ESO VLT AO Wavefront Sensor Camera

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ABSTRACT

This paper describes the development of the ESO AO Wavefront Sensor Camera head which includes: the technology transfer from OCam to ESO AOWFS, the challenges of developing a high-speed and ultra compact camera along with the global system architecture in a multi-head scenario. Examples of the AO WFS head in GRAAL and GALACSI are given.

Keywords: Adaptive Optics, AO Wavefront Detector, Wavefront Sensor, L3Vision CCD, CMOS Imager, SPARTA.

1. INTRODUCTION

Along with NGC for scientific applications ESO has initiated the design and development of an end-to-end high-speed and high-performance camera for adaptive optics. This relatively recent new camera system features frame rates above 1kHz, negligible read-out and system noise combined with an extremely low compactness/complexity ratio.

This adaptive optics detector camera system will be the VLT standard for forthcoming wavefront sensors such as GRAAL (AO for HAWK-I), GALACSI (MUSE) and SAXO (SPHERE). The camera system is referred to as NGC-AO.

2. ESO AO WFS DETECTOR

The standard detector for the AO wavefront sensor camera is the L3-Vision CCD-220 from e2V. This custom CCD was developed as part of an agreement between ESO and e2v and features split frame-transfer, 240x240 pixels, 8 output ports and 500-tap gain register per port.

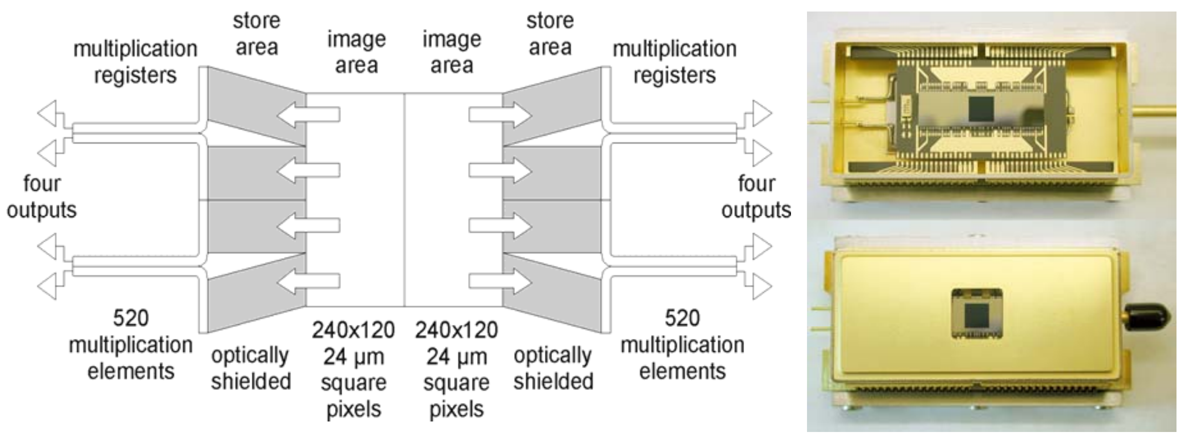


Figure 1: The CCD220

3. TECHNOLOGY TRANSFER

Almost parallel to the development of the CCD-220 and as part of Opticon, the Observatories in Marseille, Grenoble, and Haute Provence have developed the so-called OCAM camera, a test controller to validate the L3 (Low Light Level) Vision concept and the performance of the CCD-220. In order to accelerate the development of the ESO WFS camera, NGC-AO will take over the analog front-end of the OCam camera and will integrate it with a specially customized part of the digital electronics of NGC to form NGC-AO.

