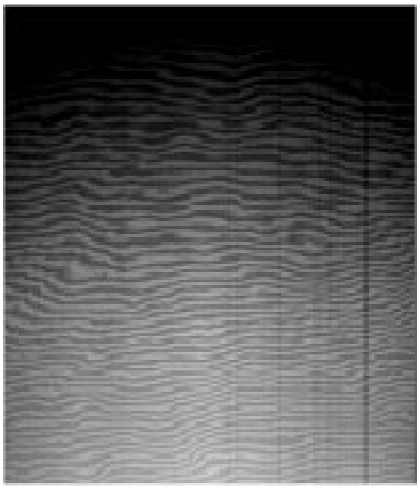
ING LA PALMA TECHNICAL NOTE No. 130

Investigation of Low Fringing Detectors on the ISIS Spectrograph.



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Investigation of Low Fringing Detectors on the ISIS Spectrograph.

1. Introduction

The ISIS red arm detector must be chosen to give best possible Quantum Efficiency (QE). Equally important, it must have low fringing. Both of these requirements can be met using deep-depletion CCDs, which are thicker than standard thinned backside illuminated detectors. Being thicker, they stop more of the red photons, boosting the QE. As fewer photons reach the rear surface of the detector, fewer are reflected back into the bulk of the device where interference effects produce strong spatial modulation of the red sensitivity, commonly known as 'Fringing'.

The current red arm detector is a deep-depletion CCD4290 from E2V technologies. Although it performs well, it falls short of the performance of the MIT/LL CCID20 used on OASIS. Given that ISIS is one of the most heavily used instruments, it is important that it has the best possible detector available. Three sample CCDs have recently been obtained on loan from E2V for tests on ISIS. The results will allow us to specify the optimum design for the next red arm detector.

2. The CCD Samples

These were all obtained on loan from E2V technologies, built into cameras here at ING and tested on the red arm of ISIS on the William Herschel Telescope.

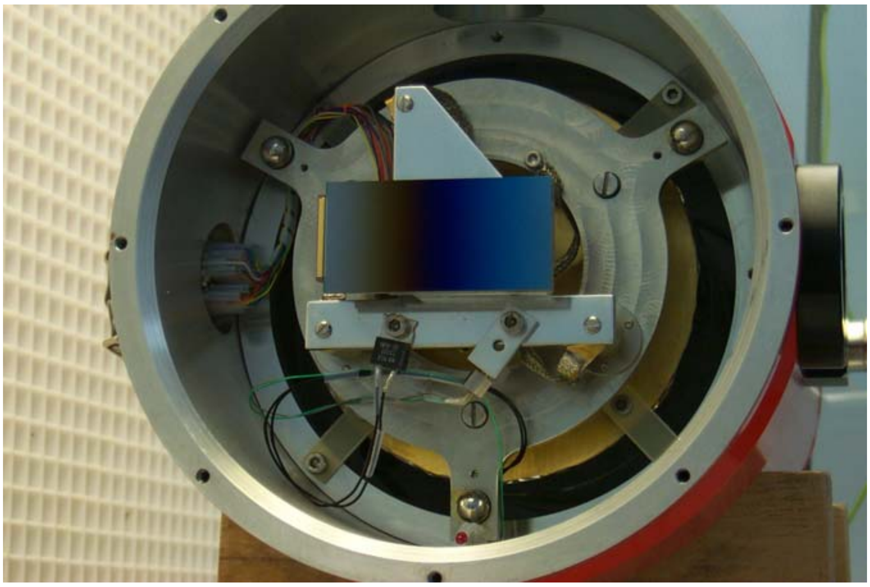
The first sample chip was a standard thin CCD4482 (non-deep depletion 2k x 4k x 15μm pixels) with a graded anti-reflection (AR) coating. The thickness of the coating varied linearly along the length of the chip so that each image row was optimised for a different wavelength. This coating was especially designed for use with the low dispersion R158 ISIS red grating. With the centre wavelength of this grating set to 6000A, the spectrum incident on the chip was then exactly matched to the AR coat at every pixel. This chip was tested to show the importance of the AR coat for minimisation of fringing.

