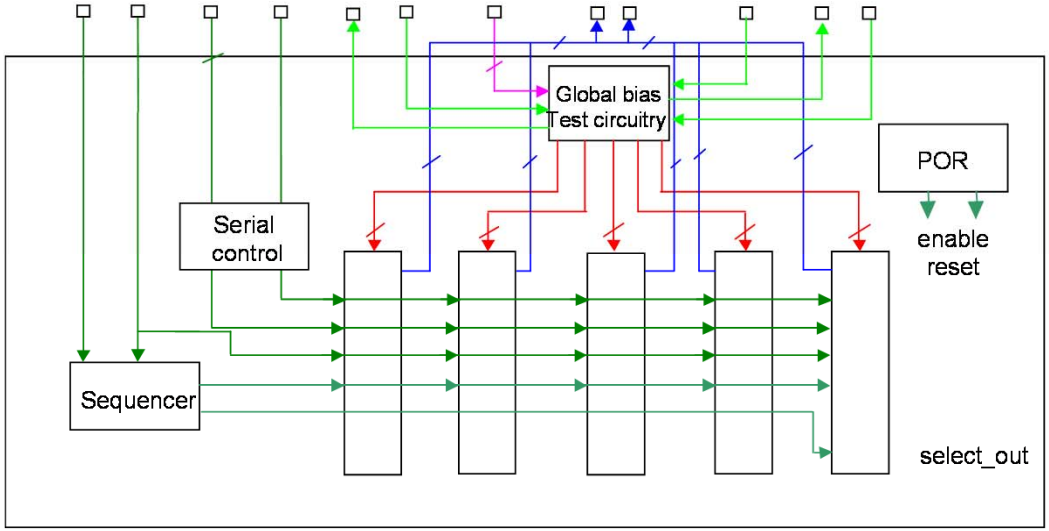


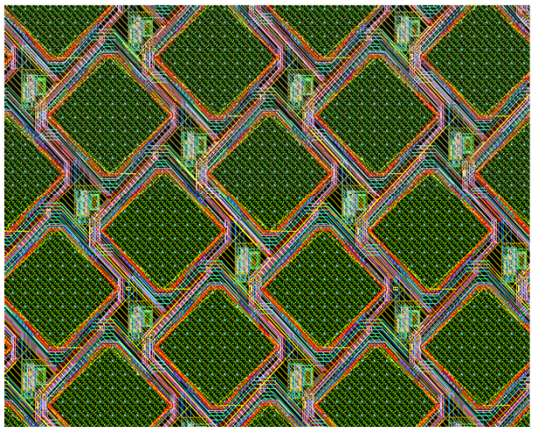
See paper by F Mayer, IISW 2015 on e2v.com

CMOS detectors-6

CIS111 (MTG FCI)

- Example of imager used for earth observation-
- Offers higher frame rate and lower crosstalk than an equivalent CCD
- CIS111 to be used on Meteosat Third Generation Flexible Combined Imager
- 5 independent imager blocks with in-package filters
- Rhombus shaped pixels in outer blocks
- Optimised for good transfer through large pixels and low lag





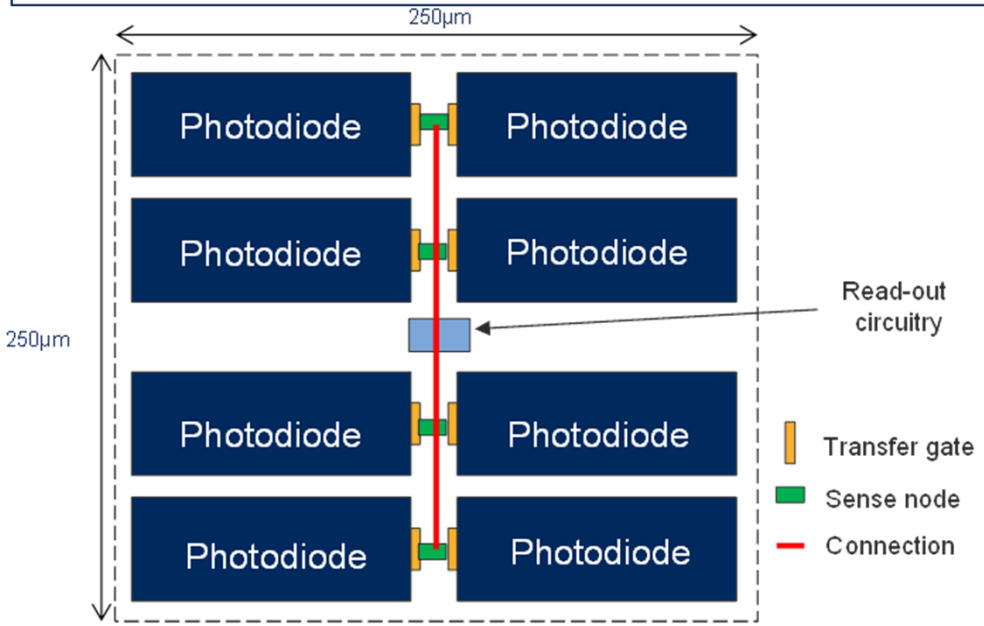
CIS111 architecture

CMOS detectors-7

CIS116 (Metimage)

