Back-and-forth spectropolarimetry

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Abstract. The spectrum is alternatively integrated in two different polarizations on the same pixels of the CCD. The CCD is read after a series of integrations. Charges are transferred after each individual exposure synchronously with switching of polarization without readout up or down along the chip. It helps to diminish the errors caused by the fluctuations of light at the slit of the spectrograph.

In the mode of back-and-forth spectropolarimetry an electrooptical modulator of light letting pass alternatively right and left circularly polarized light is installed ahead of the spectrograph slit. A CCD detector is mounted on the spectrograph camera.

The essence of the recording mode being discussed is that the charge pattern, accumulated in a given state of the modulator, which corresponds to the portion of the spectrum on the cassete part of the spectrograph, is not read after a short elementary exposure time but transferred to a specified number of lines. Then a synchronous switching of the eiectrooptical modulator state occurs, the signal is being accumulated during the elementary exposure time with further backward transfer to the same number of lines. The system recovers the original state and the process is repeated. After accumulation of the necessary number of charges the process is discontinued and the accumulated image pattern is digitized. The influence of light flux fluctuations on the spectrograph slit is reduced in this mode, and for recording of spectra in left and right circularly polarized light, the same pixels are used, i.e. the necessity for flat-fielding is ruled out.

The mode of iterative double-directed charge transfer was implemented on the basis of the CCD system S1000 by means of altering both hard- and software.

The controller scanning generator needed to be modified because previously it did not reverse the charge transfer fast enough (this required reloading from the host computer of the memory storing the scan). To reverse the charge transfer one has to reverse the temporal scans of two parallel phases. With this in view a circuit of switching signals of two phases was added.

The programme of control of the modes of accumulation and readout was added by a module specifying parameters of the mode of iterative double-directed charge transfer and operating the controller. The following parameters can be specified by the programme:

- length of the elementary exposure in the interval 0.001 ... 65 s;
- number of lines the charge is transferred to in the range 1 ... 255;
- number of charge transfer cycles in the range 1 ... 65535.

While the adjustment of the mode of iterative charge transfer on the CCD system with the matrix ISD17A was performed, it was found out that a very careful adjustment of the level of signals of all the phases is needed to provide for satisfactory values of transfer efficiency over the frame in both directions and to minimize the spurious charge generated in the process of transfer. For this purpose the phase former was supplemented with circuits for separate adjustment of the upper and lower levels (the levels of wells and bariers) of both two parallel and two register phases (the third phases are virtual).

After a careful adjustment of the modes there still remained a region of increased charge value in the upper left of the frame. This effect is, apparently, due to a technological defect of the matrix which does not manifest itself in the process of one single-direction imaging. In Fig. 1 is displayed the dark field in the mode of cyclic image transfer.

For subsequent recording of spectra, we chose a homogeneous portion of the matrix in its lower part. In the upper part of Fig. 2 is shown a portion of the solar spectrum derived by the spectrograph with a low dispersion. A light fibre was used to bring radiation to the slit. In the lower part of Fig. 2 is exhibited a vertical section of the image. One can see well the recurrence of the details on the two spectra in section. The intensity between the sections of the spectra transverse the dispersion rises with decreasing elementary exposure not only because the inefficiency of transfer is finite, but also because there is no snap-

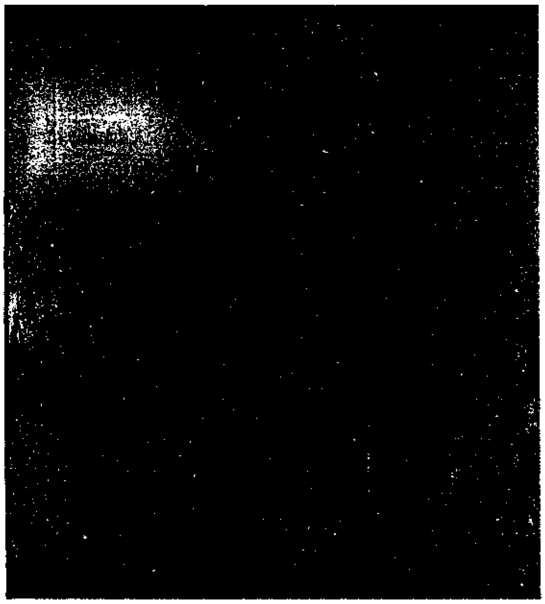

Figure 1: *The dark field in the mode of cyclic image transfer.*

action shutter to intercept light during the time of image shift. Nevertheless the efficiency is high enough even for an exposure of less than 0.2 s. The double spectrum of the Sun in Fig. 2 has been obtained with an exposure of 0.2 s after every shift, the number of lines by which the spectrum was shifted made 30, the number of the shifts was 500.