The second sample was a deep-depletion CCD4482 also with a graded AR coat. It was used to investigate how fringing varies with wavelength for different thicknesses of AR coat. The results will allow us to specify to the manufacturer which AR coat will be best for us.

The third chip was a deep depletion CCD4011 (1k x 128 x 26μm pixels) that had undergone a special fringe suppressing process thought to involve the etching of a step in the silicon behind each pixel. The chip had a constant thickness red coating optimised to give minimum reflectivity at 9000A.

3. The Test Camera

This is shown below loaded with the CCD4482 chip. It was a 2.5l LN2 cryostat from Oxford Instruments originally intended for a 2 chip mosaic of MIT CCDs.



Test Camera

The unusual appearance of the chip is due to its graded thickness AR coat. The left side appears redder because it is blue optimised, whereas the right side reflects more blue light because it is red optimised.

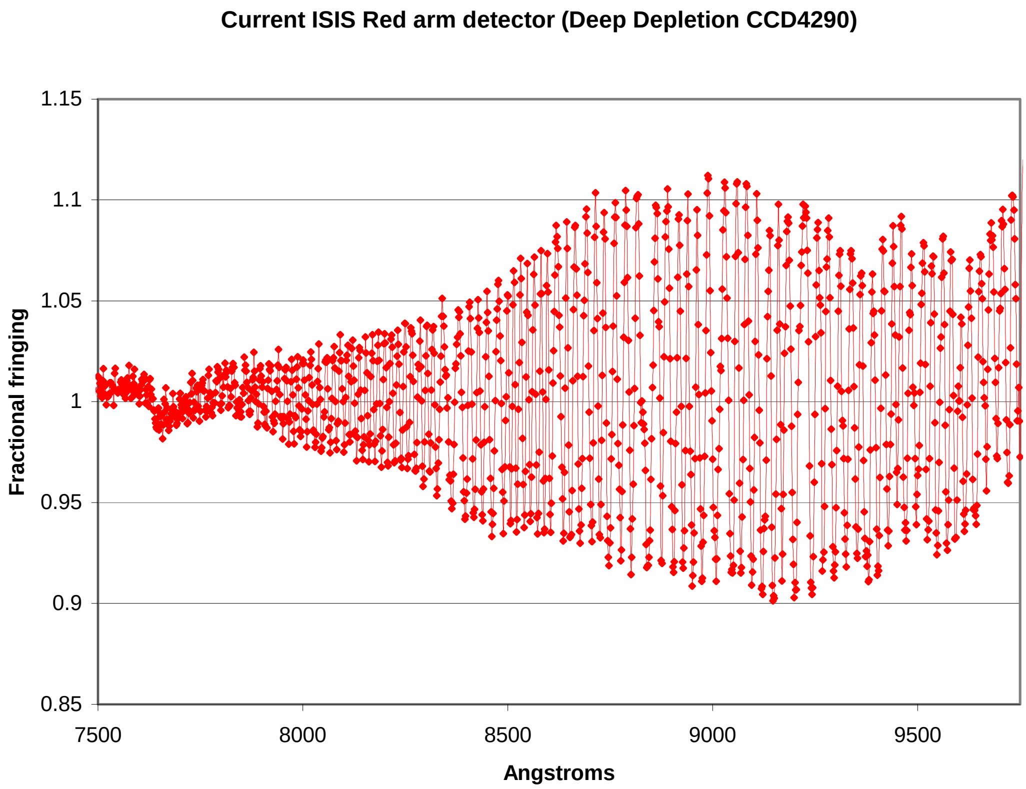
4. Measurement Technique.

Firstly, Cu-Ne arc spectra were taken with each camera and compared with the current Marconi2 red arm detector. This allowed the centre of each chip to be determined i.e. which image row was on the optical axis (or centre wavelength of the grating setting) of the instrument. It also allowed focussing of each camera.

For the actual fringing measurements, a tungsten spectrum was taken. The fits format spectra were block averaged in the spatial direction by a factor of 4 using IRAF, to reduce the noise. No block averaging in the spectral direction was done in case it affected the fringe amplitudes; fringes are generally parallel to the spatial axis of the spectra. A single image column was then exported to EXCEL using the IRAF 'listpixels' command. The fringe amplitude in the image was measured by first doing a bias subtraction followed by division of the data by a flat-field. This flat field was obtained by block averaging the tungsten spectra by a factor sufficiently large to smooth out any fringes. The resultant data was graphed to show the proportional depth of the fringes.

