Optical Detector Systems

Dietrich Baade & Optical Detector Team (ODT)

Instrumentation Division

The ODT Themes

Support of La Silla Paranal

- regular counseling and trouble shooting (e.g., NAOS, WFI)
- detector upgrades: Giraffe, FORS1 (TBC)

VLT 2nd generation instruments:

- X-shooter (2 cameras with different detectors)
- MUSE (24 identical detector systems)

VLT projects in their own right but with an additional view of getting ready for ELT:

- Shift in emphasis from scientific imaging to signal sensing
- MAD tests enabling technology with natural guide stars
- OPTICON project with e2v L3 Vision technology pushes towards the ultra-low noise domain (HAWK-I, MUSE, PF)
- New General detector Controller (NGC) is a key element

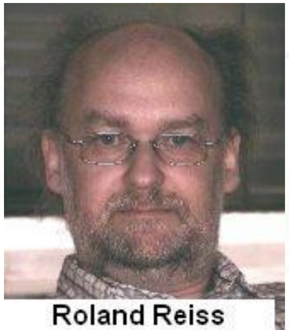
OmegaCAM for VLT Survey Telescope (VST)

Research & Development

Multi-conjugated Adaptive Optics Demonstrator

- MAD tests two wavefront-sensing (WFS) concepts:
  - o star oriented, using multiple Shack-Hartmann (SH) systems
  - o layer oriented (LO), using multiple pyramids

- 3 SHWFS + 2 LOWFS detector systems with e2v CCD39 devices (80 x 80 pixels)
- Only one method used at a time
- One FIERA controller
- Up to 400 frames/s (500 frames/s with 2x2 binning)
- With DSP optimization, FIERA spec of 1 Mpix/s much exceeded
- Read noise: ~ 6-7 e^-
- Status: waiting for shipment readiness



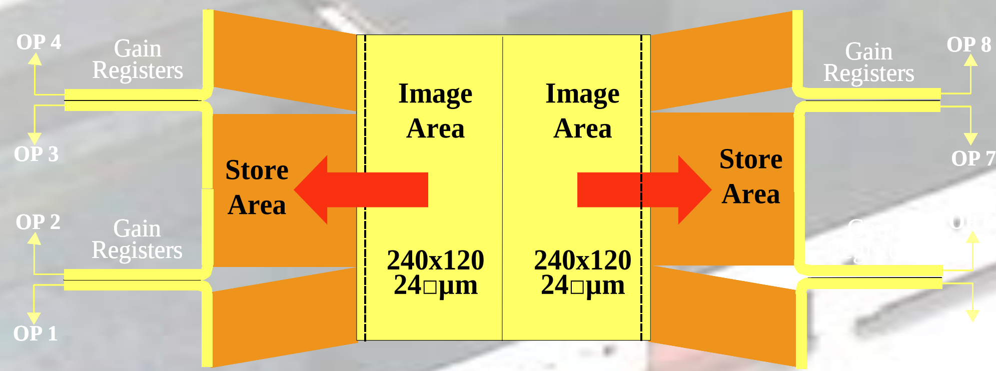
Next-generation Wavefront Sensing: OPTICON and e2v L3 Vision Technology

AO systems for 2nd-gen. VLT instruments require:

- **>1,000 actuators (→ >1,000 SH cells of 6x6 pixels)**
- **~1 kHz frame rate**
- **negligible read noise even when photon noise ~100%**
- **high movability (→ no real cryogenics → dark current)**