A schematic diagram of measurements with the BTA Main Stellar Spectrograph (MSS) (camera 2) is shown in Fig. 3. The light from a star passes through the liquid crystal modulator, which can be in two states creating phase shifts of 180° and 0°, and is deflected by Mooney rhomb to the spectrograph slit. The Mooney rhomb is in the capacity of the flat diagonal mirror of the spectrograph and serves at the same time as the achromatic quarter-wave phase retarder. Behind the spectrograph slit there is a unit of two calcite spar plates. With the transfer mode operating for data accumulation in the spectrograph camera, the detector registers four spectra in the left and right circular polarizations (Fig. 4 shows the image cross-section at the input of radiation polarized over the circle). Fig. 5 shows the relationship between the ratio of the difference in intensities right2-left2 to their sum (with bias subtracted) and the wavelength of radiation. It is evident from the figure that the region of achromatism for the liquid-crystal modulator takes about 1000 Å, which is comparable with the range of achromatism for the crystals DKDP. The control voltage for the liquid-crystal modulator is about 4.7 V. The exposition time was assumed to be from 5 to 15 min, which is typical of astronomical observations.

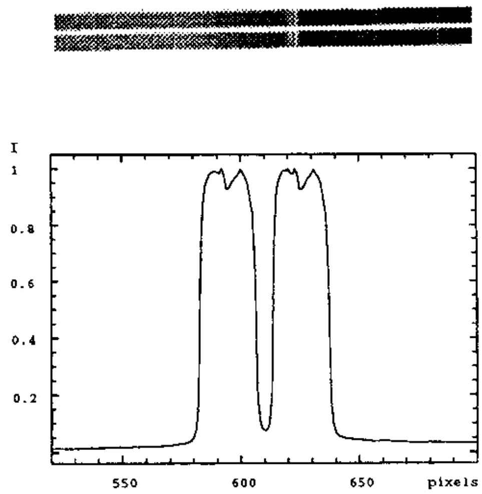

Figure 2: *The portion of the solar spectrum and its cross-section.*

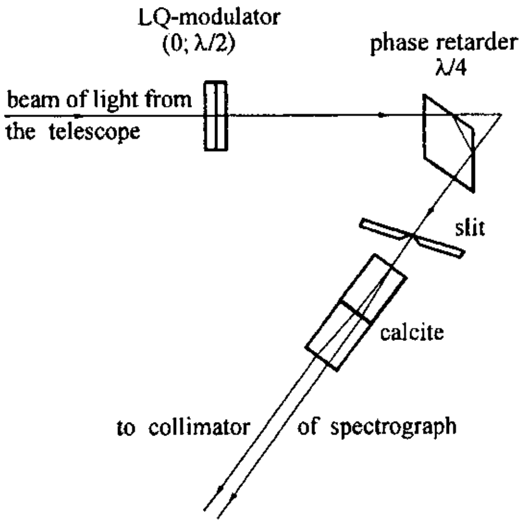

Figure 3: *The schematic diagram for measurements with the BTA MSS.*

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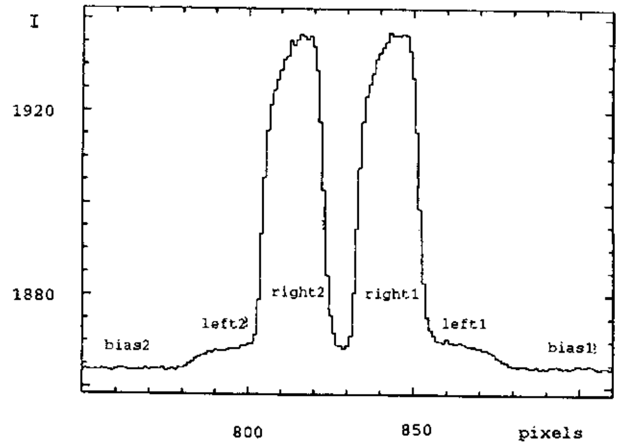

Figure 4: *The cross-section of the dispersion when the right circular polarization light is input.*

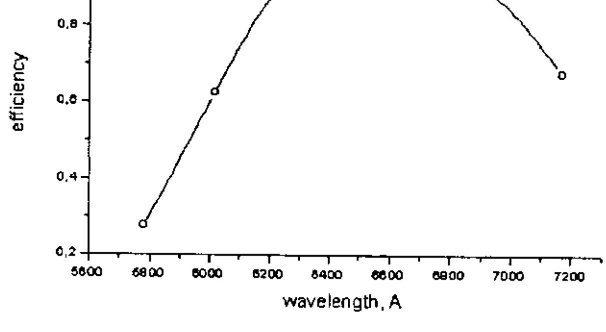

Figure 5: *The ratio of difference in intensities right2–left2 to their sum along wavelength.*