EXPERIMENTS WITH SILICON ARRAY DETECTORS IN THE RGO COUDE SPECTROGRAPH

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Two detector systems, recently developed at the Royal Greenwich Observatory, have undergone tests on the coudé spectrograph of the 30-inch telescope at Herstmonceux. The first is an intensified Reticon system, used in a photon counting mode; the second is a directly illuminated, cooled CID.

INTRODUCTION

A photon-counting intensified Reticon and a cooled CID are two of the detector systems recently developed in the Instrumental Science Division at the Royal Greenwich Observatory (RGO), under the direction of Dr I.G. van Breda. Both store data in digital form for subsequent image processing, the intensified Reticon producing a 1-D image and the CID a 2-D image. The Science and Engineering Research Council (SERC) has provided UK astronomers with STARLINK, a powerful image processing and data reduction system operating through a network of VAX 11/780 computers at six centres throughout the country. For data processing of digital spectra, the STARLINK software environment contains the SPICA package which is a development of the programs first prepared for reducing digital spectra from the Boksenberg Image Photon Counting System. During experiments to examine the performance and potential of these two new detectors for high resolution, precision spectrophotometry, STARLINK has played a vital role in allowing day-by-day assessment of results through interactive image processing.

THE INTENSIFIED RETICON SYSTEM

This system follows the principles described by Shectman and Hiltner (1976) and Stapinski et al. (1978). At RGO, Messrs A.R. Jorden and P.D. Read have been most closely associated with the project throughout its development and testing. The detector was constructed for the image tube spectrograph of the 74-inch telescope of the South African Astronomical Observatory (SAAO) and utilises the existing 3-stage EMI image

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intensifier already mounted on that spectrograph. Auxiliary transfer optics are required to re-image the output phosphor of the EMI intensifier, but the gain from the three stages is insufficient for photon counting so a further stack of three low distortion, electrostatically focussed image intensifiers (Varo 8605-1) is used to provide the required light gain. The Reticon chip (CP1001) has 1872 elements in a dual array, each of 936 elements with individual sensing area 30 μm x 350 μm. Its first application outside the laboratory was in the stable environment of the coudé spectrograph at RGO, where it was mounted at the accessible focal surface of the 1 m camera as shown in Fig. 1. At this time, only one array was operating and difficulties with electronic instabilities prevented use of the centroiding logic below a 30 μm channel. When efficiencies were compared with an electronographic image tube, it appeared that only about half the photons were being counted, which was compatible with counts observed on standard spectrophotometric stars. It had been necessary to stop down the transfer lens to achieve a more uniform intensity distribution across the field, hence the apparent light gain was decreased and discriminator level settings became very sensitive. With the lens stopped down, fast count rates