Custom test vehicle with 250 um square pixels

- **Each pixel has 8 photodiodes with a common sense node**
- **Aims to optimise lag and Charge-Voltage-Factor**
- **2.5 Me- peak signal; 84 dB dynamic range**
- **Designed for backthinning**
- **Test devices have been characterised**



CIS116 pixels

Contents-2

We illustrate selected EMCCDs

Internal electron gain allows sub-electron read-noise

Combined with backthinned spectral response for very high sensitivity

Several formats and sizes available

Standard (non EMCCDs) are not discussed in the presentation- since many are visible on e2v.com and have been discuss previously

2. EM CCDs

- **Standard L3Vision sensors**
- **Custom sensors for astronomy & science**

CCD sensors-1

CCD201

- Standard product
- 1024 X 1024 pixels; 13 µm pixels
- Larger format than CCD97 (512 X 512 pixels)
- Widely used for commercial applications
- Also useful for astronomy at low signal levels
- Sub-electron read noise
- Backthinned for high spectral response
- Inverted mode dark current

- Under evaluation for space use (NASA WFIRST Coronagraph)

See e2v.com for datasheet

Harding L, et al, "Technology advancement of the CCD201-20 EMCCD for the WFIRST-AFTA Coronagraph Instrument…," JATIS 011007, (2016).

See poster by Nathan Bush, 9904, Tues pm

CCD sensors-2

CCD282

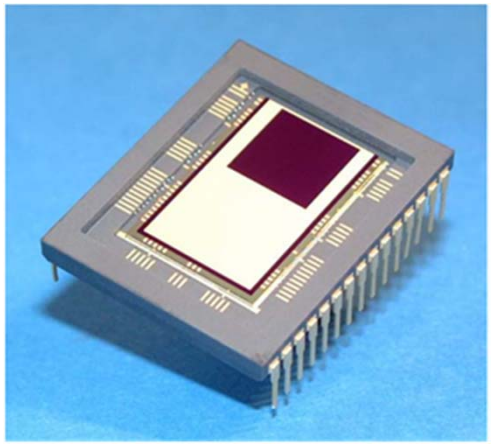
- Largest EMCCD manufactured to date
- 4096 X 4096 pixel image area
- Split frame-transfer read-out with 8 outputs
- > 4 frames per second
- Sub-electron read-noise
- Backthinned for high Quantum Efficiency
- Very low levels of clock-induced charge
- Non-inverted operation at cryogenic temperatures
- Development is complete; sensors have been delivered

Gach Jean-Luc, et al, “Development of a 4kx4k frame transfer electron multiplying CCD for scientific applications,” Proc SPIE 9154, (2014).

CCD sensors-3

CCD351

- Standard product, for commercial use
- L3Vision technology for sub-electron read-noise
- Video rate readout
- Backthinned spectral response
- In standard production



Package illustration (not final)

Typical Performance

Image section	**1024 x 1024**
Pixel size	10 µm × 10 µm
Active image area	10.24 × 10.24 mm
Package size	22.86 × 28.00 mm
Amplifier responsivity	3.5 µV/e–
Readout noise	< 1 e- (with EM gain)
Multiplication gain	100-1000 typical
Output data rate	37 MHz
Pixel charge storage	35 ke-/pixel
Dark signal (18°C)	100 e-/pixel/s

Contents-3

e2v develops sub-systems to complement its supply of sensors.