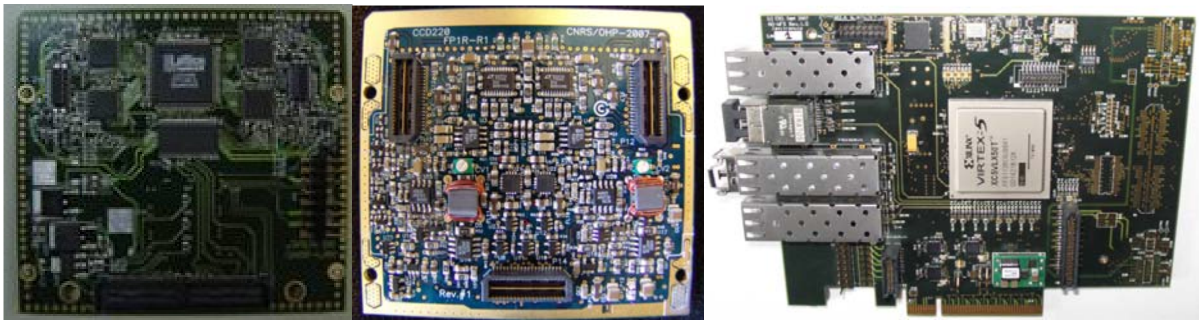


Figure 2: From left to right, OCam AD board, OCam clock board ard and NGC IF board.

4. THE CHALLENGES

Although the ESO AO camera focuses on only one type of detector the challenges in the design of the camera are various. In addition to the challenges related with driving an L3CCD and already present on OCam, e.g. 50V high-voltage generation and high-speed clock drivers, its compact size of only 235 x 190 x 75 mm imposes tight constraints to the electronics integrated inside, its volume, the electronics board arrangement and the total heat dissipation. Moreover, the high read-out speed adds an extra challenge to the sequencer which must run at sub-nanosecond resolution (78ps) and with the digital electronics which must be in close proximity of the detector.

In addition, the NGC-AO electronics must interface via dedicated fiber links to two different (wavelength, rate and protocol) nodes, namely the control LLCU (commands, telemetry, configuration) and to the ESO-SPARTA number cruncher (real-time data frames).

The camera is a self-contained LRU with extensive housekeeping capabilities like temperature sensors (CCD package, cooling block and electronics).

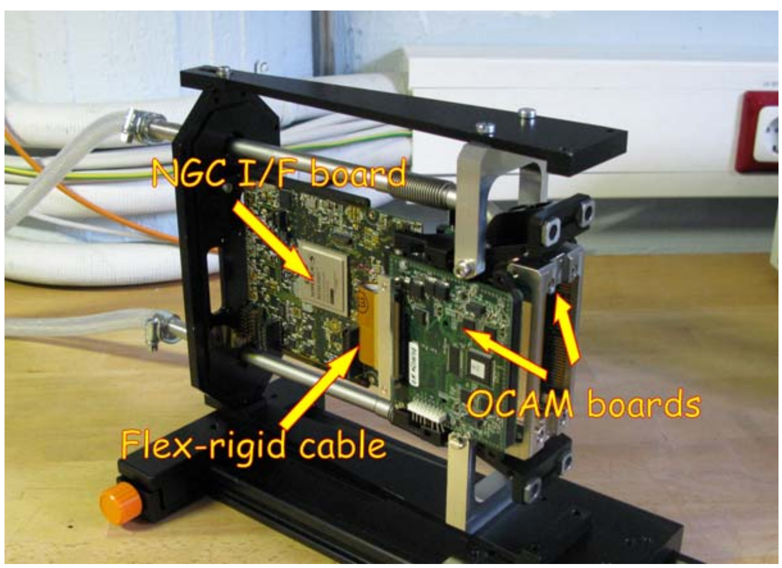


Figure 3: Integrated AO WFS head prototype.

5. SYSTEM ARCHITECTURE

On the front-end side, the components comprising the minimum detector system are the WFS camera head, the power supply and the Peltier controller. On the back-end side the components are a 19-inch control PC running Scientific Linux and a 64-bit/33MHz PCI-X board. Due to the high frame rate, raw frames are sent for processing via fiber to the ESO real-time number cruncher SPARTA.