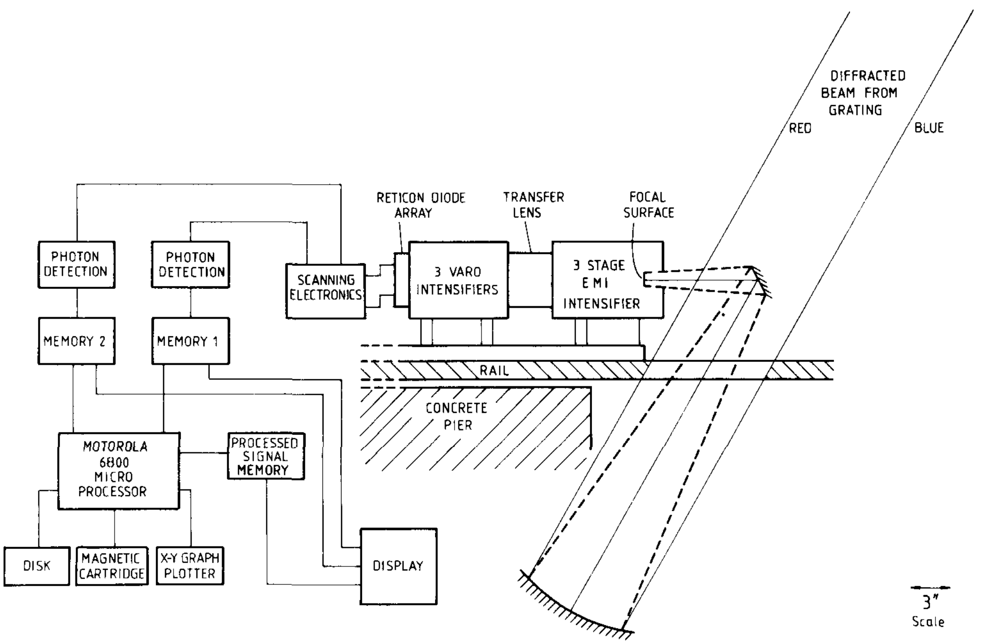

Figure 1. The 1 m camera in the RGO coudé spectrograph, showing the intensified Reticon system and associated processing electronics.

could only be achieved with a brighter image in the EMI intensification stage, and some persistence problems then became apparent. These are undoubtedly factors contributing to the observed low efficiency. At 6ms frame rate, linearity was good to a few percent up to 2.5 photons/s/channel and this was chosen as the limiting count rate for subsequent observations. The physical stability, and that of the electron optics was most impressive; arc exposures over a period of four hours gave deviations around 0.01 channels on cross-correlation, i.e. stability better than 0.5 μm.

The programme command language FORTH is used to control and operate the system; data is held on floppy disks and subsequently transferred to VAX memory files for image processing.

Astronomical Programme

Since sky subtraction has become a standard procedure with digital detectors, the use of subtraction techniques provides an interesting application for astronomical experiments with the system. Spectrum subtraction is not the prerogative of digital, linear detectors, as has been clearly demonstrated by Griffin and Griffin (1979), but it is a task eminently suited to these devices. The problem we have studied is separation of the component spectra in a "composite" star, a condition rather different from sky subtraction because of non-identity of one component with a chosen "standard" star and because of necessary compensation for differences in radial velocity. Several spectral regions (around H_9 and H_8, CaII K and H, Hδ and Hα) were observed at about 4A/mm in 58 Per, which has a composite spectrum with the primary classified as KOIII by Kuhi (1963). A number of giants with spectral types G9-K2 were also observed in these spectral regions to act as "standards", and a few early type stars were observed for comparison with the secondary spectrum. High signal-to-noise ratio spectra are required, with good flat field, to leave a reasonably clean subtracted spectrum. None of the standards was a very good match to the primary spectrum, the best fit of those observed being β Gem, KOIII. A full analysis of all the data is being undertaken, but the effectiveness of the techniques is shown in Fig. 2 where the result of subtracting β Gem from 58 Per in the region of H_9 (3835A) is shown, with the spectrum of η Aur (B3V) shown for comparison.

This material was collected during initial tests in February 1981. Since then, electronic stability has been improved, centroiding is effective to half a diode (15 μm), the dual array is working, the system operates with the transfer lens at full aperture, and with a 3 ms frame rate the counts are linear to a few percent accuracy up to 3 photons/s/channel. The detector is now installed at SAAO for low and intermediate dispersion spectroscopy.