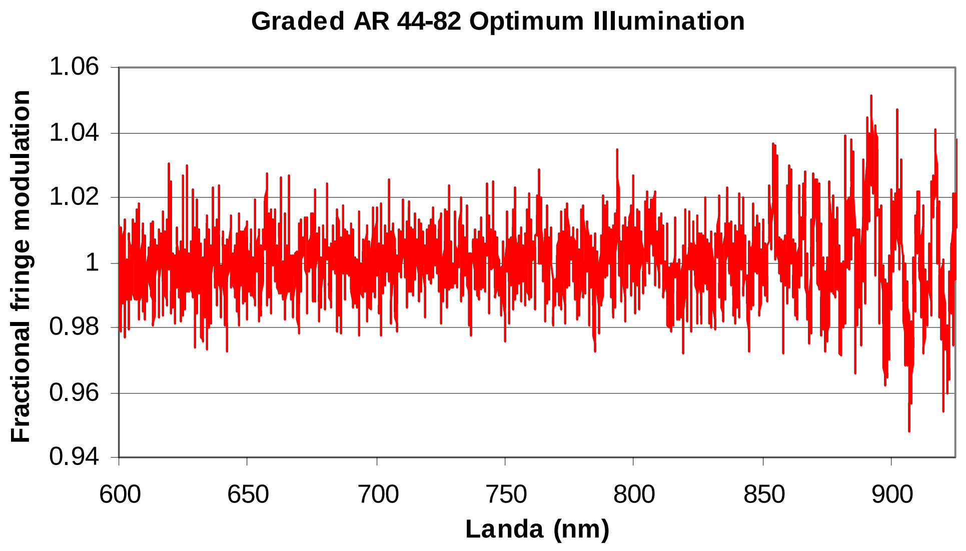
5. Fringes in Current ISIS Red Arm Detector

Fringing becomes visible above 7750A, rising to a maximum of +/- 10% at about 9000A. This detector has an AR coating optimised at 5500A so as to give it a mid band QE profile. Grating dispersion used was 0.84A/pix.

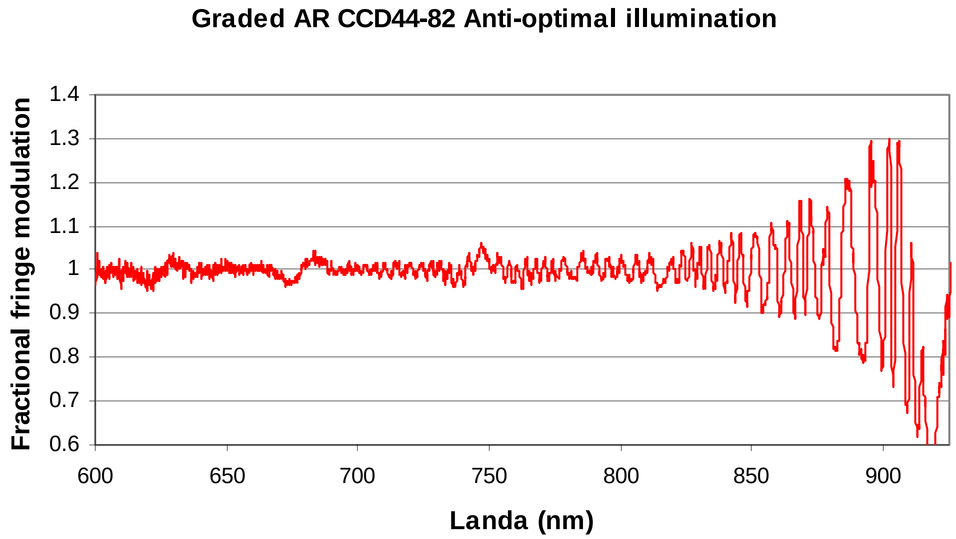


6. Fringes in the thinned CCD4482 graded AR chip

Two spectra were taken with this chip. The first was with the grating angle set to give a perfect match between illumination wavelength and AR coat optimisation, across the whole chip area. The second was taken with the grating tilted so as to project a negative-order reversed-spectrum for comparison. The difference in the fringing between these two spectra showed the importance of a good AR coat. The optimally illuminated spectra showed very low fringing even though this was a thinned non-deep-depletion CCD. This kind of CCD would be ideally suited for fixed-format spectrographs where it would yield an excellent square QE profile with minimal fringing. Dispersion in both graphs below was 1.8A/pix.