Operation homogeneity: At the user level and from the LLCU side both NGC-AO and Scientific NGC are operated in a very similar way although they are two very different systems.

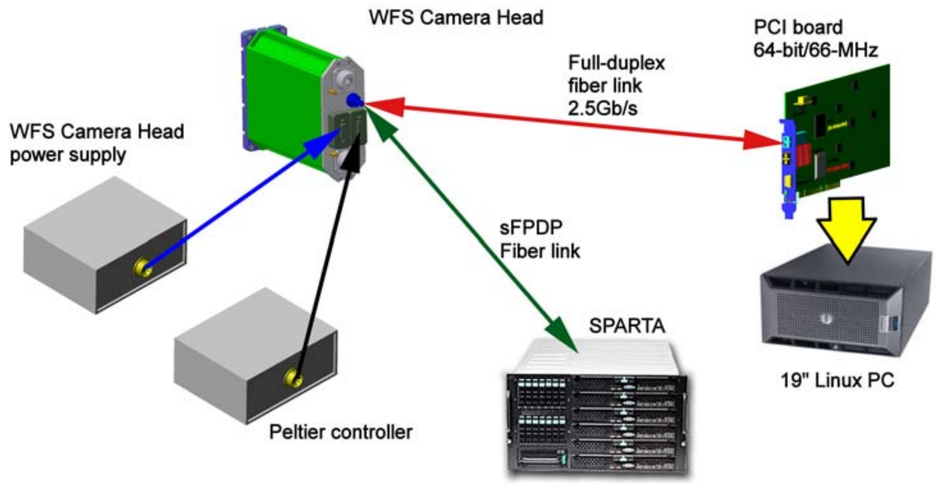


Figure 4: NGC WFS system architecture overview.

6. MULTI-HEAD CONNECTION TOPOLOGY

The camera can operate in stand-alone mode, e.g. tip-tilt, or synchronous with other heads in a multi-head scenario, in this case the cameras are connected in daisy-chain and controlled by only one LLCU. In a multi-head configuration each head runs its own sequencer and transmits the raw image frames simultaneously and independently to SPARTA.

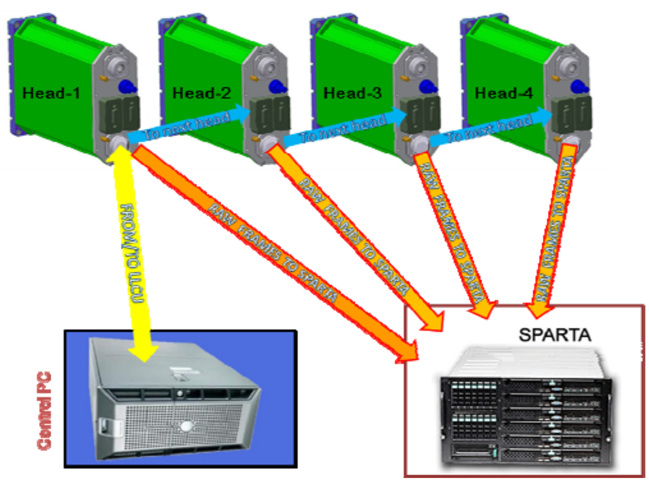
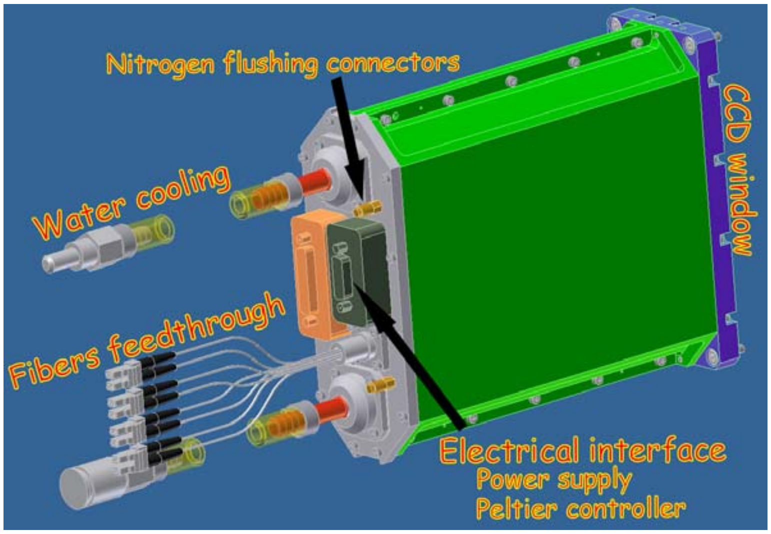