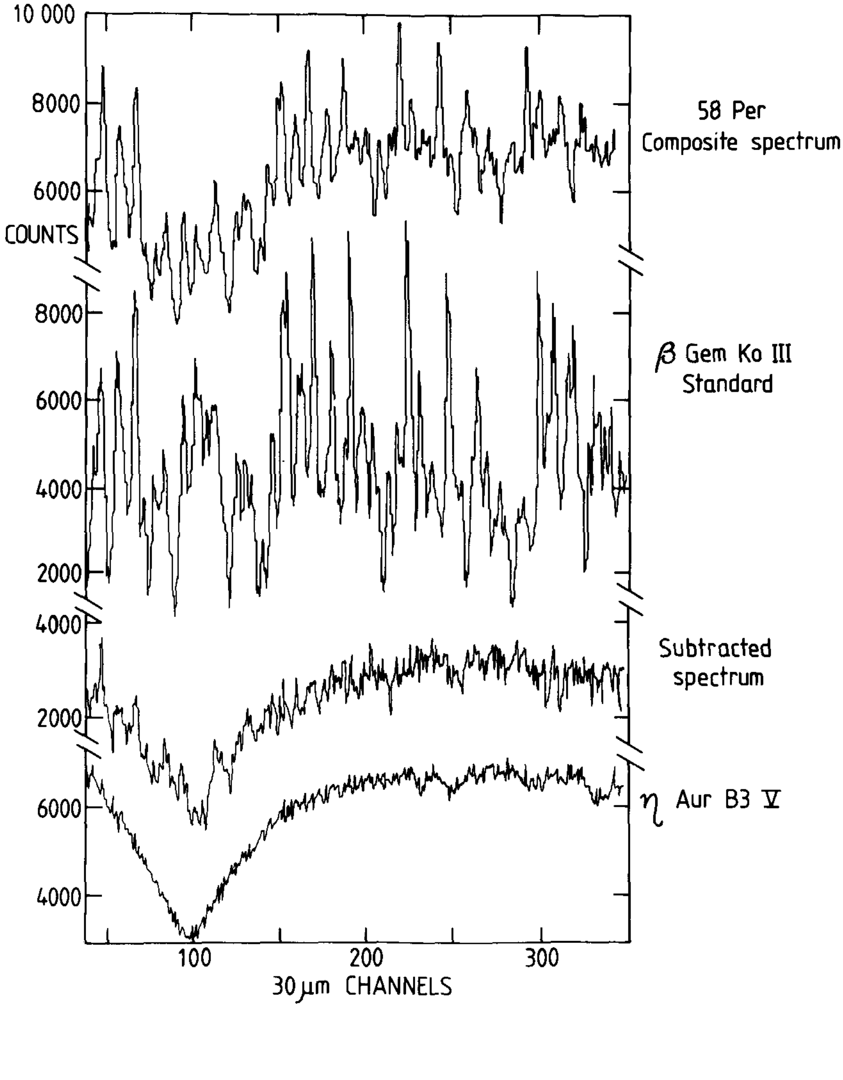

Figure 2. A portion of spectrum around H_9 (3835A) for 58 Per, β Gem and η Aur showing flat-fielded data from the intensified Reticon system. The subtracted spectrum is the result of subtracting 50% of the β Gem spectrum from that of 58 Per.

THE COOLED CID

The direct illuminated, cooled CID was developed at RGO primarily for 2-D field imagery and the design and operation of the system have been described by Jorden and van Breda (1981). A liquid-nitrogen cooled cryostat houses the GEC TN 2000 chip which has 188 x 244 elements, 60 μm x 35 μm. Dr P.R. Jorden and Mr M. Rothera have worked with us in setting up the detector in the focal surface of the coudé spectrograph (the same optical arrangement as in Fig. 1) to assess the potential of the system for high resolution spectroscopy. Although diode array development now seems to be centred on the CCD rather than the CID (Latham, 1982; this colloquium), the RGO CID has been made available to us as a fully working detector and immediately enhances facilities on our spectrograph by providing significant efficiency at red and near infrared wavelengths. The non-destructive read-out also allows monitoring of data collection.