Here the illumination wavelength was matched to the AR coat thickness at every pixel.

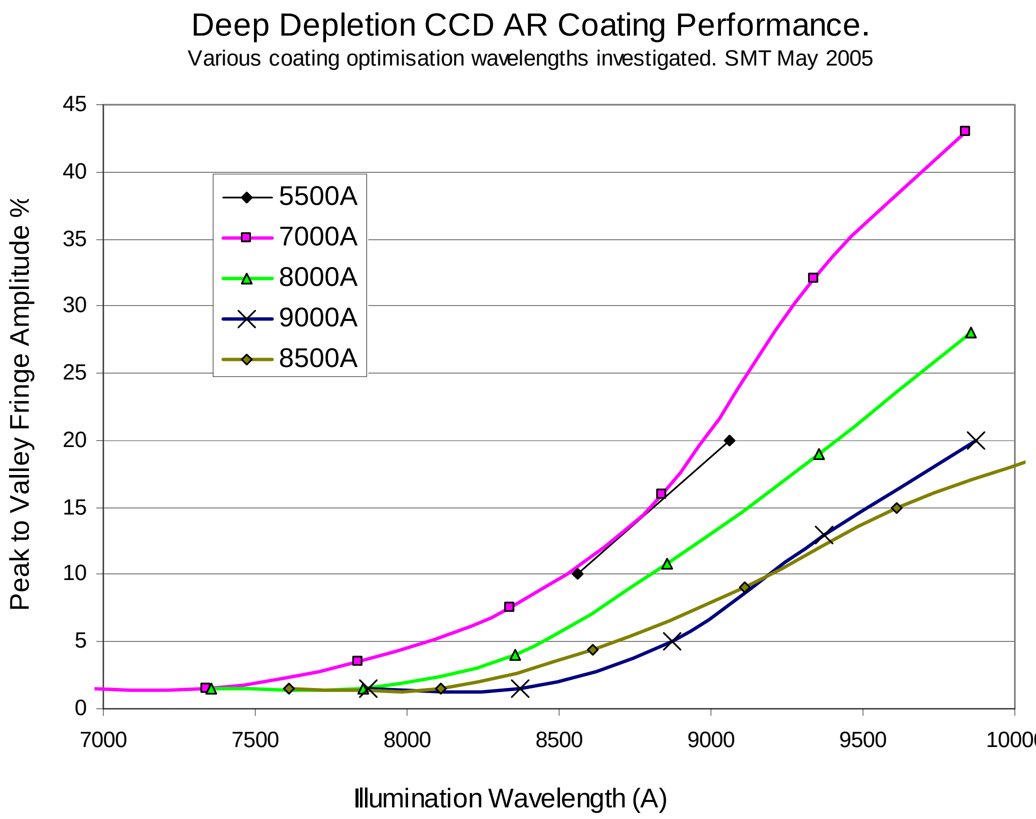


Here the illumination wavelength was not matched to the AR coat thickness

So the plots show that even a thinned non-deep-depletion CCD can give low fringes if it has the correct AR coat for the job.