Figure 5: Multi-head connection architecture.

7. CAMERA MECHANICS

The mechanics junctures are rendered air tight and the camera is flooded with nitrogen at about 1.5atm to avoid water condensation. Highly compact humidity, temperature and pressure sensors are inside the electronics to monitor the operation working parameters and to provide alarms.



8. OVERILLUMINATION

The CCD220 is an EMCCD (Electron Multiplication CCD) with gain in the serial register by impact ionization which can result in aging or damage due to over-illumination. NGC-AO electronics senses the global RD current flowing to the CCD to detect over-illumination events and to reduce the gain in the multiplication register. In addition and at a much higher speed the NGC-AO firmware inspects the pixel values in real-time.

9. THE AO WFS IN GRAAL AND GALACSI

The four AO WFS and the tip-tilt cameras installed in GRAAL and GALACSI are shown in Figure XXX.

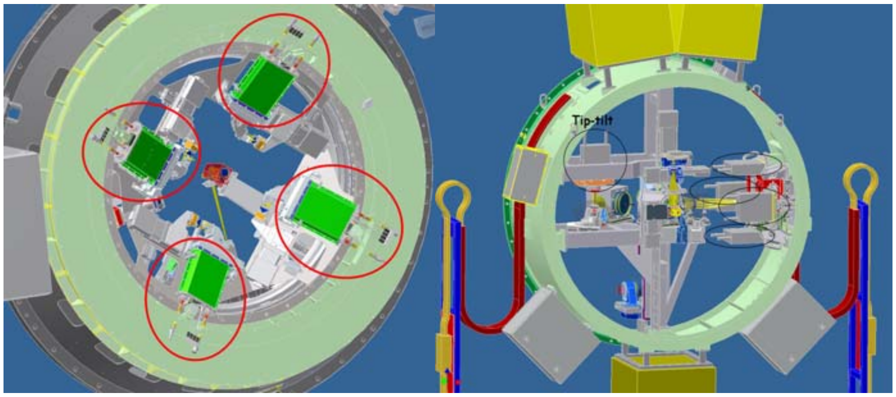


Figure 6: On the left GRAAL with 4 AOWFS heads and on the right GALACSI with one additional tip-tilt camera.

10. SUMMARY

Item	Value
CCD technology	e2v L3 Vision
Format	240 x 240, 8 output ports
Pixel size	24 x 24 μm^2
RON (high gain mode)	< 1e- (0.2 goal)
Frame rate	Above 1kHz, 1.2kHz nominal
CCD type	Split frame transfer 2-phase image section
Cooling	Integral Compact Peltier package + Water cooling
Water cooling flow	3l/min
CCD temperature	-40DegC
Video chain ADC	14-bit
Digital electronics	Xilinx Virtex-5 at 200MHz
Sequencer	200MHz, 5ns ticks, 78ps resolution
Link to PC	1310nm fiber link at 2.5Gb/s. Xilinx Aurora protocol
Link to SPARTA	850nm fiber link at 3.125Gb/s 1.4 Gb/s pixel rate sFPDP protocol (V-Metro)
Power supplies	2V, 3.6V, -10V, 15V, 25V, 60V
Peltier controller	Custom made, based on JUMO 2 heads per unit
Head size	3.5kg approx.
Gas filling	Nitrogen, flushed with a pressure difference of ~ 0,5bar

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