The chip was arranged to have the small element dimensions in the direction of dispersion, giving about 0.13A/channel at 6000A. Again, the program command language is FORTH, but in this case the 2-D images are written to a 2.5 Mb disk for subsequent transfer to 9-track VAX-readable tape. For precision work, data consists of a bias frame subtracted from an exposed frame, each of 128 read-outs. At present the whole chip is read out, but it is hoped to read a narrower strip of the chip for spectroscopy and perhaps increase the number of read-outs to reduce noise still further. Results of divisions of various flat fields are illustrated in Fig. 3. The device is very stable over an average observing run and quite good from one day to another. There is obviously a significant difference in pixel-to-pixel variations with large wavelength changes so frequent flat fielding is necessary if spectral regions are widely separated. This presents few problems in practice, as bright sources can be used, but each full frame of 128 read-outs takes about 3 minutes and the procedure can therefore become time-consuming.

The most significant problem in achieving quality spectrophotometry is the appearance of signal in the background. Fig. 4 shows a modest sky spectrum containing around 10^5 electrons in the continuum pixels and being a mean of 10 exposed strips, represents about 10^6 electrons in the total row signal along the slit. The background is observed at a higher level than the dark current, and appears quite uniform along individual rows in the unexposed area of the chip. A first-order correction can be applied by subtracting a proportion of the signal.

In normal seeing conditions at Herstmonceux (2-3 arcsec), starlight occupies only one or two pixels along the slit length, and these are not uniformly illuminated because of the profile of the stellar image. Application of a uniform flat field is therefore not strictly correct, as it does not allow for non-uniform sensitivity in individual pixels. However, more significant improvement in the accuracy of photometry could be achieved by illuminating more pixels along the slit,

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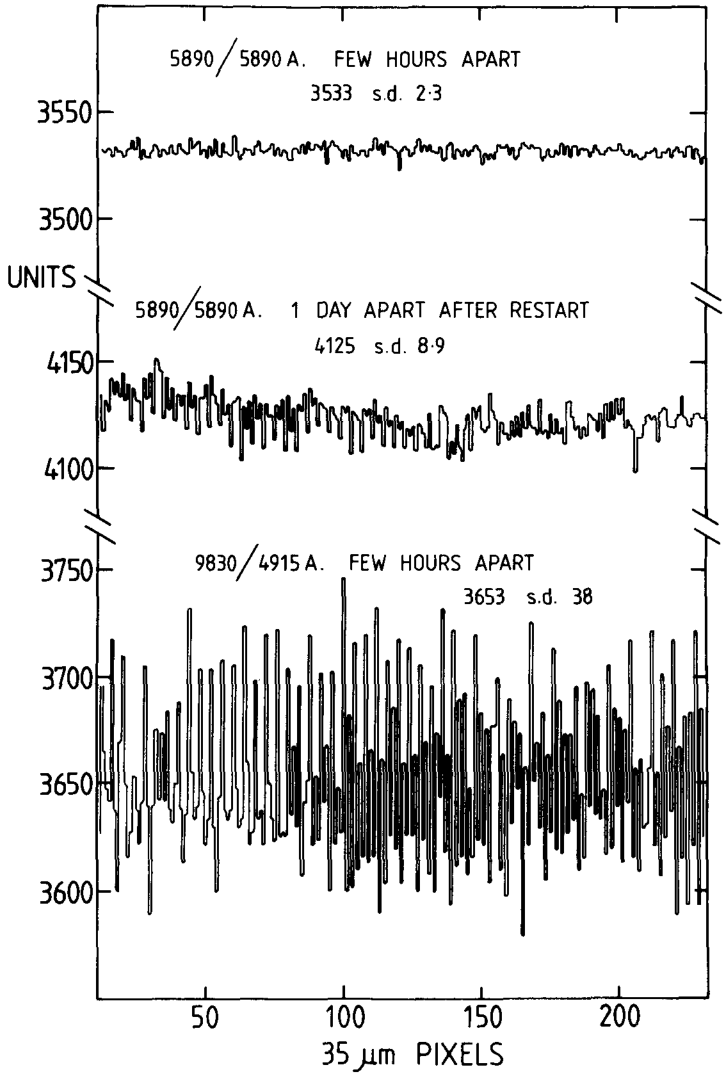

