e2v CCD and CMOS technology developments for astronomical sensors

Paul Jorden

SPIE AS14, 9154 Detector conference

Co-authors
Doug Jordan, Paul Jerram, Jérôme Pratlong, Ian Swindells. e2v

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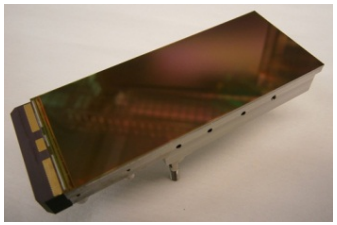
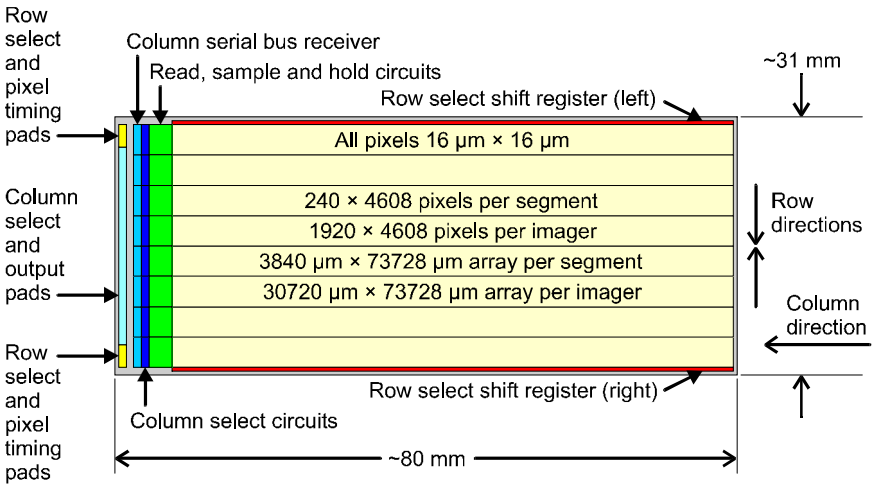
Introduction

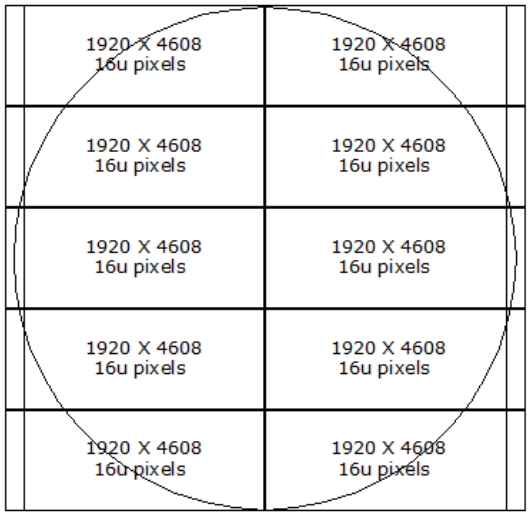
Themes of this presentation

- **CMOS imagers for astronomy**
- EMCCD developments
- Red Sensitive CCDs
- Major space CCD programmes
- Cameras and Systems

CMOS imager programmes-1
TAOS-II CIS113 sensor







TNO detection by occultation

See Shiang-Yu Wang poster

Sensor: 1920 x 4608 16 µm square pixels.

8 segments for parallel read-out

Independent access of left and right sides

Multiple ROI mode for 20 fps sampling rate

Noise floor < $5e^-_{RMS}$ and low dark current.

Backthinned for 90% QE

Saturation signal (node) ~ 18 ke-

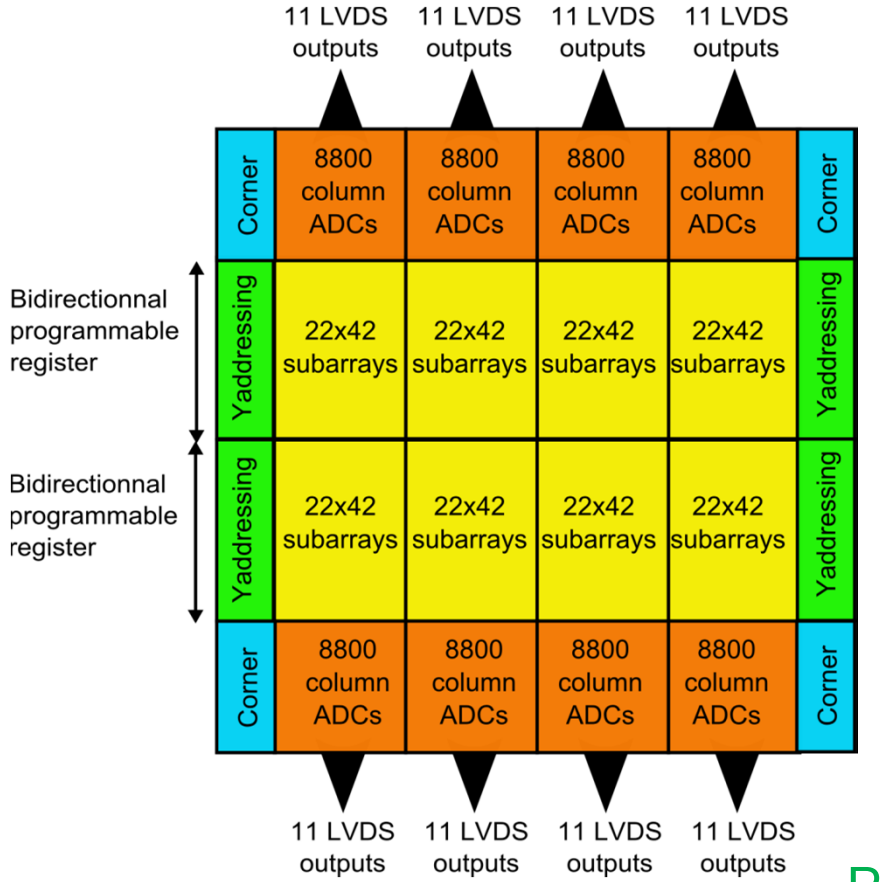
Each focal plane: 10 buttable image sensors

3 focal planes to be built for three telescopes

Frontside samples to be tested Jul-14

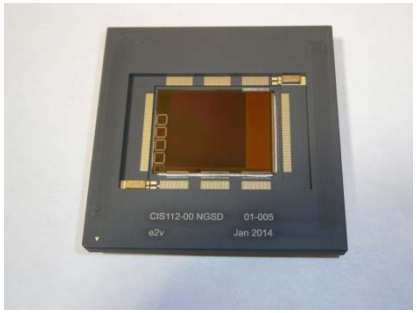
CMOS imager programmes-2
NGSD/LGSD CIS112 sensor