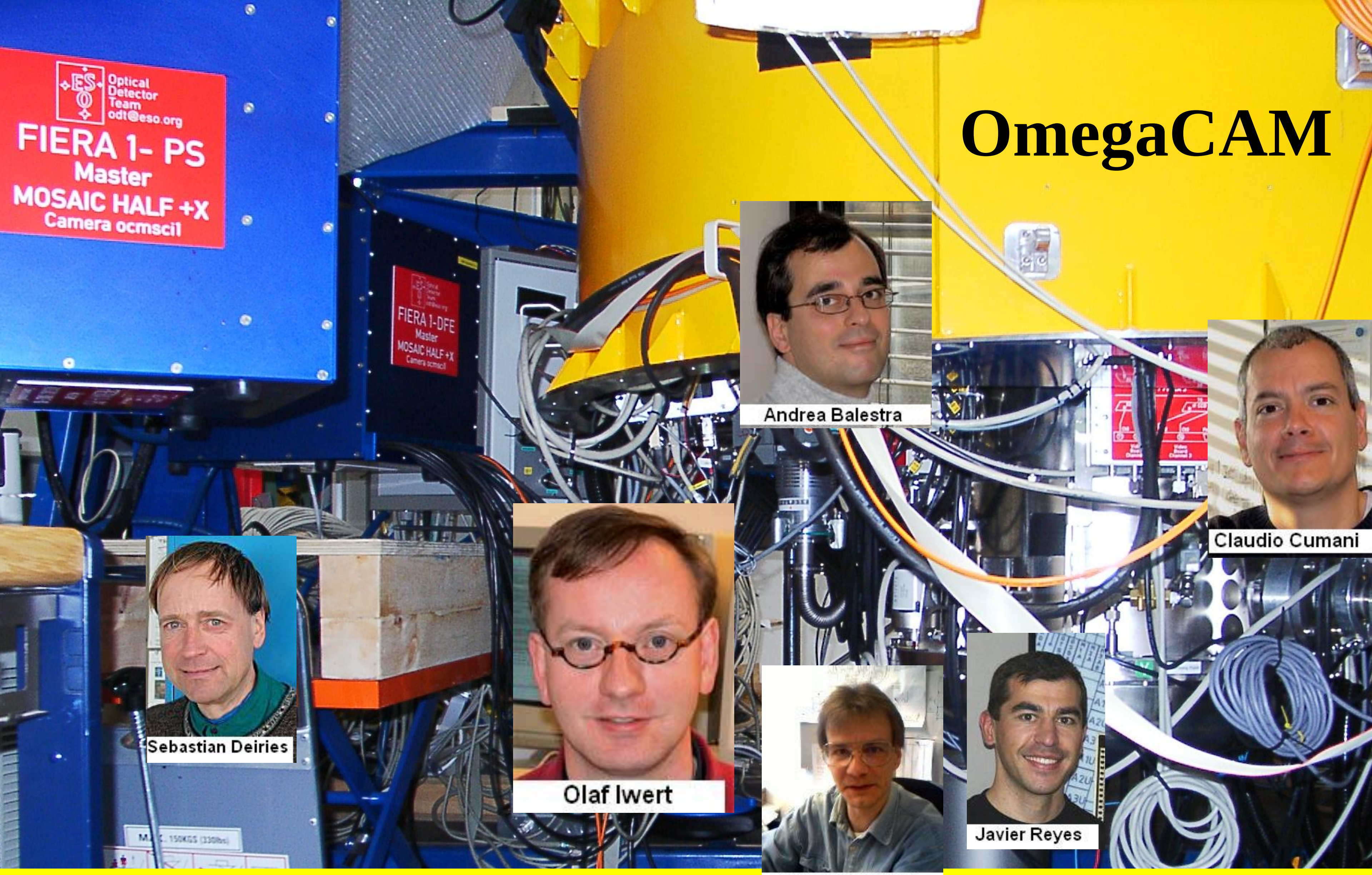
➢ **OPTICON-funded custom development by e2v (Q2/2007)**

➢ **L3 Vision (electron-multiplication) technology**



- 6+1 systems for GRAAL (HAWK-I)
- 5+2 for GALACSI (MUSE)
- 1+1 for Planet Finder

OmegaCAM



- **1 x1 wide-angle camera for 2.6-mVLT Survey Telescope (VST)**
- **32 (+4) 2k x 4k CCDs (0.27 10^9 science pixels)**

