Early Results from the MODS 8k x 3k CCDs

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Abstract

First results are presented for the 123 mm wide e2v CCD231-68 CCDs on the Ohio State University MODS spectrograph for the Large Binocular Telescope. Both the blue and 40 micron thick red variants are now in operation on the spectrograph. The characteristics of these 8k x 3k 15 μ CCDs and the Ohio State controller are given. An astronomical spectra taken with our 62.5 μ diameter telescope (of a G2 V star) is shown.

Background

The two dual-channel MODS Spectrographs will be the instrument for low and medium resolution multi-object optical spectroscopy on the 11.8-m equivalent aperture Large Binocular Telescope. The design goals for MODS included high throughput and complete coverage from the atmospheric cutoff in the UV to the practical limit of silicon detectors in the near IR. Since the space in the focal plane perpendicular to the dispersion was required for multi-object spectroscopy the spectrograph had to operate in a single order mode. Grating dispersers were required because no reasonable prism disperser could provide the desired resolution of up to ~8000. Gratings can cover, at best, a factor of two in wavelength without something akin to cross dispersion, and therefore, to cover the desired factor of three in wavelength, two separate channels, red and blue, are required. The adopted solution was to place a high efficiency dichroic beam splitter directly behind the slit-mask, reflecting the light redward of of 550nm and transmitting the blue light. The two separately optimized channels can thereby operate simultaneously on the same field. High throughput is achieved by both optimizing the red and blue optics and coatings as well as by minimizeing the number of surfaces. The colimator is a simple decentered parabaloide while the camera has just two transmissive elements, a highly aspheric corrector and the vacuum window/field flattener, and a spherical primary mirror.

Detector design

Two considerations led to the definition of the detector format. The available 6 arcmin telescope field and the desired ¼ arcsec resolution along the slit defined one dimension of the detector. As a practical matter the family of optical designs chosen for camera does not produce more than about 4000 resolution elements in the dispersion direction. Several combinations of existing detectors were considered, unfortunately all of them lead to an unacceptable gap in the spectral direction, right in the middle. A new design, 8k x 3k with 15 μ pixels from e2v, satisfied our requirements.

Models of the final signal-to-noise showed that maximum observing efficiency requires a very low noise readout. Readout noise is, obviously, most important in observations of faint objects with low signal-to-noise, which is one of the prime missions of MODS. We initially thought that perhaps as many as 16 outputs would be required to achieve ~2 electrons read noise while reading the entire array in a reasonable amount of time. e2v convinced us that the high responsivity that they were achieving on their CCD44-82 and similar devices, ~8μ/e$^-$, would allow ~2 e$^-$ RMS readout in a reasonable time from only 4 outputs. Figure 1 shows the agreed upon architecture.

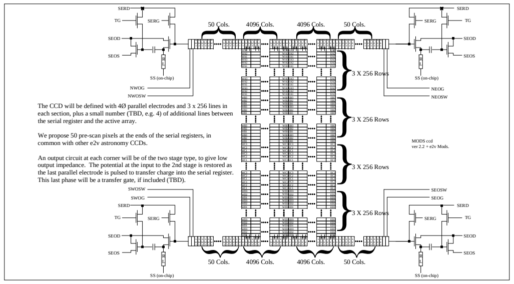

Figure 1. Schematic of the e2v design for MODS. 3 phase vertical registers are shown instead of the 4 phase registers of the final design.

Since each CCD need operate *only* on a red or a blue channel of the instrument it was decided to have separately optimized red and blue detectors. The blue devices are produced on e2v's normal 15 μ thick epitaxial material with their "Astro Broadband" anti-reflection coating. The red devices are fabricated on 40 μ thick epitaxial "Deep Depletion" material with a red optimized anti-reflection coating. Figure 2 shows the measured QE for the final parts.

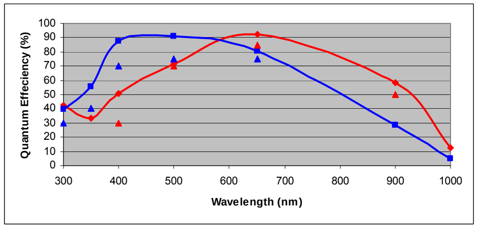

Figure2. Measured QE for the Blue and Red variants of the MODS CCDs. The triangles show the specified minimum QE.