See Mark Downing talk



LGSD architecture 1760 X 1680

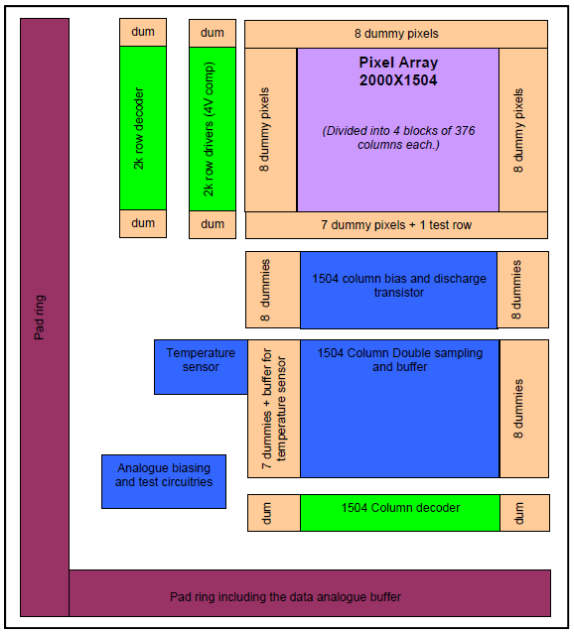
- Designed for AO WFS
- 20X20 pixel sub-arrays
- 24 um pixels
- Backthinned for high QE
- < 3 e- read-noise target
- LGSD (later) & NGSD (“1/4”-size)



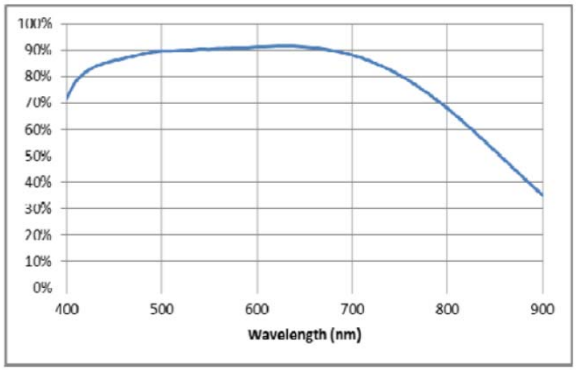
NGSD 880 X 840

Prelim BT samples to be tested next month

CMOS imager programmes-3
CIS115



CIS115 architecture; four outputs

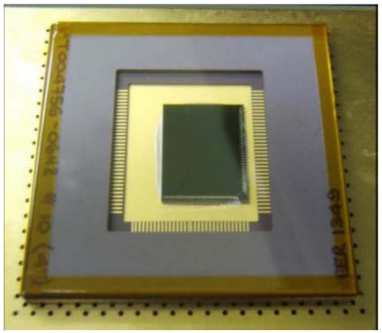


Typical back-illuminated QE

The CIS115 is derivative from the CIS107 [developed with Astrium, CNES]. See poster by Shiang-Yu Wang about CIS107 measurements.

To be supplied as demonstrator device, mainly for prospective space missions; designed as one "quadrant" to allow a 4k X 3k imager.

Intended for ESA JUICE mission



1504 X 2000, 7 um pixels

CIS115 measurements

Performance overview	CIS115	CIS107		
	Pixel 4	Pixel 1	Pixel 6	Pixel 10
Dark Current at 21°C				
Mean (µV/ms)	0.24	0.32	1.46	0.32
DSNU rms (µV/ms)	0.69	0.67	1.94	0.35
Mean dark current (e-/pix/sec)	4			
Readout Noise in Darkness				
Readout Noise (µV)	257	264	280	213
Readout noise (e-)	4.5			
Signal Characteristics				
Peak output voltage	~1800 mV	~1300 mV	~1100 mV	~800 mV
Peak signal (e-)	36,000			
CVF (µV/e-)	50	57	62	13

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- **EMCCD developments**
- Red Sensitive CCDs
- Major space CCD programmes
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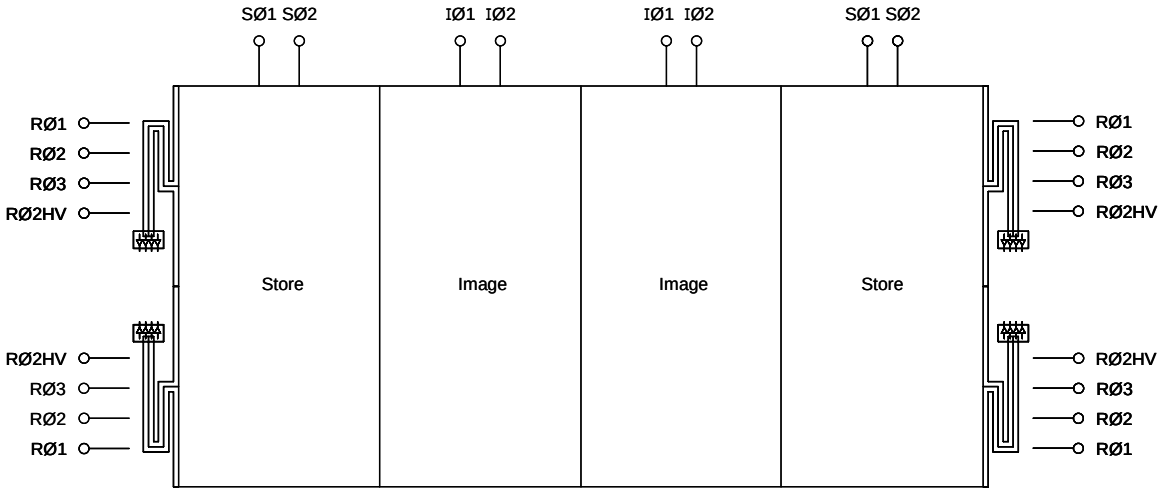
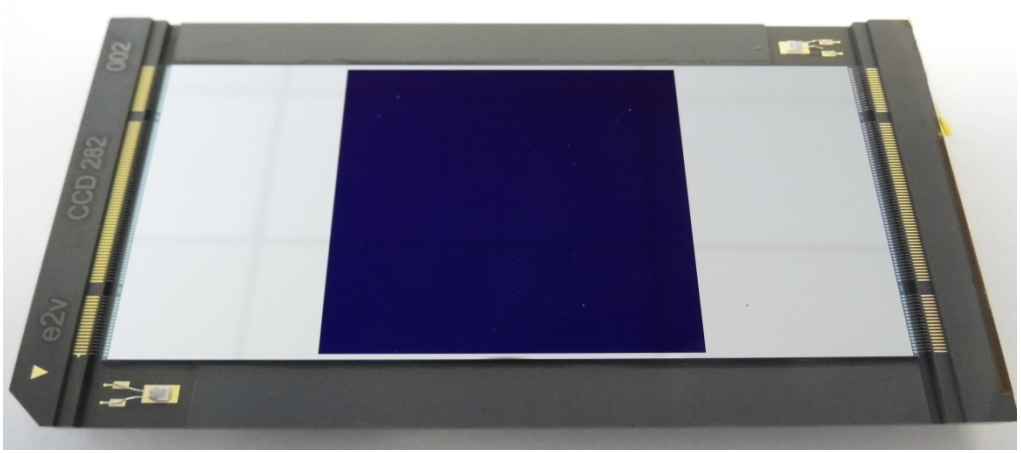
EMCCD developments
CCD282





