e2v CCD and CMOS technology developments for astronomical sensors

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SPIE AS14, 9154 Detector conference

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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

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 < $5e^{-}\text{RMS}$ and low dark current.  
Backthinned for 90% QE  
Saturation signal (node) $\sim$ 18 ke-  
Each focal plane: 10 buttable image sensors  
3 focal planes to be built for three telescopes

TNO detection by occultation  
See Shiang-Yu Wang poster

Frontside samples to be tested Jul-14
See Mark Downing talk

- 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)

Prelim BT samples to be tested next month
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

### Performance overview

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

Typical back-illuminated QE
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EMCCD developments
CCD282

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

21 “science rafts” make up the 3.2Gpix focal plane

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

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)

Pictures courtesy: ESA, Astrium
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 use TH7888 in micro-cameras
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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

Assembly pictures of components

- CCD290 ready for insertion
- CCD47 being inserted

Lower surface: gold-plated Silicon Carbide

See Bruce Atwood poster
Cameras and systems-2
OSU-KMTN focal planes

It fits in the metrology machine!
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
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

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

CCD47-20 guiders
1024 X 1024 Frame-transfer
11 X 13 mm image area
Cameras and systems-6
WSO-UV detectors

Triple detector system [INASAN instrument concept]

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

Acknowledgements

Thanks to many colleagues at e2v who contributed material and to others associated with projects and developments described here.

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
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