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<u>OmegaCAM</u>

Sleeping Beauty

Jack in the Box

(Waiting for a

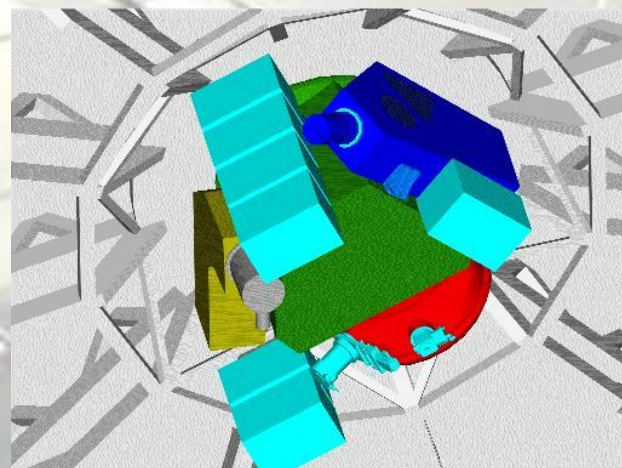
<u>V</u>ery <u>S</u>weet <u>T</u>empter)

Detector system (cf. 2005 EWR presentation by Olaf Iwert):

- **passed acceptance tests by OmegaCAM consortium**
- **undergoing some last tests at variable directions of gravity**
- **will be boxed in April (?)**

X-shooter

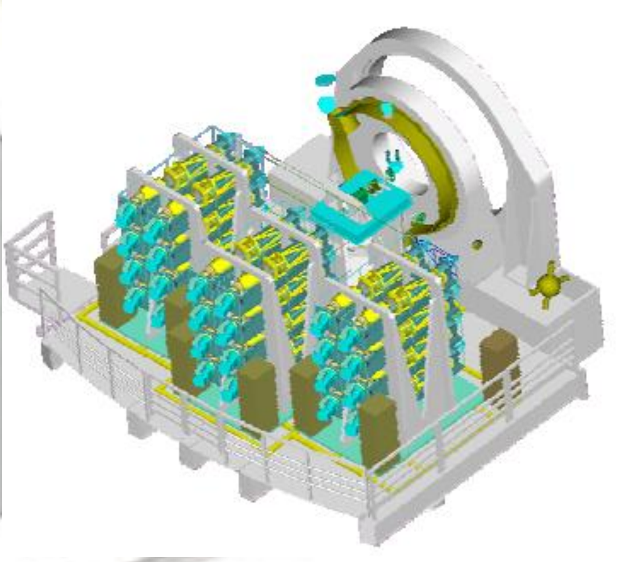
- **First ESO instrument to bridge the 1-micron barrier**
- **1 IR arm (Rockwell Hawaii-2 RG with IRACE controller)**
- **2 optical arms (e2v CCD44-82 and MIT/LL CCID-20)**



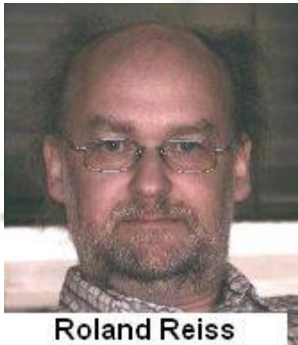
- **FIERA software defines 2 nearly fully independent virtual cameras on one common front-end electronics**
- **Detectors selected and fully characterized**
- **FDR this week; integration has started**
- **Commissioning in 2008**

Multi-unit Spectroscopic Explorer (MUSE)

- Twenty-four separate detector systems
- 4K x 4K CCDs (or 2 x 1 2K x 4K mosaics)
- 465 – 930 nm: high red response is mission critical
- CCDs from e2v and Fairchild
  in house for evaluation
- Need to save mass and volume
- Must ease AIT; have draft of ICD



- First optical instrument to use NGC
- First usage of 2nd-generation cryostat head
- Prototype detector system at the end of 2006



R&D projects (I): boosted UV sensitivity

Recipe accidentally (re-)discovered:

- **heat (and illuminate) CCD for some hours in dry oxygen-rich gas**

Results:

- **quantum efficiency in UV much enhanced**
- **synthetic air almost as good as pure O_2 (safety!)**
- **under vacuum, stability for at least 2 months**

