Performance of the e2v 1.2 GPixel cryogenic camera for the J-PAS 2.5m survey telescope

M S Robbins*¹, M Bastable¹, A Bates¹, S Eames¹, G Fenemore-Jones¹, G Haddow¹, P R Jorden¹, B Lane¹, A Marin-Franch², J Mortimer¹, I Palmer¹, N Puttay¹, R Renshaw¹, M Smith¹, A Taylor¹, K Taylor³, J Tearle¹, P Weston¹, P Wheeler¹, J Worley¹

¹ e2v, Waterhouse Lane, Chelmsford, Essex, CM1 2QU, UK; ² Centro de Estudios de Fisica del Cosmos de Aragon, Plaza San Juan 1 piso 2, 44001 Teruel, Spain; ³ Universidade de Sao Paulo, IAG, Rua do Matao, 1226, Sao Paulo, 05508-900, Brazil
J-PAS CryoCam

Introduction

- J-PAS - Javalambre Physics of the accelerating universe Astronomical Survey
- J-PAS is a 5 year wide-area astrophysical mapping survey which primarily aims to explore dark energy in the universe
- The dedicated 2.5m telescope (built in Teruel, Spain) will use 56 narrow band optical filters to build up a 3-D map of the universe by studying red-shifts
- e2v are supplying the 1.2 GPixel camera which is mounted on the back of the T250 telescope

http://www.j-pas.org/
Overview

Presenting a review the factory performance of the e2v JPAS CryoCam following AIVT

- Overview of Cryocam
- The Opto-Mechanical Sub-System
  - Opto-Mechanical Description
  - Geometric Verification
- The Instrument Control and Support Sub-System
  - Sub-System description
  - Thermal Performance
  - Vacuum Performance
- Detector Control Sub-System
  - Electronics overview
  - Electrical Performance
    - CCD Level
    - Module Level
    - System Level
- Conclusion
J-PAS CryoCam

Overview of CryoCam

- Precision focal plane
- Custom high integrity cryostat
- PLC Camera Control
- Low Noise Electronics
- Custom Sorption Pump
- Low reflectivity light baffle
- Science 14 x e2v CCD290-99
- Wavefront 8x e2v CCD44-82
- Autoguide 4x e2v CCD47-20
- LN2 delivery system
J-PAS CryoCam

Overview of CryoCam

- Precision focal plane
- Custom high integrity cryostat
- PLC Camera Control
- Low Noise Electronics
- Custom Sorption Pump
- LN2 delivery system
- Science 14 x e2v CCD290-99
- Wavefront 8x e2v CCD44-82
- Autoguide 4x e2v CCD47-20
- Low reflectivity light baffle
Overview of CryoCam
J-PAS CryoCam

The Opto-Mechanical Sub-System

- Assembly housed within custom vacuum cryostat
- LN2 passed through a Cu ring and changes phase
- Cold plate attached to Cu ring with Cu straps
- Initially evacuated with a Turbo Pump
- Vacuum held with a sorption pump
The Opto-Mechanical Sub-System – Geometric Verification
The focal plane inside the cryostat plane and flatness measurements made at -110 °C showing the 14 science devices, 8 wavefront and 4 autoguide CCDs.

Flatness achieved - **27 µm peak to valley** for (spec 40µm target 30µm)
J-PAS CryoCam

The Instrument Control and Support Sub-System

- Pair of LN2 Dewars mounted on telescope fork
- Temperature control implemented through PLC system
- Controls rate of flow of GN2 flowing from cryostat
- No heaters in cold plate assembly
- PID control employed
- Time constant ~3.5 hours
The control temperature and the Dewar fill level
The control temperature and the radiative heat load on the cold plate
Sorption pump only – no cryostat conditioning
J-PAS CryoCam

Detector Control Sub-System

14 Science CCDS
8 Wavefront CCDS
4 Autoguide CCDS

CRYOSTAT ENVELOPE
Vacuum Feedthroughs

CCD CONTROLLER ENVELOPE

DRIVER MODULE (1 of 14)
- BIAS DAC
- CLOCK DRIVERS
- Oversampling ADC
- FPGA
  - DSP DATA FILTERING
  - CCD TIMING
  - OUTPUT DATA SERIALISER
  - LOCAL FRAMESTORE

DRIVER MODULE (1 of 8)
- BIAS DAC
- CLOCK DRIVERS
- Oversampling ADC
- FPGA
  - DSP DATA FILTERING
  - CCD TIMING
  - OUTPUT DATA SERIALISER
  - LOCAL FRAMESTORE

