A Tenth Birthday Present for UVES: A CCD Upgrade of the Red Arm

Jonathan Smoker[1]
Nicolas Haddad[1]
Olaf Iwert[1]
Sebastian Deiries[1]
Andrea Modigliani[1]
Suzanna Randall[1]
Sandro D'Odorico[1]
Gaël James[1]
Gaspare Lo Curto[1]
Pascal Robert[1]
Luca Pasquini[1]
Mark Downing[1]
Cédric Ledoux[1]
Christophe Martayan[1]
Thomas Dall[1]
Jakob Vinther[1]
Claudio Melo[1]
Andrew Fox[1]
John Pritchard[1]
Dietrich Baade[1]
Hans Dekker[1]

[1] ESO

During July 2009, a new MIT CCD, Zeus (previously part of the EMMI spectrograph), was installed in UVES to replace Nigel, the high-wavelength part of the red CCD mosaic. The main characteristics of Zeus are reported.

The Ultraviolet and Visual Echelle Spectrograph[1] (UVES) is the VLT's high resolution optical spectrograph located at the Nasmyth B focus of the VLT Unit Telescope 2 (Kueyen). It is a cross-dispersed echelle spectrograph designed to operate with high efficiency from the atmospheric cut-off at 300 nm to the long-wavelength limit of the CCD detectors (about 1100 nm). The maximum resolution is 80 000 and 110 000 in the blue and red arms respectively (for details, see Dekker et al., 2000). The instrument was installed at the Paranal Observatory in 1999. The red arm detector consisted of a mosaic of an EEV CCD (named Sting) at lower wavelengths and an MIT/LL CCD (called Nigel) at higher wavelengths. The latter was the first device from Massachusetts Institute of Technology Lincoln Laboratories (MIT/LL) to become available to ESO via a best effort development programme led by the University of Hawaii. The next generation of MIT/LL CCDs that ESO received and installed (for example for the ESO Multi-Mode Instrument [EMMI] and the FOcal Reducer and low dispersion Spectrograph [FORS2]), were of superior quality. Upgrading the CCD mosaic in UVES has long been on ESO's agenda. The opportunity finally arose to carry it out with the decommissioning of EMMI and the availability of an MIT/LL CCD (named Zeus) from that instrument. Ten years after its installation, UVES is still an instrument very much in demand (it occupies fourth position in the list of most-requested VLT instruments). The installation of the new CCD significantly increases the performance at the red end of its spectral range, which is interesting for both stellar and extragalactic work.

Readout Mode	Gain Zeus : Nigel (Electrons per ADU)	Readout Noise Zeus : Nigel (Electrons rms)
225 kHz, 1 × 1, low gain	1.41 : 1.50	3.7 : 3.8
225 kHz, 1 × 2, low gain	1.41 : 1.50	3.7 : 3.8
625 kHz, 1 × 1, low gain	1.41 : 1.50	4.7 : 4.9
50 kHz, 2 × 2, high gain	0.46 : 0.57	2.1 : 3.4

Table 1. Common readout modes for MIT/LL CCD Zeus compared with Nigel. The saturation level is now ~ 65 000 ADUs compared with ~ 45 000 ADUs for Nigel.

Characteristics of Zeus

Zeus is a deep depletion 2k × 4k CCD (MIT serial number 4-10-2), with pixel size of 15 μm and nominal thickness of 40 μm, compared with the old CCD Nigel, which had a thickness of 20 μm. For the replacement of Nigel, the UVES red cryostat was shipped to Garching and hence only the blue arm of UVES was available between 1 May and 15 July 2009. In Garching the quantum efficiency (QE) of the old mosaic was measured, Nigel was replaced by Zeus, and the QE of the new mosaic obtained. The readout modes are the same as previously offered and the most commonly used ones are listed in Table 1.

Due to variation in the packaging of the CCDs, the gaps between the two parts of the mosaic are now ~ 1250 μm at the bottom, close to the readout register, and ~ 1470 μm at the top. This introduces tilts in the dispersion direction of arc or sky lines of + 0.35 pixels for the EEV and – 0.05 pixels for the MIT, when a 10-arcsecond-long slit is used. The spectral format has also slightly changed, requiring upgrades to the exposure time calculator and UVES pipeline. Versions 4.4.7 and higher of the pipeline will reduce both old and new mosaic observations.

The cosmetics of Zeus are excellent. The most obvious defects are three bad columns in the 50 kHz, 2 × 2 high gain (HG) readout mode with peak values of between 1 and 50 ADU above the bias level and a glow of about 10 ADU peak visible in the first 200 pixels in 625 kHz, 1 × 1 low gain (LG) and 50 kHz, 2 × 2, HG. The MIT/LL CCD is linear to better than 0.7 % up to ~ 55 000 ADU in 50 kHz, 2 × 2, HG and 225 kHz, 1 × 1, LG, with a saturation level of ~ 65 000 ADU compared with ~ 45 000 ADU for Nigel.

Owing to the fact that Zeus is a thick CCD, the fringing is much reduced compared with Nigel. Figure 1 shows a comparison of the extracted spectrum of a B-type star without flatfielding for Nigel and Zeus.

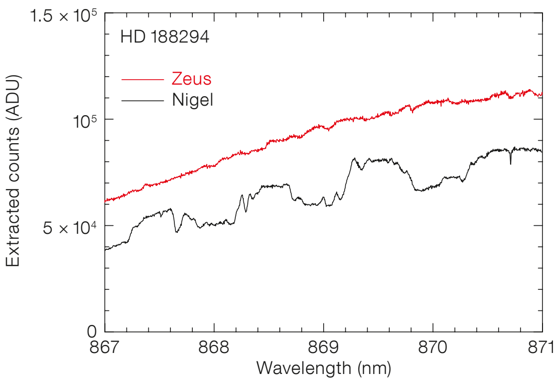

Figure 1. Part of the spectrum of the same fast-rotating star HD 188294 obtained with Nigel and Zeus. The greatly reduced fringing with Zeus is apparent. No flatfielding has been performed.