103 mm die length

Main features

- 4k X 4k image area
- 12 µm pixels
- Split frame transfer sections
- 8 EMCCD outputs
- Sub-electron readout noise
- Min. 4 fps at 10 MHz pixel rates
- Designed for photon counting
- Non-inverted (non-MPP) operation at cryo temperatures
- Backthinned for high spectral response; 90% peak
- Alternate formats possible; TBC

See Jean-Luc Gach talk

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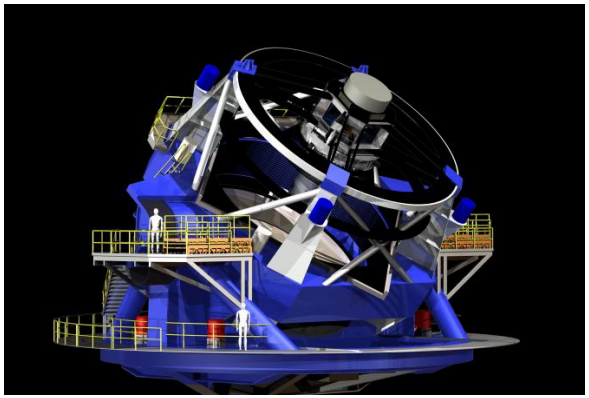
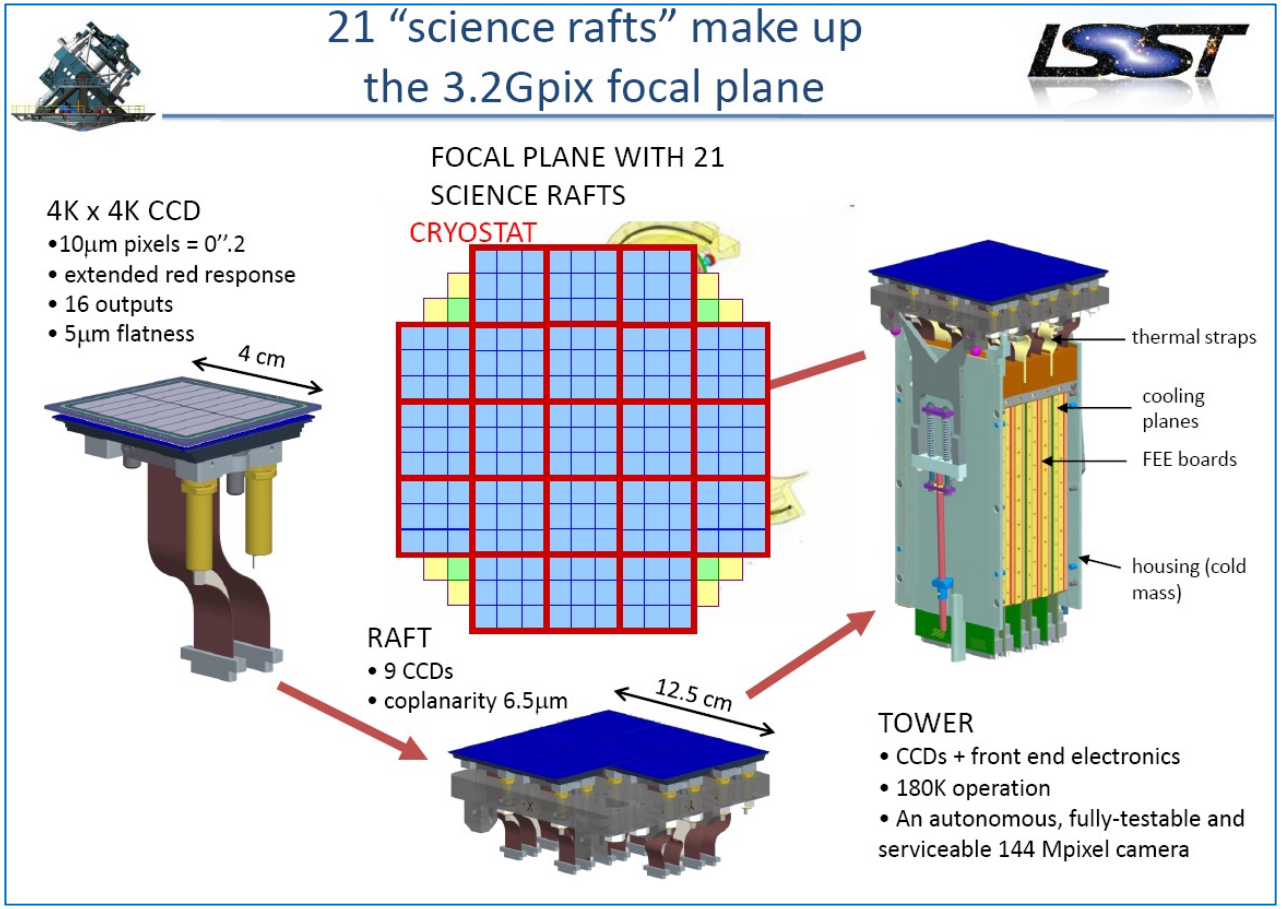
CCDs with high red sensitivity-1
LSST CCD250

- 4k X 4k 10 µm format
- 189 science sensors
- 100 µm thick; 5 um flat
- High precision SiC buttable package
- 16 outputs; 2 s readout
- 5 e- read-noise