7. Fringes in the deep depletion CCD4482 graded AR chip

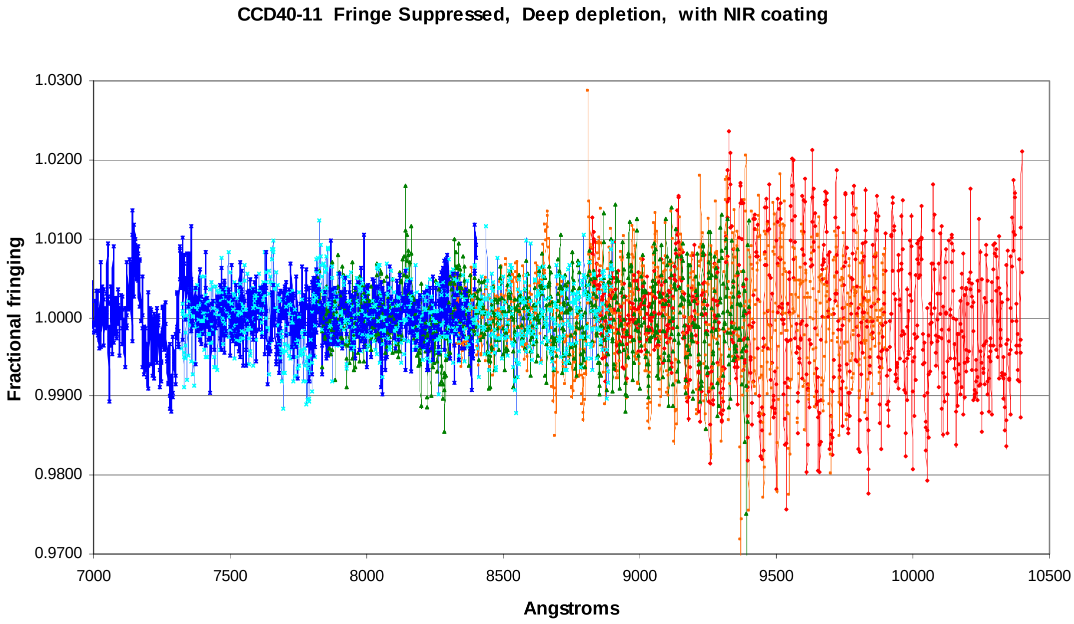
A more thorough investigation was done of this chip. A number of spectra were taken with different grating angles so as to illuminate each part of the chip (i.e. each AR coating thickness) with a full range of wavelengths. A graph was then built up to show fringe amplitude versus wavelength for each AR coat. Dispersion was 0.9A/pix.



These measurements show that the current Marconi2 red arm detector would perform a lot better, in terms of fringing, if it had a redder AR coat. An AR coat chosen to give minimum reflectivity between 8500 to 9000A (see dark green and blue curves above) would seem to give the best low fringing performance.

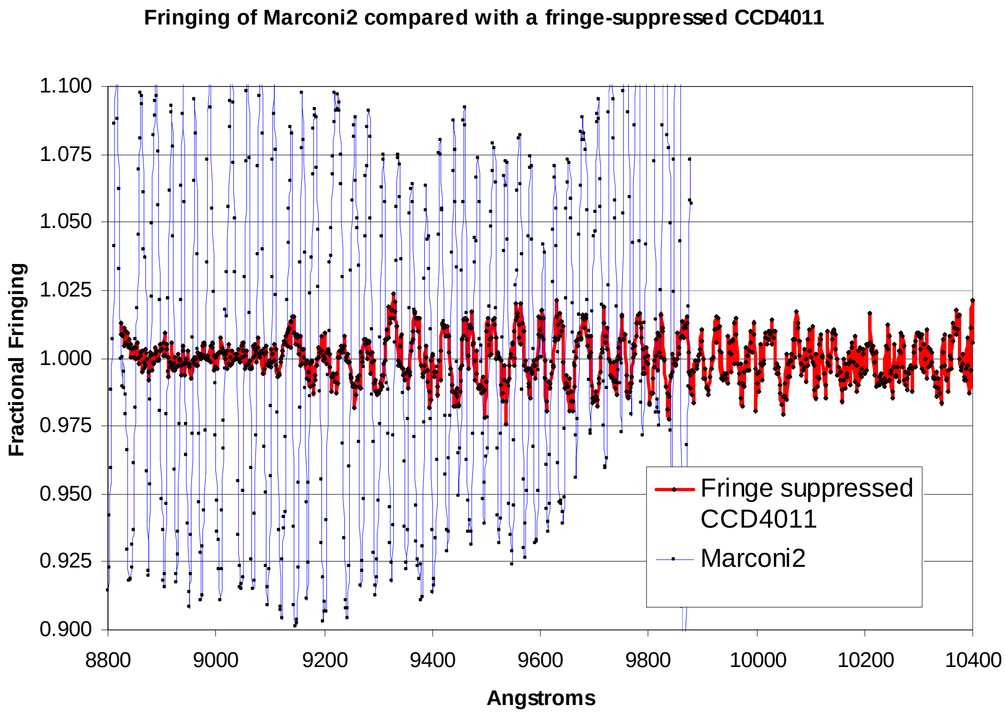
8. Fringes in the fringe-suppressed CCD4011 test chip