Detector Mounting and Electronics

The CCDs are mounted in a vacuum insulated detector box. The camera field flattener is the vacuum window. The CCD is cooled though a flexible heat link to a 7 liter capacity LN_2 Dewar. The LN_2 Dewar and the detector box share a common vacuum space and are coupled through an elbow. Bellows are use to connect both ends of the elbow to decouple the mass of the Dewar from the detector box. The camera is a de-centered Schmidt design and the detector box is located completely outside the optical beam. The CCDs are operated with OSU's ICIMACS detector electronics and new dual channel post amplifiers that, in order to maximize the read rate from each output, interleaves the dual slope integration with ADC conversion and resetting the integrator capacitor. 18 bit ADCs are used, two per channel, to properly sample the 2 e$^-$ noise from the CCD and the 200k e$^-$ full well.

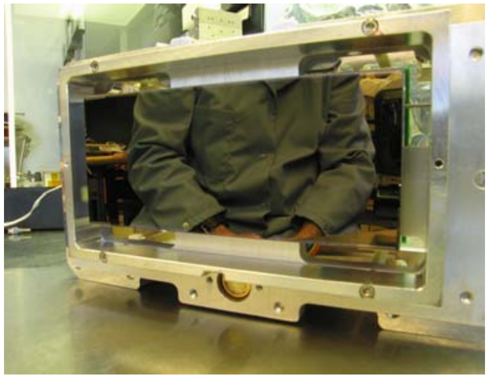

Figure 3. A red variant of the CCD231-68 in the detector mount. The gold package below the CCD is a Ge quad-cell used to actively maintain alignment of the spectrograph.

Status, Next Steps, and Results

The first copy of MODS is now fully assembled with all the optics, mechanisms, enclosure, and detectors installed. Details such as the glycol plumbing for electronics cooling are currently being addressed. Lab acceptance is scheduled for early November 2009 with packing and shipping to Mt Graham before the end of the year. MODS is scheduled on the LBT in mid January 2010. The detector systems will be removed for final tuning during the rather long process of packing the remainder of the instrument. The eight post-amplifiers (gain+DCS+ADC) now in service (4 red and 4 blue) are from two different batches fabricated during the system development. We have now received 20 copies (eight for MODS 1, eight for MODS 2 and four spares) of what we hope is the final version which will be installed as part of the final tuning process.

Figure 4 shows a calibration spectrum taken simultaneously in the red and blue channels. Not wanting to wait for the first astronomical spectra from MODS we have fed the spectrograph with a 63μ diameter fiber illuminated with daytime cloudy skylight. Figures 5 shows a wavelength calibrated extracted spectra from the red channel.

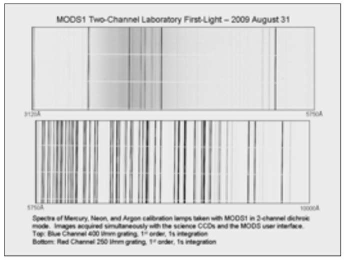

Figure 4.

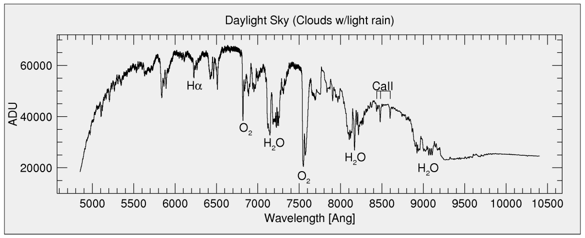

Figure 5.

Conclusion

While not yet fully characterized, e2v's CCD231-68s are clearly a success. CTE is excellent in both directions as shown by sharp radiation events. QE is as expected as shown by both e2v's measurements and by comparing the results, obtained with our projector, to previously tested CCDs. Cosmetics are consistent with e2v's "grade 1" designation. The responsivity is as claimed by e2v and while we have not seen 2 e$^-$ noise we have every indication that by fixing some known system problems and optimizing the CCD operating parameters we will see the predicted noise rather than the ~3e$^-$ now observed. Perhaps of more importance to the community, e2v has demonstrated that their migration to a 6" wafer line has gone well and that they can make thinned full wafer devices.