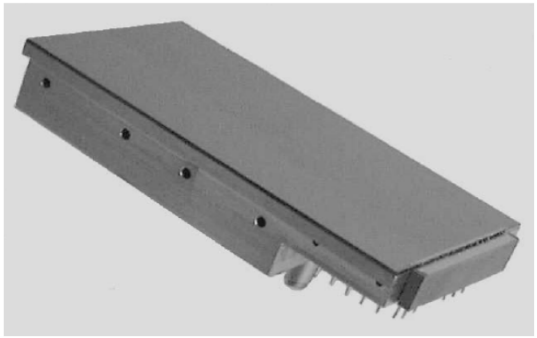




Pictures courtesy: LSST

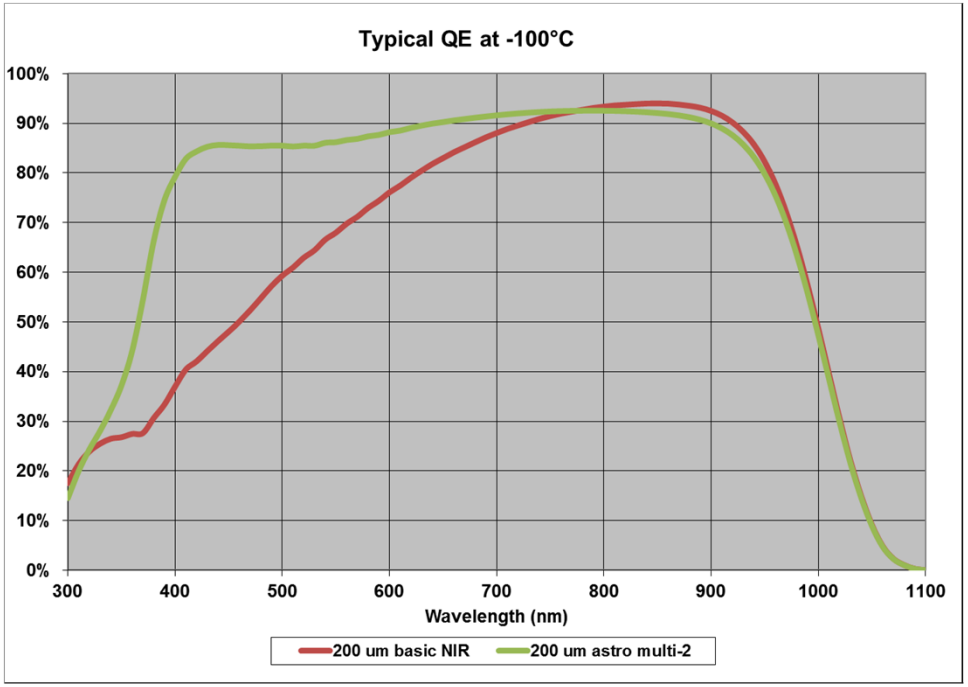
See Peter Doherty talk

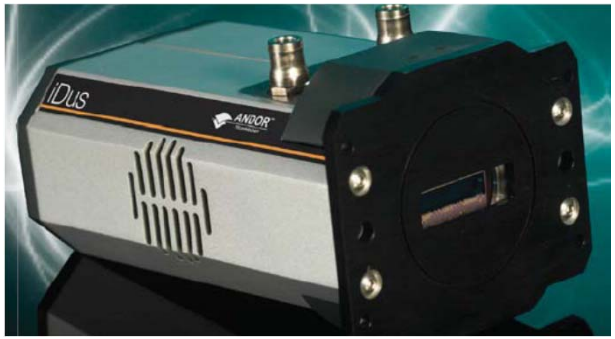
CCDs with high red sensitivity-2
CCD261



CCD261-84

- 2k X 4k, 15 µm pixels
- 200 µm thick
- 2.5 e- noise floor
- Precision Buttable package





CCD261 2000 X 256 15 um pixels

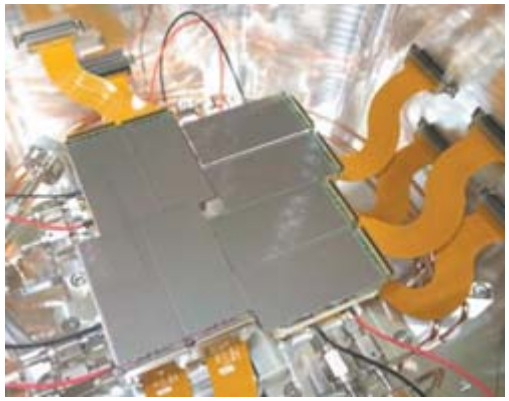
- Deep depletion together with inverted mode operation (patent)

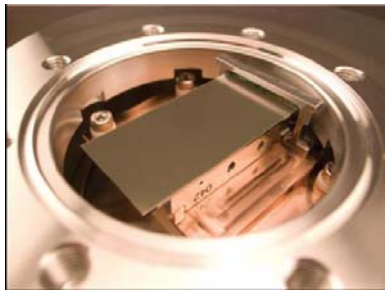
Picture courtesy: Andor iDus 416 spectroscopy camera

CCDs with high red sensitivity-3
X-ray detection

CCD262-50

- 1024X512, 50 µm pixels
- Deep depletion (40 µm thick); 80% QE @ 6 KeV
- Low noise from 8 ports
- Fully depleted for good MTF (front illuminated)





Eight CCD262s installed in butted detector arrangement for X-ray Free Electron Laser

CCD292-50 second generation for XFEL (Riken)

- 1024X512, 50 µm pixels
- High-rho (>200 µm thick) for higher QE @ 12 KeV
- Back illuminated

Samples delivered

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Major recent space programmes-1