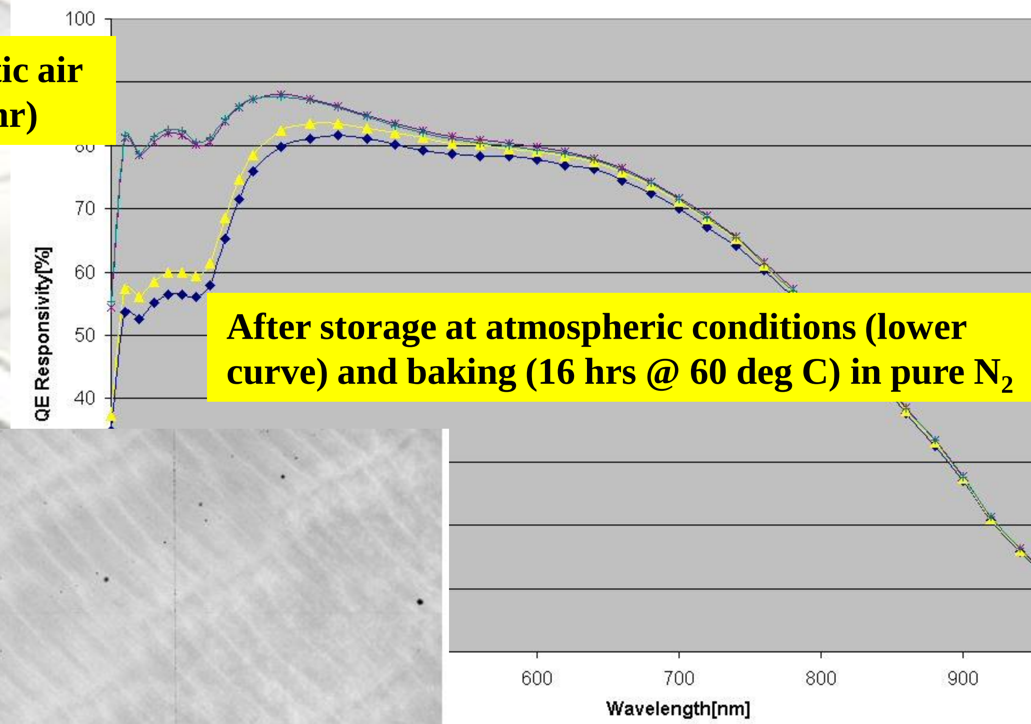
TBD:

- **relevance of light source during baking?**
- **explanation (manufacturers do not know)**

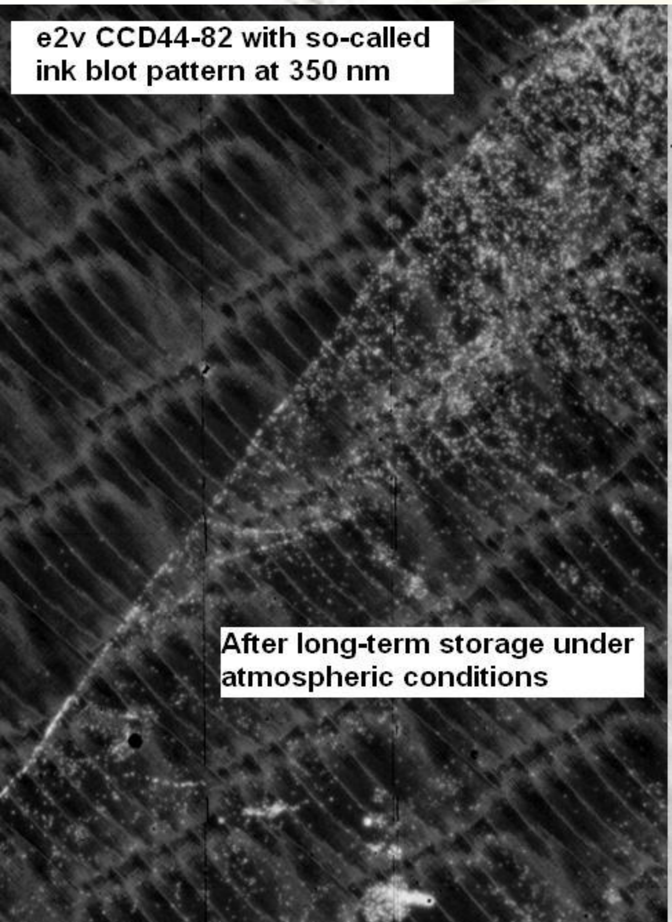

Sebastian Deiries

“Marlene” (formerly in UVES blue arm)