DRIVER MODULE (1 of 4)
- BIAS DAC
- CLOCK DRIVERS
- Oversampling ADC
- FPGA
  - DSP DATA FILTERING
  - CCD TIMING
  - OUTPUT DATA SERIALISER
  - LOCAL FRAMESTORE

INTERFACE MODULE
- CAMERALINK TO FIBRE OPTIC TRANSLATOR
- POWER
- DATA
- POWER
- DATA
- POWER
- DATA

POWER CONVERSION & DISTRIBUTION
- COMMAND HANDLER
- SCIENCE DATA TRANSFER
- WFS DATA STREAMED
- AG DATA STREAMED
- 48V DC POWER SUPPLIES

Remote PCs
LC DUPLEX FIBRE OPTIC CABLES (LONG)

SCIENCE
WFS
AG
J-PAS CryoCam

Detector Control Sub-System – CCD Level Performance

- The CCDs supplied as high grade devices
- All CCD testing undertaken using dedicated production test equipment
- CCDs tested for noise, responsivity, linearity, QE, CTE, dark signal, PRNU, DSNU, defects....

14xCCD290-99 Science Devices
9kx9k full frame
16 differential outputs
630 kHz and 400 kHz

8xCCD44-82 Wavefront
2kx2k frame transfer
100x100 window at 1 fps

4xCCD47-20 Autoguide
1kx1k frame transfer
50x50 window at 4 fps
J-PAS CryoCam

Detector Control Sub-System – Module Level Performance

• Each of the 22 electronics modules bench tested and tested with associated test devices.
• Test device is mounted in a “mini” cryostat
• Tested for functionality, noise, linearity, gain, CTE

A wavefront module being tested
J-PAS CryoCam

Detector Control Sub-System – Module Level Performance

Channel 1
mean = 1071.1
noise = 1.97

Channel 2
mean = 1030.5
noise = 1.94

Channel 3
mean = 1073.5
noise = 1.93

Channel 4
mean = 1046.5
noise = 1.93

Channel 5
mean = 1043.0
noise = 1.96

Channel 6
mean = 1069.4
noise = 1.95

Channel 7
mean = 1096.1
noise = 1.98

Channel 8
mean = 1048.9
noise = 2.09

Channel 9
mean = 1105.4
noise = 2.15

Channel 10
mean = 1087.4
noise = 1.93

Channel 11
mean = 1045.0
noise = 1.96

Channel 12
mean = 1129.4
noise = 1.94

Channel 13
mean = 1117.9
noise = 1.91

Channel 14
mean = 1075.2
noise = 1.51

Channel 15
mean = 1079.2
noise = 2.17

Channel 16
mean = 1096.6
noise = 1.92
J-PAS CryoCam

Detector Control Sub-System – System Level Performance

- System level performance assessed for noise, cross talk and functionality
J-PAS CryoCam

Detector Control Sub-System – System Level Performance

a)

- Flat panel illumination source and chart
- Support structure
- Light tight enclosure
- Pinhole
- Focal plane

19 cm

0.5 m

b)
The measured system level noise for all science devices operating in parallel.

Inter channel and inter device cross talk less than 106 dB
System noise from a single science output measured over a 6 day period. All devices are operating and a noise measurement is made every 25 seconds.
J-PAS CryoCam

Conclusions

• The e2v CryoCam has completed factory acceptance tests and passed the System Acceptance Review 😊😊😊

• From the final critical design review it has taken 15 months to complete the complex AIVT phases of the programme.

• System level tests have verified performance against all key aspects of the customer requirements

• Key features include
  • Precision construction and metrology to meet geometrical/mechanical specifications
    • e.g. exceeding the focal plane flatness spec to achieve 27 um p-v cryogenic flatness
  • Validated differential digital correlated double sampling signal chain
    • providing read-noise that exceeded guaranteed specification
  • Custom cryogenic/vacuum system for reliable and low maintenance operation

• We have demonstrated that the supply of a complex, high performance camera system can be undertaken by a commercial organisation. This includes use of rigorous quality systems, delivering guaranteed performance levels, as well as being to an agreed price and schedule
J-PAS CryoCam

Acknowledgements

Many people at e2v, in addition to the core e2v J-PAS team, have contributed to the successful delivery of this program.

I would also like to thank the J-PAS collaboration and those supporting the collaboration for valuable interactions throughout the project.
WE PARTNER WITH OUR CUSTOMERS TO IMPROVE, SAVE AND PROTECT PEOPLE’S LIVES

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