Pictures courtesy: ESA, Astrium

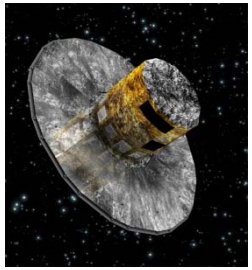
GAIA CCD91-72, 106 FMs

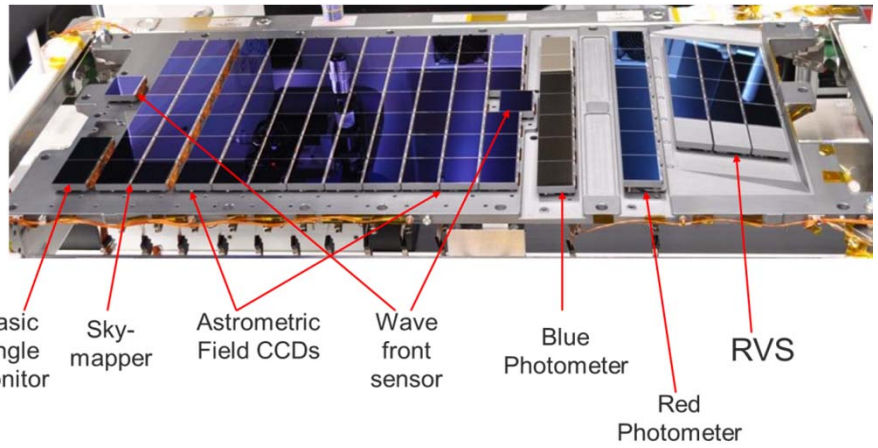
4500 x 1966 10 X 30 µm pixels

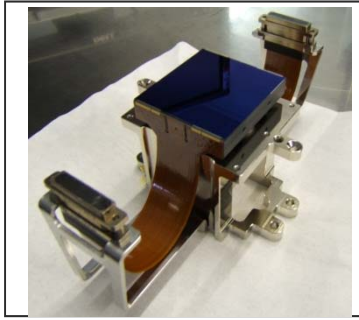
Operational

Largest focal plane in space

See Plenary







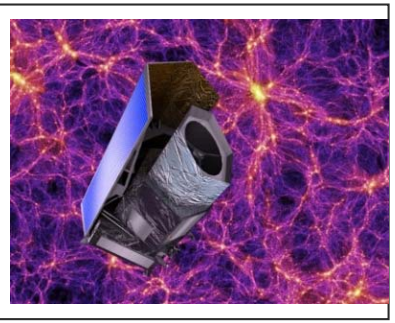
Euclid CCD273-84

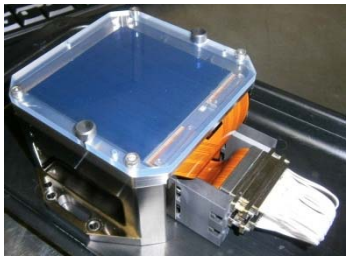
4096 X 4096 12 µm pixels

Development phase complete

Qualification phase in progress (sample devices)

Two year Flight phase to follow in 2015 (36+ spare FMs)





Plato CCD270

4510 X 4510 18 µm pixels; 4 CCDs per FPA

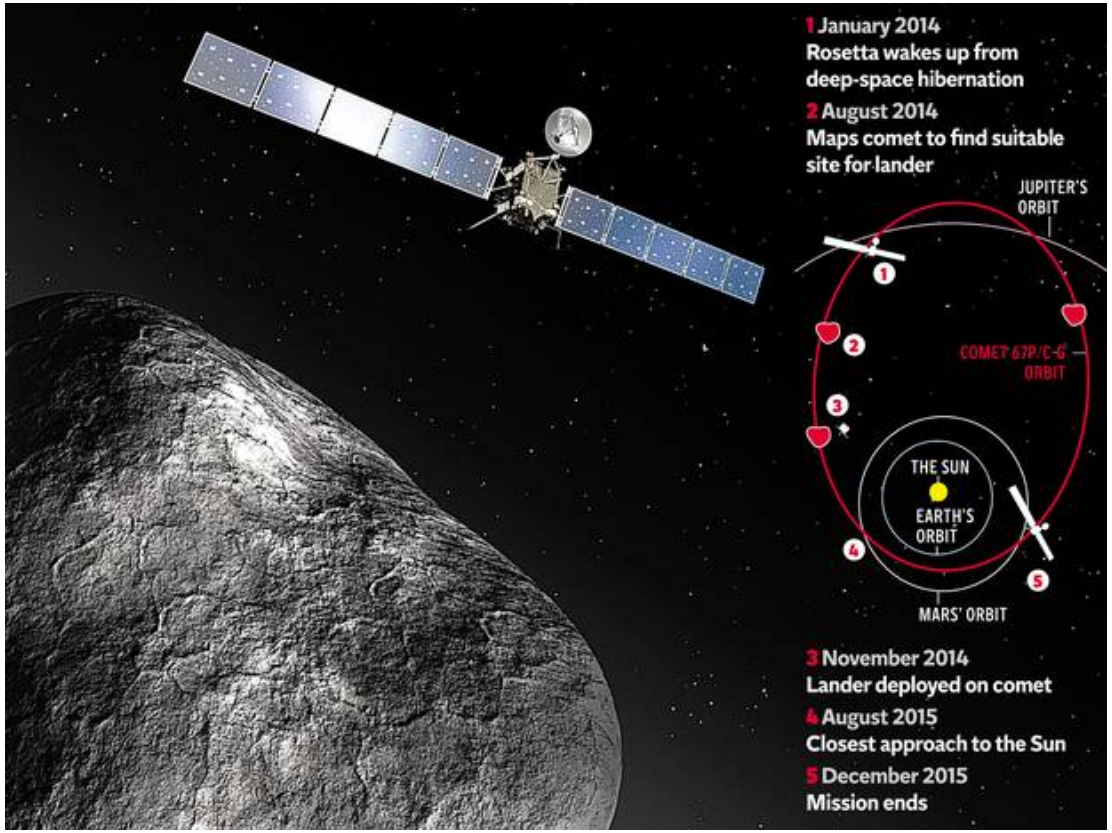
34 FPAs. Will be largest focal plane area

Development phase complete

Validation phase soon (24 devices)

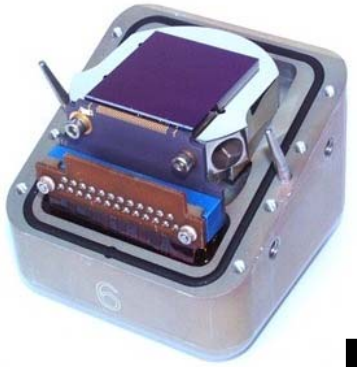
Flight phase to follow (152 FMs)

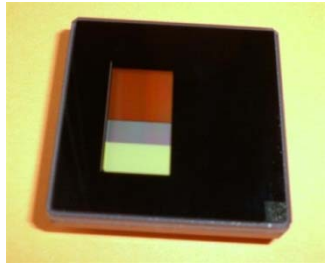
Major recent space programmes-2
Rosetta

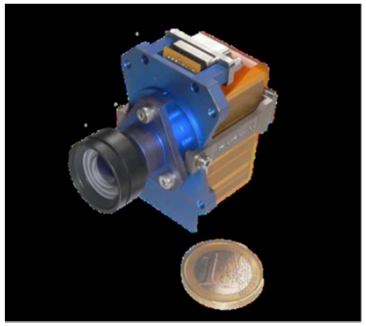


Launched in March 2004 to reach comet 67P/Churyumov–Gerasimenko in August 2014.