After baking (@60 deg C) in synthetic air (3 hrs; lower curve) and pure O_2 (1 hr)



After storage at atmospheric conditions (lower curve) and baking (16 hrs @ 60 deg C) in pure N_2



R&D (II): non-linear photon transfer curves

Photon transfer curves are useful to check, e.g., the linearity of detector systems:

$$\text{illumination} \sim \text{response} \sim \text{rms}^2_{\text{response}}$$

Result:

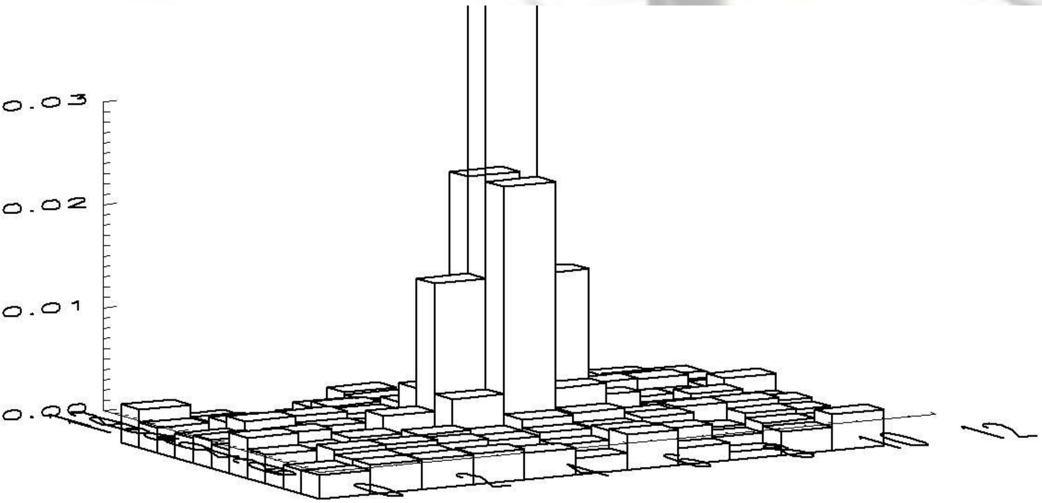
- **Response is proportional to illumination**

➢ **Detector response is basically linear**

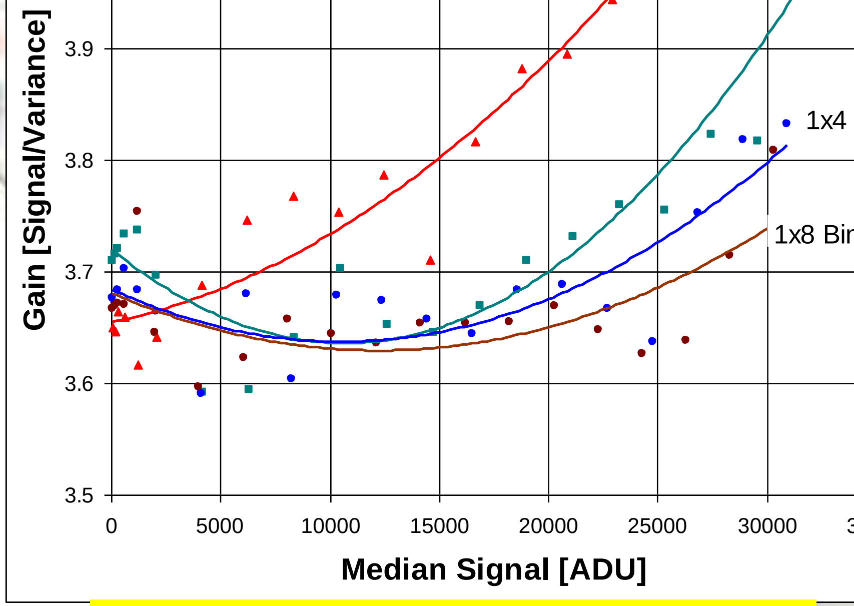
- **PTCs of some CCDs (e2v 44-82, MIT/LL CCID-20) non-linear**