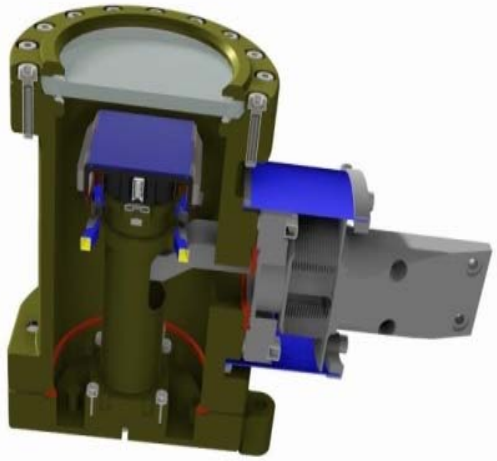
- **Bespoke systems are optimised for each application and use common modules where appropriate.**
- **Performance of sensors combined with system can be guaranteed.**

Precision System Assemblies-1

WUVS

World Space Observatory UV Spectrograph

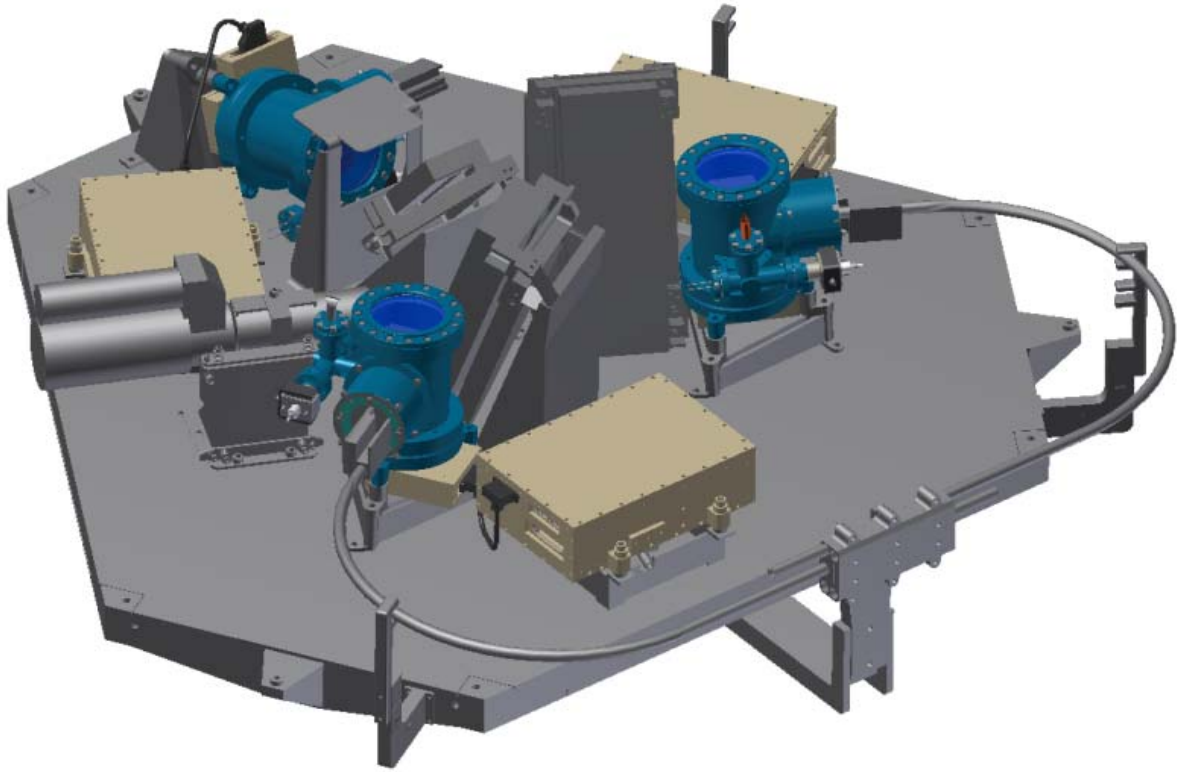
- 115-310 nm range covered by three sensor channels
- Custom sealed vacuum cryostat enclosures for 9 year life
- with flight electronics (associated with RAL Space)
- UV optimised custom CCD272 operated at -100°C
- Components maintain alignment after shock & vibration of launch
- Design and manufacture underway