Has now covered 6.3 billion km







Six e2v instruments on Rosetta

Orbiter: Navcam CCD47-20, OSIRIS 2 CCD42-40 cameras, VIRTIS-M TH7896

Lander: ROLIS and CIVA both useTH7888 in micro-cameras

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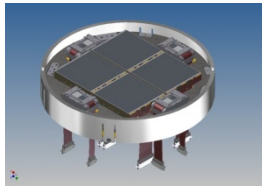
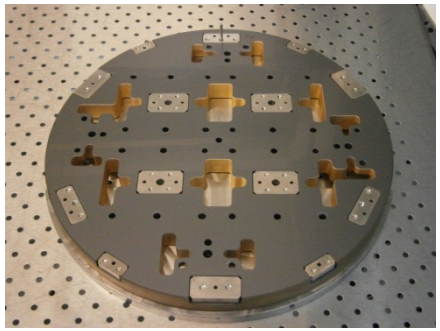
- **Cameras and Systems**

Cameras and systems-1
OSU-KMTN focal planes

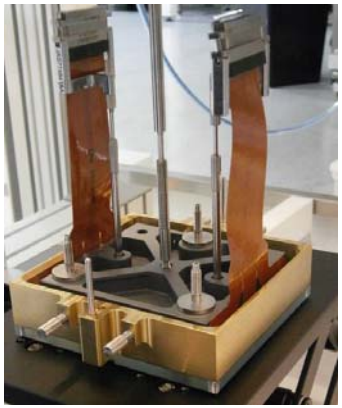


Korea Micro-lensing Telescope Network (KMTN)- overview

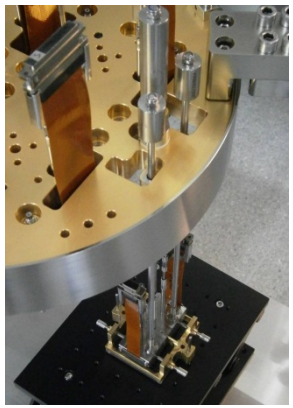
- Three 1.6-m southern-hemisphere telescopes.
- Continuous monitoring of micro-lensing events in the galactic bulge.
- Each telescope equipped with a 340 megapixel camera.
- OSU designs and builds the three cameras with electronics
- e2v designs and builds the three focal planes with sensors
- Custom-designed precision cryogenic detector mounting plates
- Optimised custom sensors



Top surface of plate

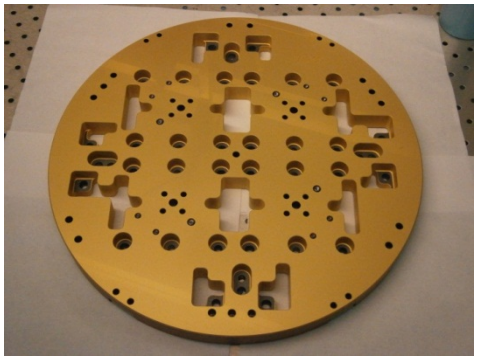


CCD290 ready for insertion



CCD47 being inserted

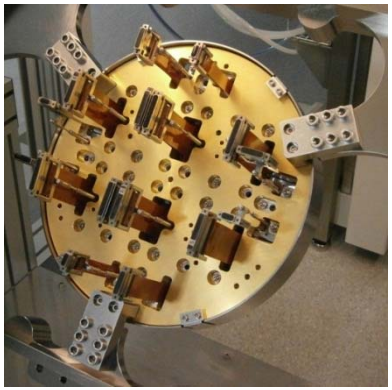
Assembly pictures of components



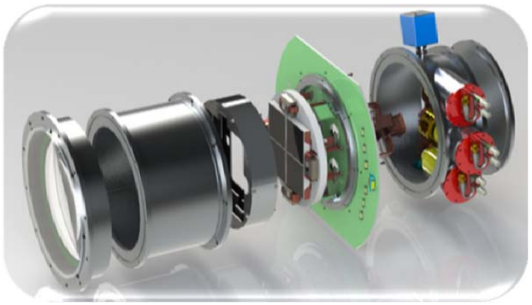
Lower surface: gold-plated Silicon Carbide

See Bruce Atwood poster

Cameras and systems-2
OSU-KMTN focal planes



Lower view with sensors installed

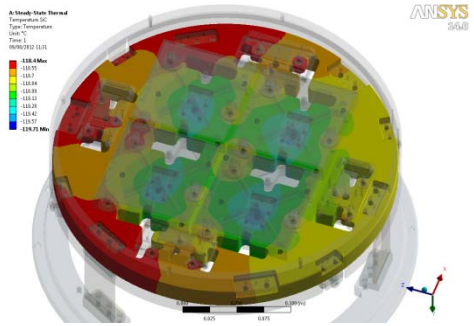


OSU cryogenic camera

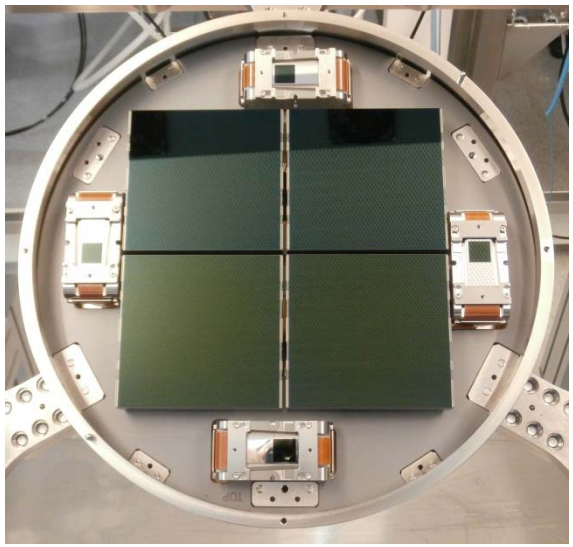
e2v detector mounting plate:

- Four 9k x 9k Science CCDs
- Four 1k x 1k FT Guide CCDs
- Precision Silicon Carbide plate
- Surfaces co-planar to 40 µm p-v

It fits in the metrology machine!