➢ **At high illumination levels, detectors *seem* to beat photon statistics ...**


Mark Downing



2-D cross-correlation function



Non-linear photon transfer curve

Analysis:

- Neighbouring pixels know about each other’s signal

Explanation:

- TBD (charge diffusion [spill-over] is excluded)

THANKS

Without well integrated, cool (even cryogenic) and evacuated (but by no means empty) support from the Integration and Cryovacuum Department

optical detector systems would be rather hot potatoes …

Not to forget numerous ADD, DMD, INS, LSP, and TEC staff!

New general Detector Controller (NGC)

Dietrich Baade & NGC Team

Instrumentation Division

Rationale

- **In the decade since 1998, a total of 30 FIERA and IRACE systems will be deployed.**
- **Extremely successful (<u>nearly negligible telescope downtime</u>) but various limitations, e.g.:**
  - **mass (OmegaCAM: ¼ ton), volume, heat dissipation**
  - **obsolete components**
  - **voltage range and swing**
  - **speed, number of channels**
  - **2 successes (= 2 costs)**

➢ **Make new design, taking advantage of new technologies**

➢ **Do it as a joint IR+ODT effort, merging all past experience**

NGC Design Principles (I.)

- No parallel bus system for communication and data transfer
- Central element on each board is a Xilinx Virtex Pro FPGA
- High-speed serial fiber links between back and front ends

NGC Design Principles (II.)

- Common core (= basic board)
- Additional boards for special applications

- Basic board has 4 channels
- 32 channel acquisition board for larger systems
- With high-speed serial links boards combinable to arbitrary number of channels

- Power dissipation of basic system 10-20 W: no water cooling
- Extensive telemetry and self-testing for remote diagnostics

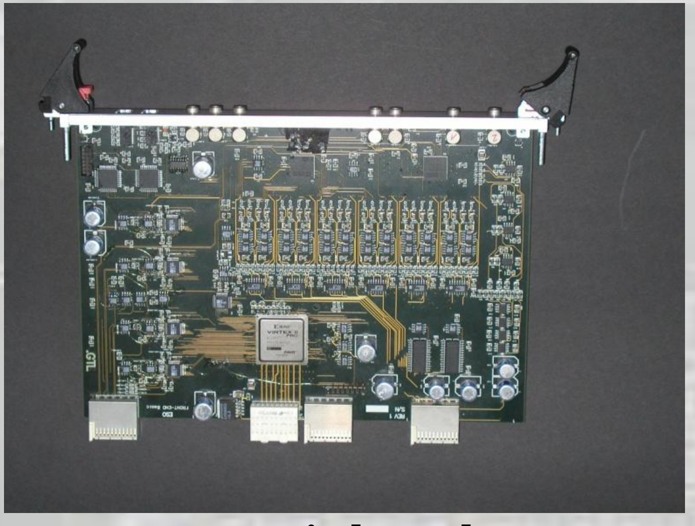
NGC Design Principles (III.)

- PCI interface to acquisition computer
- USB I/F for maintenance purposes under consideration
- Linux-based control software VLT & DICD compliant
- Common software to access NGC hardware
- Wavelength-specific S/W for detector control and user I/F

