SLICING THE UNIVERSE
CCDs for MUSE

Roland Reiss[1], Sebastian Deiries[1], Jean Louis Lizon[1], Manfred Meyer[1], Javier Reyes[1], Roland Bacon[2], François Hénault[2], Magali Loupias[2]
[1]European Southern Observatory, Karl-Schwarzschild-Str. 2 D-85748 Garching by Munich, Germany; [2]CRAL - Observatoire de Lyon, 9 avenue Charles André, 69230 Saint-Genis-Laval, France

Abstract: *MUSE, the Multi Unit Spectral Explorer, is a 2nd generation instrument for the VLT. It is built by a consortium of European institutes and ESO. MUSE consists of 24 Integral Field Units each equipped with its own cryogenically cooled CCD head. The detector size is 4096x4096 with 15 µm pixels.*

In this paper we discuss the requirements for the CCDs and give an overview of the design status of the detector system. Because of the large number of units the complexity of each unit has to be reduced to save cost and man power and increase reliability. We present a novel preamplifier to be used inside the very compact detector head with pulse tube cooling and show how ESO's New General detector Controller (NGC) is adapted to this application.

Key words: CCD; cascode amplifier; detector controller; instrument; pulse tube.

1. OVERVIEW

MUSE is an integral field spectrometer mounted at the Nasmyth focus of one of the VLT telescopes. Figure 1 shows the tentative optical configuration. The Fore Optics (FO) splits a large field of view into 24 sub-fields. 24 Integral Field Units (IFU) provide the spectral decomposition of the sub fields. The IFUs include an Image Slicer Subsystem (ISS), Spectrometer Subsystem (SPS) and an Instrument Detector Subsystem (IDS). The spectral coverage of MUSE is 465 to 930 nm, the total field of view in wide field mode is 1x1 arcmin^2, and 7.5x7.5 arcsec^2 in narrow field mode. The total weight of the instrument will be approximately 7 tons. Commissioning of MUSE is planned for 2011.

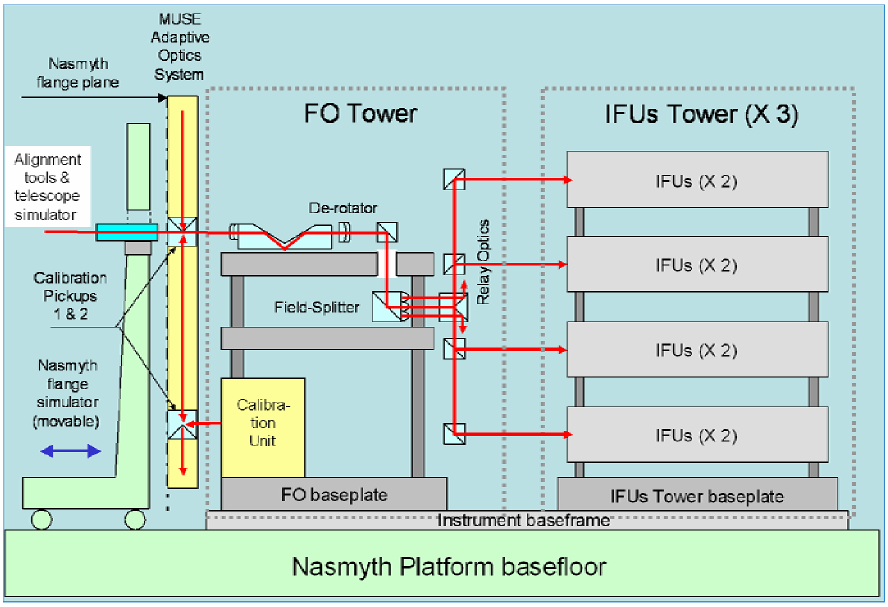

Figure 1. MUSE optical configuration

2. CRYOGENICS

The 24 detectors are housed in 24 separate cryostats which are cooled using separate low frequency Pulse Tube Heads (PTH). The 24 PTHs are custom made and powered by two Coolpack 6000 compressors from Leybold. The prototype cooler has been developed in collaboration with the Service Basse Temperature from the CEA Grenoble. The actual performance of the prototype is 4 Watts at 120 K at a Helium flow rate of 100 l/s. The design is driven by the tight space and weight constraints of MUSE. Figure 2 shows a prototype of the new compact CCD head, which will also be the standard head for future optical ESO instruments.