Thermal & mechanical FEA

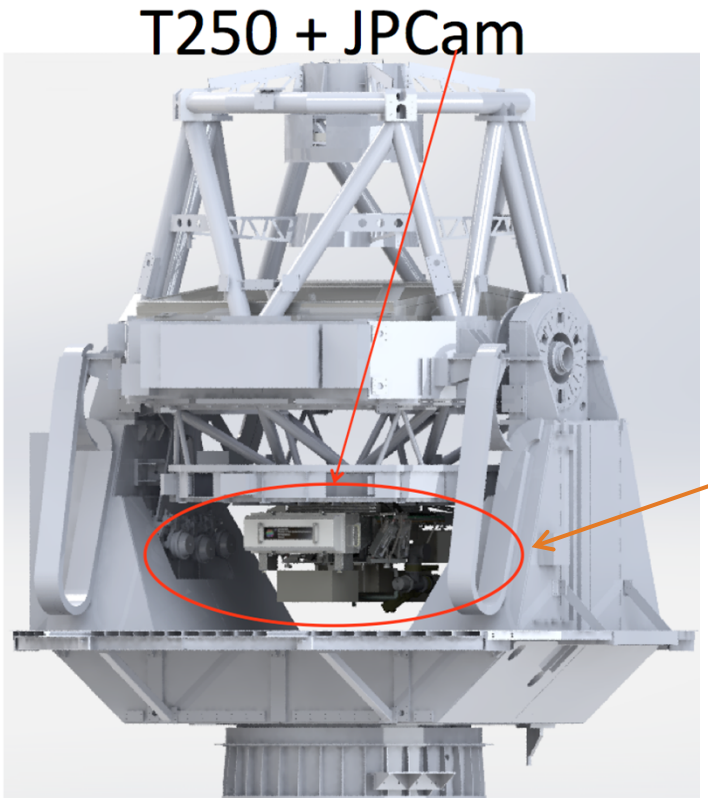


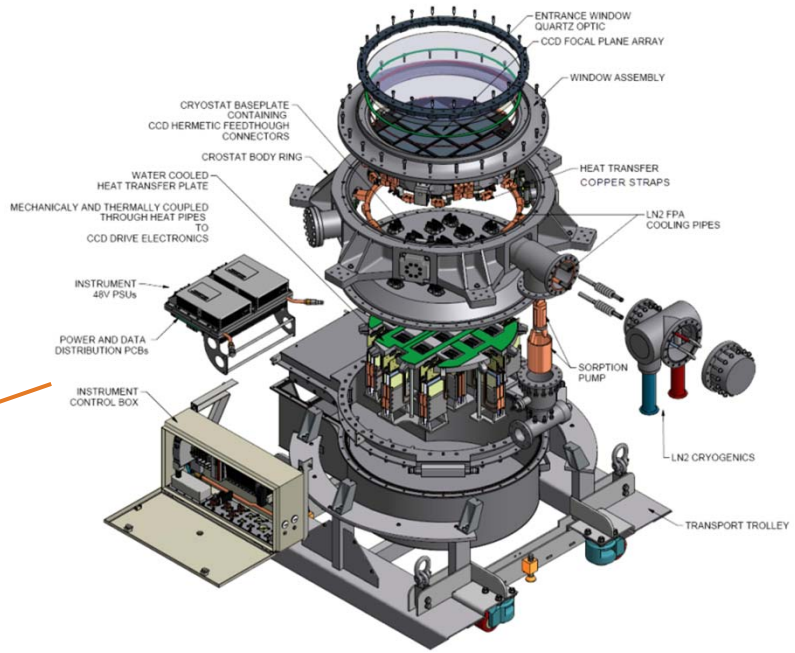
All sensors assembled onto plate

Three complete focal plane assemblies delivered to OSU

Cameras and systems-3
J-PAS 1.2 Giga-pixel camera

See Richard Harriss talk





JPCam

Cameras and systems-4
J-PAS 1.2 Giga-pixel camera

Three types of CCD:

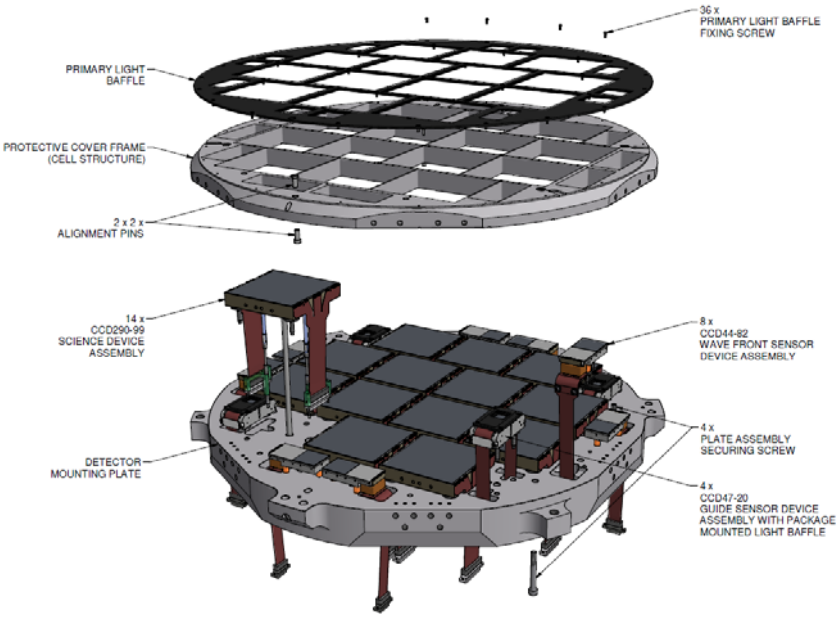
- 14 x CCD290-99 (Science CCDs)
- 8 x CCD44-82 (Wavefront Sensors)
- 4 x CCD47-20 (Autoguider CCDs)

Camera includes:

- Readout electronics for all the CCDs
- 22 CCD drive modules
- Power and data handling electronics
- Multiple FPGAs to read 2.4 GBytes of data/ frame
- Digital CDS (Correlated Double Sampling) readout
- Designed for < 5 e^- noise performance