This chip had very low fringing that was rather hard to measure since its level approached the intrinsic pixel to pixel sensitivity variations seen in all CCDs. The chip was only 26mm long and it was necessary to take several overlapping tungsten spectra to measure the fringing across the full wavelength range. The overlapping spectra are each shown in the following graph with a different colour.



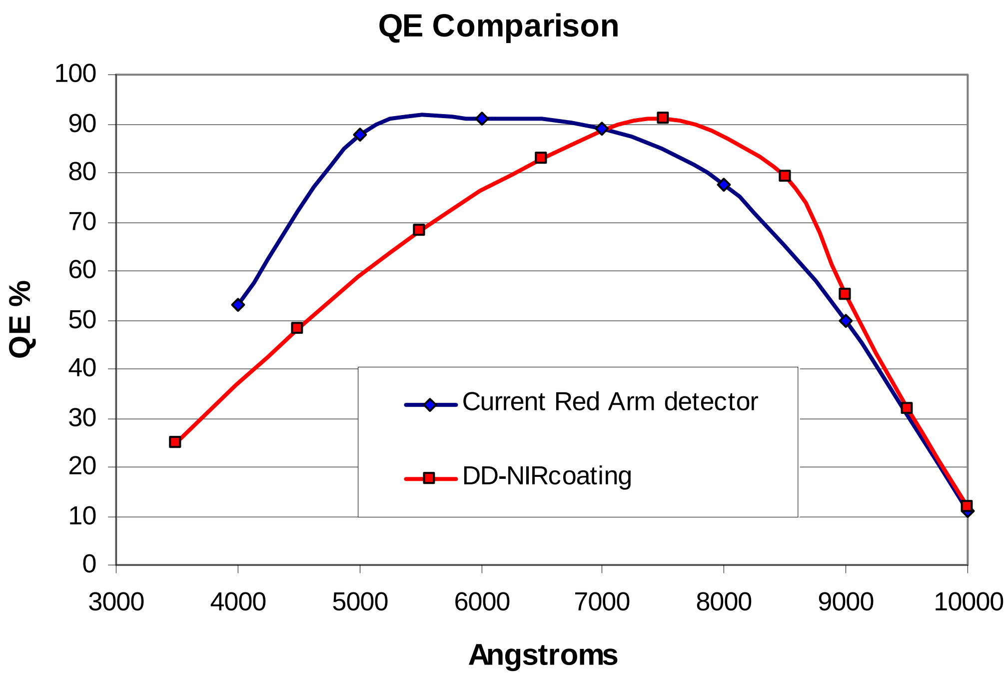
The fringes only become apparent above 8750A, rising to a maximum of +/-2% at 9500A. The anti-reflection coat on this device (described as an NIR coat in manufacturer's literature) was optimised for 9000A. Dispersion was 1.6A/pix.

The red part of the plot above is shown again below with the current fringing of the ISIS red (Marconi2) detector superimposed for comparison.(Dispersions: 0.84A/pix for the Marconi2, 1.6A/pix for the 40-11)



9. QE considerations

Opting for a red biased AR coating to reduce fringes will tend to suppress the blue end sensitivity. The plot below shows the manufacturer's QE data for a deep depletion CCD with an NIR (minimum reflectivity at 9000A) coating, compared to the QE of the current red arm detector as measured here.



10. Conclusions

The next ISIS red arm detector should clearly use the fringe-suppression process combined with an AR coat optimised for minimum reflectivity between 8500 and 9000A. The fringe amplitude should then not exceed +/2%, which is 5 times lower than the current detector and marginally better than even the CCDID20 from the MIT/LL consortium.