The QE for Zeus was measured both in the laboratory and on-sky by the use of standard stars. The efficiency of Zeus is approximately 84 % at 800 nm, 64 % at 900 nm and 18 % at 1 µm. Figure 2 shows the ratio of the Zeus/Nigel QEs. Between ~ 500–700 nm the efficiencies of the two CCDs are very similar, however redwards of 700 nm there is a steady increase in throughput, reaching a factor of ~ 1.6 at the wavelength of the calcium triplet at 860 nm and increasing to a factor of ~ 2 at 900 nm.

Although the move to the thick CCD has brought enormous benefits in terms of reduced fringing and increased QE, there is a (small) price to pay. The first issue is a higher cosmic ray count, which has increased by ~ 70 % with respect to the value in Nigel. A cosmic-ray removal test using *lacosmic* in IRAF found, in 3600 s of integration time, that ~ 0.27 % of pixels were affected by cosmic rays. The second issue is increased remanence after oversaturation caused by strong argon lines in the ThAr arc calibrations redward of ~ 660 nm. These can last for several hours and the pre-existing policy of not allowing such attached calibrations at night during service mode will be strictly enforced. The Paranal Instrumentation team, in cooperation with the Optical Detector Team Garching, is investigating the possibility of mitigating this problem by using a special readout mode to get rid of the remanence before the next science or calibration image.

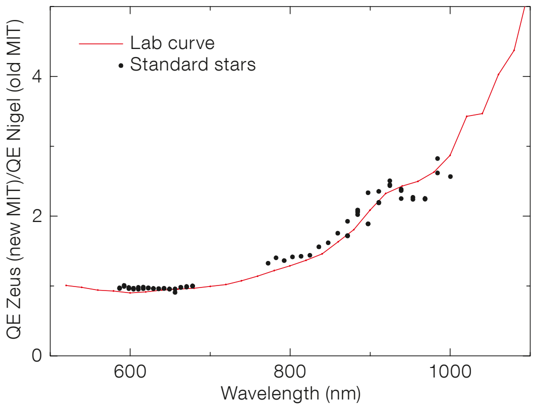

Figure 2. Ratio of quantum efficiencies of Zeus and Nigel derived from laboratory measurements and standard stars.

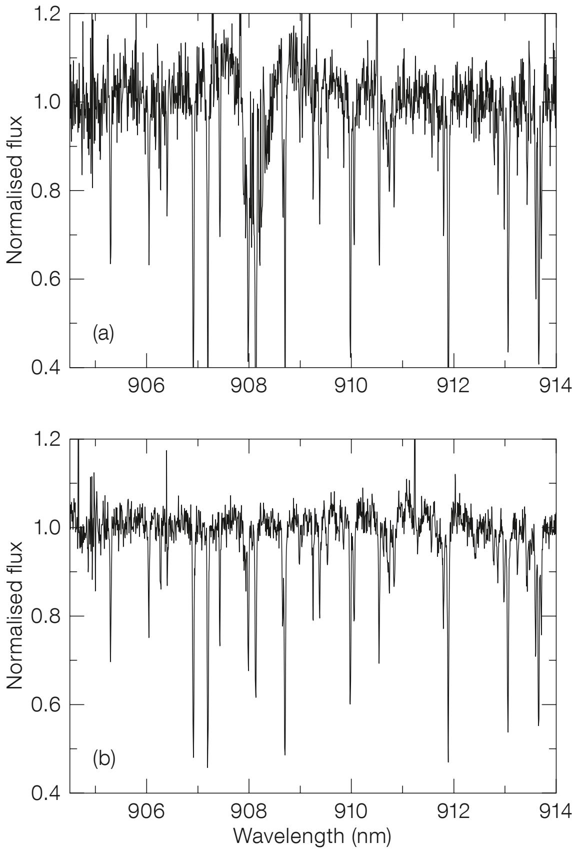

Figure 3. (a) Exposure of 4500 s with a 0.9-arcsecond slit towards the quasar QSO 1331+1704 with the old CCD mosaic from 904.5–914 nm. (b) A repeated observation with the same exposure time, but with the new mosaic. The narrow telluric lines were weaker in the later observations.

Zeus — on-sky tests

A number of on-sky test exposures were taken of fast-rotating stars previously observed with Nigel in the Paranal Observatory Project (Bagnulo et al., 2003). All data are publicly available in the ESO archive[2]. The extracted profiles and spectral resolution are similar in Nigel and Zeus, indicating little change in the point spread function before and after the upgrade.

Additionally, the quasar QSO 1331+1704 was observed. This quasar had previous observations from the first UVES commissioning. Figure 3 shows a comparison of the old and new observations at a wavelength of around 910 nm with equal exposure times. The improvement in the signal-to-noise ratio of the spectrum is immediately apparent. We note that the EEV CCD spectra (bluest part of the red mosaic) for the two epochs are very similar, indicating that the improvement is not due to better observing conditions, but to the new CCD.

In conclusion, the on-sky tests confirm the laboratory measurements and indicate that the replacement of the CCD has lived up to expectations, enhancing the longest wavelength data from UVES.

References

Bagnulo, S. et al. 2003, The Messenger, 114, 10
Dekker, H. et al. 2000, SPIE, 4008, 534

Links

[1] UVES: http://www.eso.org/sci/facilities/paranal/instruments/uves/
[2] ESO archive: http://archive.eso.org/eso/eso_archive_main.html