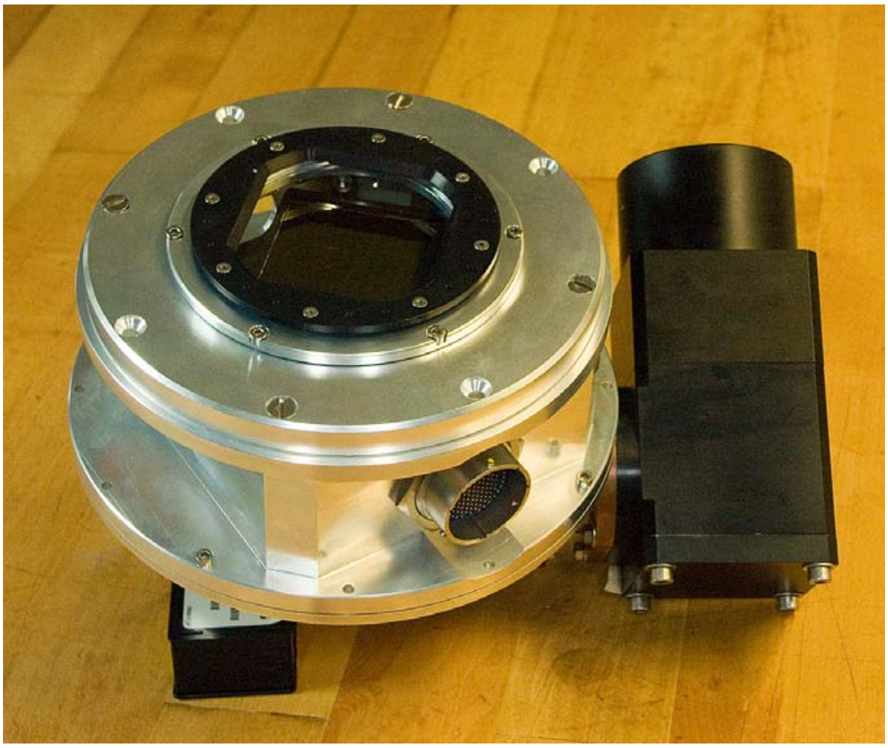

Figure 2. CCD head prototype

3. CCD HEAD ELECTRONICS

The first buffer stage for the CCD outputs is a cascode stage with two low noise JFETS Q1 and Q2 (Figure 3). Q1 acts as a source follower with a gain slightly below 1. Because the resistors R1 and R2 are equal, the signal voltages across R1 and R2 are also equal but with opposite phase. R3 and R4 provide the DC bias for Q2. The advantage of this circuit is a gain two times higher compared to a single buffer stage. As a benefit the circuit delivers a true differential output signal. L1 is a common mode choke to improve noise immunity. Q3 is the usual JFET current source to set a proper load current (1 to 2.4 mA) on the CCD output.

The subsequent video processing stage consists of a differential input amplifier with a line clamp circuit. The way how the video signal will be further processed is currently under investigation. Options under consideration are:

- Classical clamp-and-sample, similar to the circuit used i.e. with FIERA (Gerdes et al., 2000), where the sampling is actually done by the Analog-to-Digital Converter (ADC).
- Sample-hold stage with subsequent differential amplifier to subtract the sampled reference level from the signal level. The resulting signal is then sampled and converted by the ADC.
- Sampling of reference and signal level with the same sampling ADC and subtraction by software (Digital Double Sampling).