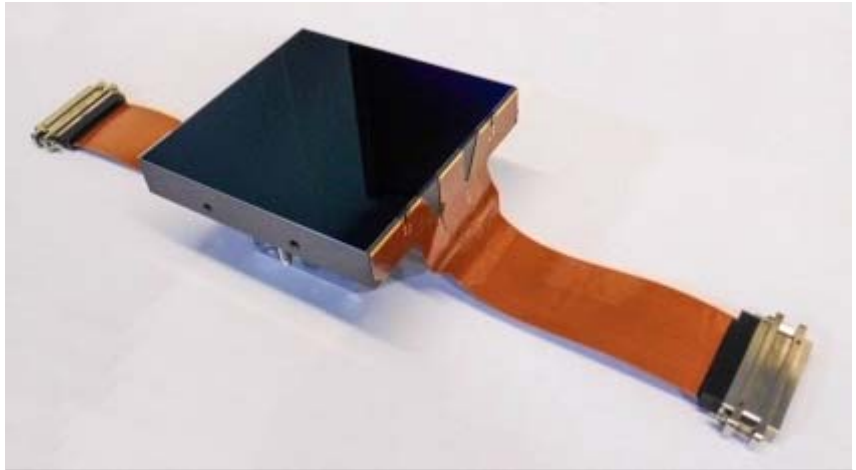
Camera features:

- Cryogenically cooled using mixed phase LN2
- PLC for the cooling and vacuum systems control



Focal plane assembly

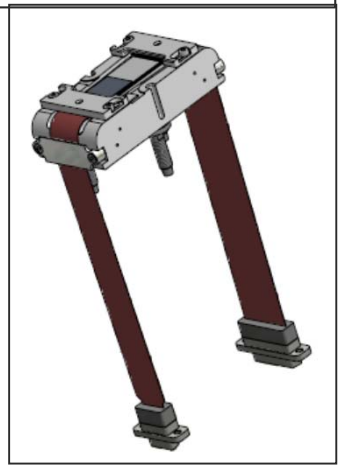
Cameras and systems-5
CCD sensors for J-PAS

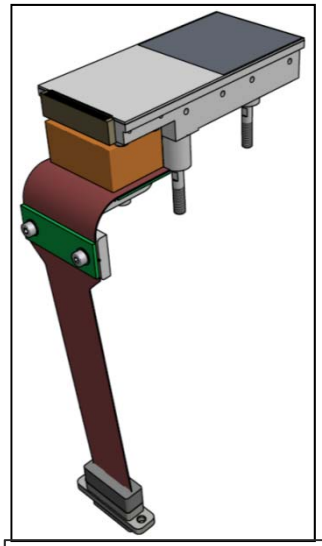


CCD290-99 science sensors
9216 X 9232 format, 10 µm pixels
92 X 92 mm image area

- All at 20.00 mm height
- All have same spectral response
- All used with differential outputs
- Flex cables for FPA assembly

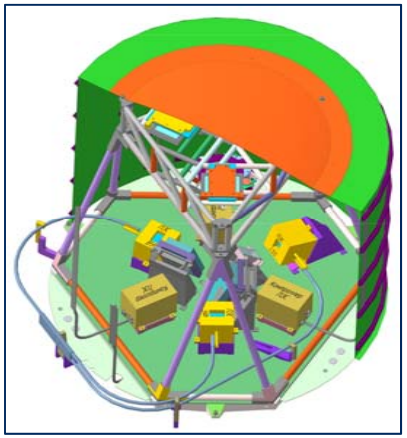
CCD47-20 guiders
1024 X 1024 Frame-transfer
11 X 13 mm image area



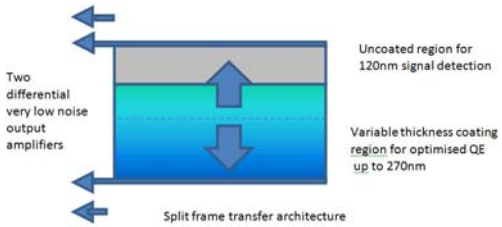


CCD44-82 wavefront sensors
2048 X 2048 Frame-transfer
31 X 31 mm image area

Cameras and systems-6
WSO-UV detectors

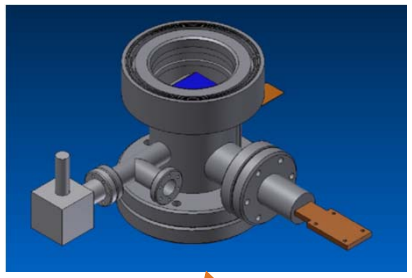


Triple detector system [INASAN instrument concept]



Detector characteristics- CCD272

Characteristics	VUVES	UVES	LSS
Spectral range, nm	115-176	174-310	115-310
Size of photosensitive , mm	37.3 x 49.1	37.3 x 49.1	37.3 x 49.1
Pixel size, µm	24	24	24
Quantum efficiency, not less than, %			
at wavelength 120 nm	20	-	20
at wavelength 150 nm	30	-	30
at wavelength 175 nm	25	25	25
at wavelength 250 nm	-	50	50
at wavelength 300 nm	-	50	50
Readout noise, not more than, e^-, sd	3	3	3
Digitalization, bits	14	14	14
Dark current, not more than, e^-/pixel/hour			
At beginning of life	12	12	12
At end of life	36	36	36
Exposure time, sec	1-3600	1-3600	1-3600
Dynamic range in one frame, not less than	10000:1	10000:1	10000:1



- Customised coatings for UV application
- Custom permanently sealed enclosure with heat-pipe
- Low noise differential digital (DCDS) low noise electronics

Acknowledgements & References

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References at this meeting

Jean-Luc Gach, *Development of EM CCD282*, 9154, Sun 22nd

Mark Downing, *NGSD CMOS imager for E-ELT*, 9154, Mon 23rd

Richard Harriss, *Giga-pixel camera for J-PAS*, 9154, Mon 23rd

Bruce Atwood, *KMTN camera system*, 9154 poster, Mon 23rd

Shiang-Yu Wang, *e2v CMOS sensors*, 9154 poster, Mon 23rd

Shiang-Yu Wang, *CMOS camera for TAOS-II*, 9147 poster, Mon 23rd

Matt Lehner, *TAOS-II survey status*, 9145, Tues 24th

Philippe Feautrier, *Advanced AO sensors*, 9148, Tues 24th

Peter Doherty, *Testing of fully depleted CCDs for LSST*, 9154, Tues 24th

Thanks for your attention

Older References

P Jorden et al, SDW 2013, The KMTNet 340 Megapixel focal planes, in press 2014

D Jordan et al, SDW 2013, A novel 4k4k EMCCD for scientific use, in press 2014

K Taylor et al, JAI 2013, JPCam: a Gpixel camera for J-PAS

B Atwood et al, SPIE 8446-246, 2012, Design of the KMTNet camera

M Downing et al, SPIE 8453-12, 2012, Back-illuminated 700 fps imager

P Jorden et al, SPIE 8453-20, 2012, A Gigapixel cryo camera for J-PAS

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