Figure 3. The top two records are flat field divisions at 5890A, where one unit represents approximately 170 photoelectrons. The bottom record shows division of two flat fields in widely separated spectral regions and demonstrates the difference in pixel-to-pixel variations at these wavelengths.

for example, by trailing or by using a superpositioning image slicer of the type described by Richardson (1972). Both methods produce a more uniform effect at the detector and better 2-D flat fielding can be accomplished. However, trailing only illuminates the pixels sequentially, so that dark current is building up in all the diodes even when no signal is present. Typical slit widths are of order 0.8 arcsec, so in the case of the image slicer, signal-to-noise would also be improved by increased throughput and simultaneous recording in all diodes along the slit length. Such a system could be exploited further by a CCD having lower read-out noise and using the property of single read-out noise along diodes in the slit length direction.

DISCUSSION

The intensified Reticon system is now in action at SAAO, and future developments are being directed towards more compact systems. In earlier tests, poor weather prevented serious observations with the CID,

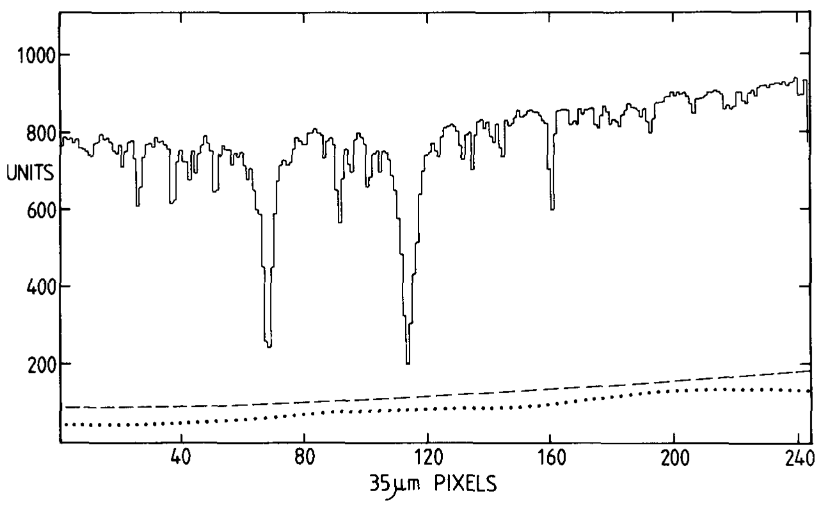

Figure 4. Sky spectrum in the region of the NaD lines shown as the mean of 10 pixels along the slit (λ increases to the left). The dotted line shows the mean background in these channels when no signal is present, whilst the dashed line is the mean of 10 strips from both sides of the spectrum on the exposed image, illustrating the amount of "smearing" observed.

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but sufficient performance characteristics have been determined to encourage preparation of observing programs. Availability of STARLINK has played a significant part in interactive data processing and assessment of both systems.

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REFERENCES

Griffin, R. and Griffin, R., 1979. Mon. Not. R. astr. Soc. 187, p. 91.

Jorden, P.R. and van Breda, I.G., 1981. "Solid State Imagers for Astronomy". Proc. Soc. Photo-Opt. Instr. Eng. 290, p. 113.

Kuhi, L.V., 1963. Publ. astr. Soc. Pacif. 75, p. 448.

Latham, D., 1982. This colloquium.

Richardson, E.H., 1972. Proc. ESO/CERN Conf. Auxiliary Instrumentation for Large Telescopes, Geneva, p. 275.

Shectman, S.A. and Hiltner, W.A., 1976. Publ. astr. Soc. Pacif, 88, p. 960.

Stapinski, T.E., Rodgers, A.W. and Ellis, M.J., 1978. Seventh Symposium on Photo-Electronic Image Devices, Imperial College London, p. 335.