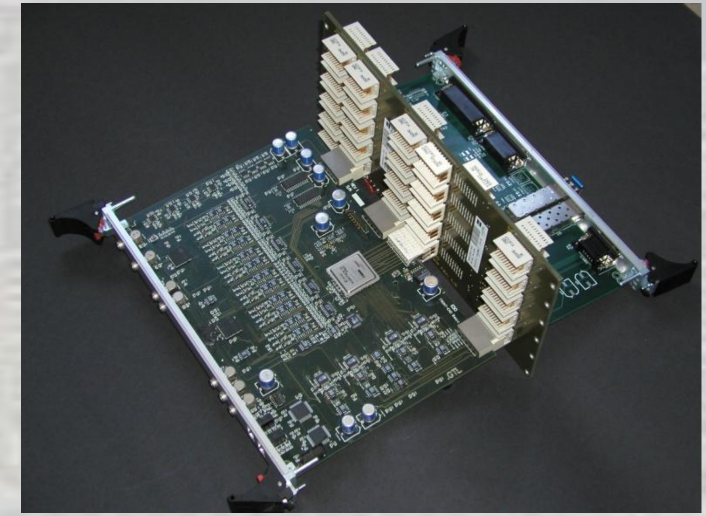
NGC Status

2003 Mar.:	study specification
2004 Mar.:	requirements document
2004 Nov.:	1st light of prototype (4 chan.) with IR array
2005 Mar.:	1st light of prototype with optical CCD
2005 June	prototype control software
2005 Jul.:	control software requirements
2005 Oct.:	prototype 32-channel acquisition board
2005 Oct.:	pre-amplifier for CCDs
2005 Nov.:	user manual of base (wavelength-indep.) software
2005 Nov.:	first images with L3 Vision CCD (5 Mpixel/s)
2006 Jan.:	design documents for IR and OPT software
2006 Feb.:	first release of waveform editor

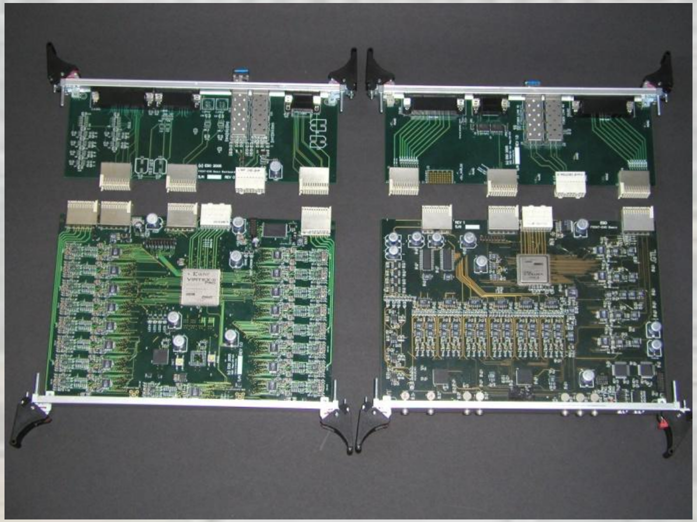
NGC picture gallery



Basic board



Basic board + associated backboard;
backplane between them
(minimum for 4 channels, e.g. 1-4 CCDs)



Basic and 34-channel acquisition board
+ associated backboards (minimum for
IR Hawaii-2RG [or OmegaCAM])

NGC Planning

- 2006 May: all boards revised
- 2006 May: power supplies and mechanics defined
- 2006 Jul.: test with CCD finished
- 2006 Sep.: tests with Rockwell Hawaii 2 RG finished
- 2006 Dec.: prototype for MUSE (TBC)
- 2007 Jan.: NGC1 for KMOS (Hawaii-2RG)
- 2007 May: first tests with e2v CCD-220 (AO)
- 2008 Mar.: NGC1&2 for KMOS
- 2008 May: NGC1&2 for ZIMPOL (Planet Finder)
- 2008 Sep.: NGC1&2 for Planet Finder (Hawaii-2RG)
- 2008 Sep.: NGC1 for MUSE
- 2008 Dec.: AO (GALACSI, GRAAL) prototype
- 2008 Dec.: 6+1 systems for GRAAL (HAWK-I)
- 2008 Dec.: 5+2 systems for GALACSI (MUSE)
- 2008 Dec.: 1+1 AO systems for Planet Finder
- 2010 Jun.: NGC7 for MUSE

NGC Team building from a mixed cast of characters


Siegfried Eschbaumer


Dietrich Baade

Phase 1: Falling into place.


Joerg Stegmeier


Andrea Balestra


Gert Finger


Claudio Cumani


Javier Reyes

se 2: Shaping up.


Leander Mehrgan


Manfred Meyer


Stefan Hoetzl


Alessandro Bortolussi

Phase 3: Ridin aves.


Christoph Geimer

(Human resource management mode of NGC Waveform Editor)