Precision System Assemblies-2

WUVS

Triple detector unit detector layout with camera electronics units



See Poster by Vladimir Panchuk, 9905, Sun pm

Precision System Assemblies-3

e2v Bringing life to technology

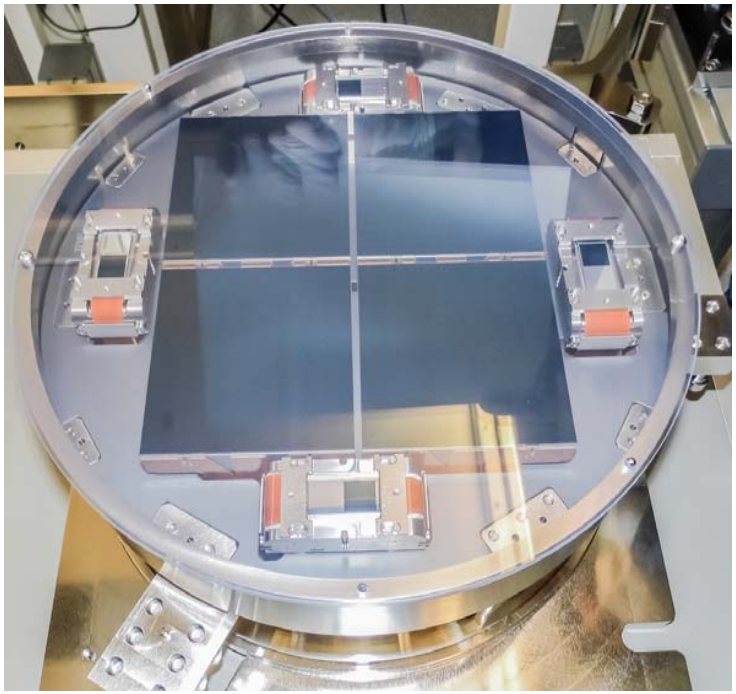
KMTNet focal planes

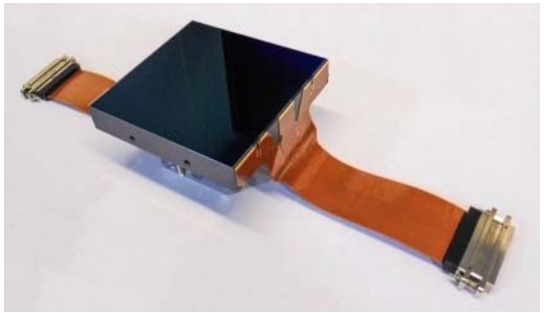
Korea Micro-lensing Telescope Network

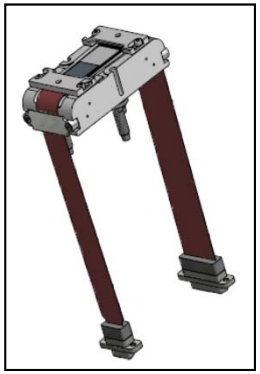
3 telescopes each with its own camera; 350 mm focal plane; 340 MegaPixel each

Each camera had four CCD290 science sensors and four guide sensors; < 30 µm flatness

Focal planes are complete (e2v) , operational and installed in cameras (by Ohio State University)







See Poster by Dae-Sik Moon, 9906, Mon pm. Also see previous paper Jorden et al, SPIE 2014

Precision System Assemblies-4

J-PAS Cryocam

A 1.2 Gigapixel cryocam for use on the 2.5m OAJ telescope for the J-PAS survey.

e2v has just completed this important commercially-suppled astronomical camera

Precision System Assemblies-5

e2v Bringing life to technology

J-PAS Cryocam

Table of key features

450 mm focal plane diameter	-100ºC operating temperature	Stable to +/- 0.5ºC
27 µm peak-valley flatness	Measured at -100C	Stable against flexure
14 science CCD290-99 sensors:	1.2 Gig pixels	9K X 9K sensors
8 wavefront sensors:	CCD44-82 FT	Custom packages
4 guide sensors:	CCD47-20 FT	Custom packages
Integrated electronics	224 science channels	< 5 e- read-noise at 400 kHz
Modular CCD drive units	Synchronized readout of science CCDs	Local frame stores
Complete LN2 cooling system	Integrated vacuum system	Post-delivery support
Cold light baffle	High Quantum Efficiency	minimum reflection AR coat

See paper by Mark Robbins, 9908, Tues 28 June 2016, am, S8

And K Taylor et al, JPCAM, JAI vol 3, 2014

Summary

And some closing remarks

This paper is an update of e2v technology developments and products since:

Jorden P R, Jordan D, Jerram P, Pratlong J, Swindells I, "e2v new CCD and CMOS technology developments for astronomical sensors," Proc SPIE 9154, (2014).

- An increasing number of sensors are being developed using CMOS architectures
  Many of these are backthinned and offer low read-noise (comparable to CCDs)
- CCDs continue to be used in larger quantities and with greater heritage
  CCDs offer better red response in general (thicker silicon)
- e2v offers custom system solutions including cryogenic cameras and electronic modules to complement its supply of sensors- and with guaranteed performance

Thank you for your attention

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OUR INNOVATIONS LEAD DEVELOPMENTS IN COMMUNICATIONS, AUTOMATION,
DISCOVERY, HEALTHCARE AND THE ENVIRONMENT