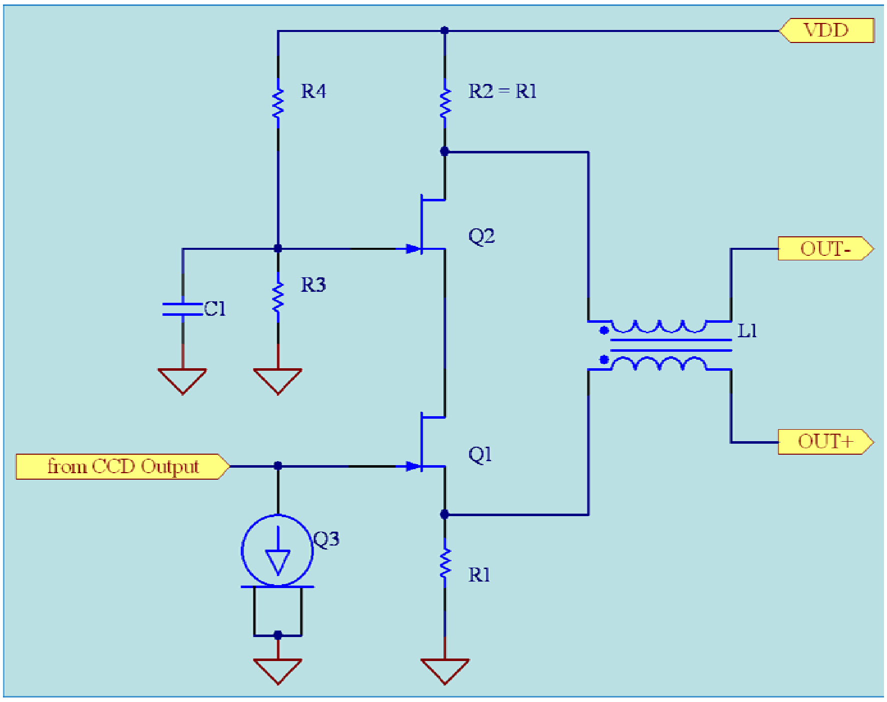

Figure 3. Cascode CCD buffer stage

4. DETECTOR CONTROLLER

Because of the large number of units the complexity of each unit has to be reduced to save cost and man power and increase reliability. ESO's New General detector Controller (NGC) will be used for MUSE. NGC has been selected because of it's compact size and low power consumption. Each of the 24 CCDs is driven by a single board containing 4 video channels, 20 bias and 16 clock sources. One controller unit will contain 4 such boards (Figure 4). In total 6 NGCs are required to operate the 24 CCDs. A detailed description of NGC can be found in Meyer et al., 2005.

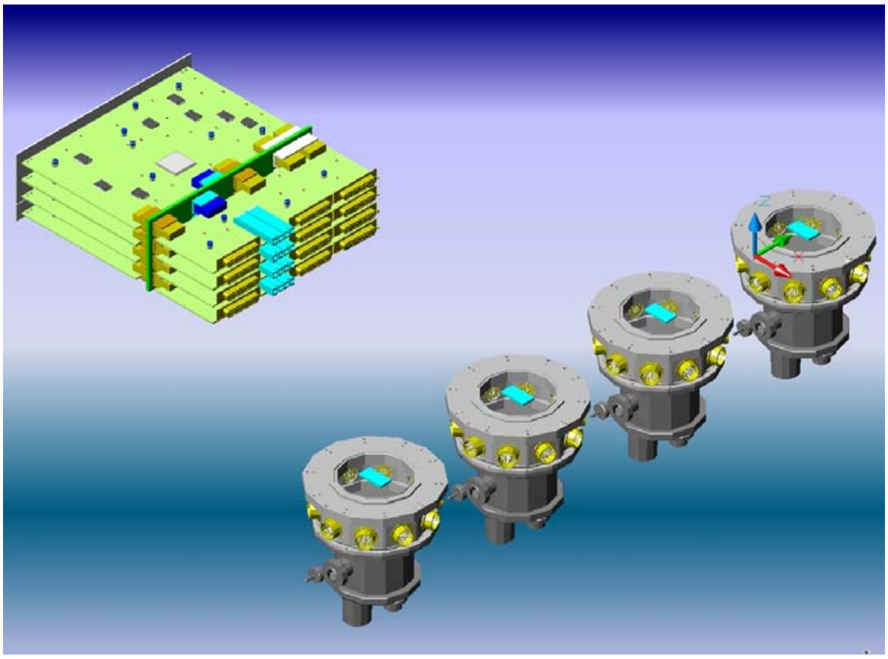

Figure 4. NGC configuration

5. CCD REQUIREMENTS

Table 1 below shows the preliminary requirements for the most important CCD characteristics. Given the faintness of the science targets, the detector QE is of prime importance. Special attention is given to the redder ($\lambda > 0.6$ µm) part of the spectral range where the QE should be optimized. The gap from 570 to 610 nm in the QE requirements is given by the fact that a notch filter in the optical path supresses scattered light of the Sodium Laser guide stars used for Adaptive Optics (AO).

Constraints on the chip flatness are due to the camera aperture (f/1.9) and expected image quality.

Table 1. Preliminary detector requirements

Item	Value	Remarks
Detector format	4096 x 4096 or 2x 2048 x 4096	
Detector dimensions	61.4 x 61.4 mm2	
Pixel size	15 x 15 µm2	
QE 465 – 570 nm	85% min; 90% goal	
QE 610 – 800 nm	85% min; 90% goal	
QE 800 – 930 nm	60% min; 70% goal	
PRNU	< 10%	Peak-to-peak
Fringing	< 10 %	Peak-to-peak of avg. sensitivity
Fringe stability	< 1%	Within 24 hours
Flat field stability	< 1%	Per night
Readout time	Goal:1 min; max: 3 min	4-port readout
Readout noise	< 4 e- RMS	@ 50 kpix/sec
Binning capability	4 x 4	Without increase of noise
Dark current	< 2 e-/pix/h	
Charge transfer efficiency	> 0.999995	
Linearity	< 1%	Up to 50,000 e-
Full well	> 100,000 e-	
Blooming full well	> 200,000 e-	
Charge diffusion	< 0.1 pixel	FWHM equivalent gaussion convolution
Surface flatness	< 20 µm pp	
Cosmetics	Science grade	Number of defects TBD, no bright or dark columns.

REFERENCES

Gerdes, R, Beletic J. W., and Duvarney, R. C., 1998, Design concepts for a fast-readout low-noise CCD controller, Proc. SPIE Vol. 3355, p. 520-528, Optical Astronomical Instrumentation, Sandro D'Odorico; Ed.

Meyer M. et al, 2005, ESO's next generation controller. Talk at SDW2005 in Taormina.