TH 7832CDZ (TH X31513) BILINEAR CCD ARRAY FOR ASTRONOMY APPLICATIONS

J.L. COUTURES and G. BOUCHARLAT
THOMSON-CSF Division Tubes Electroniques
38, rue Vauthier BP 305
92102 BOULOGNE-BILLANCOURT CEDEX France

ABSTRACT. Photodiode linear arrays are perfectly adapted for spectral analysis. The TH 7832CDZ bilinear array is a new device specially adapted to low level detection (exposure < 7 nJ/cm^2) with a reading efficiency of the photodiode signal better than 97 % on all the dynamic range ($>$ 70 dB).

1. GENERAL DESCRIPTION

The aperture of the sensitive line is 750 μm with 13 μm pixel pitch. The gap between the two sensitive lines is 500 μm. There are two identical sensitive lines in order to have the possibility of processing two pieces of information at the same time, e.g. for background signal suppression. Two CCD registers are associated to each photodiode line, one to read information from odd pixels and the other one from even pixels. One of the particularities of this device is an electrical input on each CCD register which generate bias charges.

2. EFFECTS OF THE BIAS CHARGE

2.1. Reading Efficiency

The bias charges, added to the signal charges on the photodiode, increase the reading efficiency of the signal. This effect is rendered evident by the response to a transient light versus the time. Fig 2a shows the transient response on one output (odd or even pixels) without the bias charge. The light has a quasi uniform level along the sensitive line after the transient. The output signal level reaches the correct value after several integration times (Ti). If the light has a short duration, just during one integration time (as one event for example), the reading efficiency is the ratio of the first step value to the asymptotic value. On the photograph fig 2a, the reading efficiency should be about 15 %.

The photograph fig. 2b shows the response with an added bias charge. In this case, the output signal has the correct value after the first integration time when the light is on.

G. Cayrel de Strobel and M. Spite (eds.), The Impact of Very High S/N Spectroscopy on Stellar Physics, 45–48.

Usually, for large length photodiodes read by CCD register or by switches to a bus, the signal reading efficiency decreases with low level signals. The bias charge reduces this effect. With a bias charge equal to 1 volt (bias voltage read at the output), and for signal levels on 1.5 % to 50 % of the saturation level, the reading efficiencies are respectively 98 % and 99 % (see fig 3).

2.2. Noise Level of the Device

In order to have a large dynamic range, the detector must have the lower detection noise than possible. The following table gives all the noise source values (in electrons) of the bilinear detector, from experimental results, at room temperature, 5 ms integration time and 1 MHz output sample frequency :

Reset noise for :	
- optical input stage	$295e^-$
- electrical input stage	$70e^-$
- reading output stage	$110e^-$
Shot noise for leakage current :	
- on photodiode	$53e^-$
- on CCD register	$11e^-$
Transfer noise on CCD register	$45e^-$
Output amplifier noise	$100e^-$
RMS total noise	$344e^-$

Among all the noise sources, the optical input stage has the highest noise. This noise is proportional to the square root of the photodiode capacitance. So the larger the photodiode is, the higher the capacitance is and the stronger the optical stage reset noise is.

Fig 4 shows experimental results on noise measurement with a variation of the added bias charge. The solid curve gives the noise variation on the standard transfer conditions. The noise level increases as the bias charge level up to an asymptotic value about 330 electrons. In order to prove that the noise variation is not due to the using of a bias charge, the dashed curve represents the noise variations when the bias charge is transferred from the electrical input to the output stage, without a transfer between photodiode and register. We can verify that the two variations for reading efficiency (fig 3) and noise level (fig 4) versus the bias charge level are the same pattern. Then a bad transfer efficiency from photodiode to CCD register acts as a low pass filter for signal and noise. When the reading signal efficiency increases with the bias charge, the noise level increases as the cutoff frequency of the filtering.

3. GENERAL ELECTROOPTICAL CHARACTERISTICS

The following table gives the typical electrooptical characteristics of the bilinear CCD array, at room temperature, 5 ms integration time and 1 MHz output sample frequency :

Output conversion factor .... 1.6 μV/e^-
Response to a light source (tungsten filament lamp
(2854K) + infrared filter) .... 300 V/μJ/cm^2
Saturation output signal (with 0.8 V added bias charge) .... 2 V
Saturation exposure .... 7 nJ/cm^2
Average dark current (with respect to the integration time) .. 1 mV/ms
Quantum efficiency :
- at 400 nm wavelength .... 55 %
- at 700 nm wavelength .... 75 %
Contrast transfer function (at 500 nm wavelength
and Nyquist point) .... 68 %
Minimum integration time .... 250 μs

4. CONCLUSION

The bilinear CCD array TH 7832CDZ is packaged in dual in line integrated circuit package with quartz window or coupled with fiber optical window. The sensitive line geometrical ratio is suitable for coupling to spectrographs. An integration time reduction is allowed owing to the low level detection possibilities with a good reading efficiency in the full 70 dB dynamic range. Just one integration time is necessary to suppress background level from signal with the process of the two sensitive line readings. According to the application the bias charge could not be used in two cases. First, when the signal has slow variations with respect to the frequency of the integration time repetition (200 Hz maximum signal frequency with the minimum integration time). Then, the noise detection is filtered and his level falls to 110 electrons. Second, when the usefull signal is added with a constant background level which acts as the bias charge (level higher than 0.8 V).

DISCUSSION

VOGT Presumably, by going to the CCD register readout to achieve lower noise, you have sacrificed a lot of dynamic range, as compared to the RETICON. RETICONs have saturation exposure levels of ≃ $2x10^7$, whereas your device looks more like $2x10^6$ electrons. However, your CCD register has not yielded a significantly lower readout noise than the level of ≃ 350 electrons which Gordon Walker's RETICON devices achieve. Therefore, it seems that your array has succeeded only in lowering the dynamic range of the diode array approach.

COUTURES Yes the saturation exposure level is 2 10^6 e– but the purpose is to detect low level signal with a correct reading efficiency. What is the reading efficiency for RETICON devices ? 70 % ? Is a part of photodiode noise filtered on RETICON devices as the signal is ?

COTTRELL What is the cost of one of these devices ?

COUTURES Not known, possibly not very expensive.

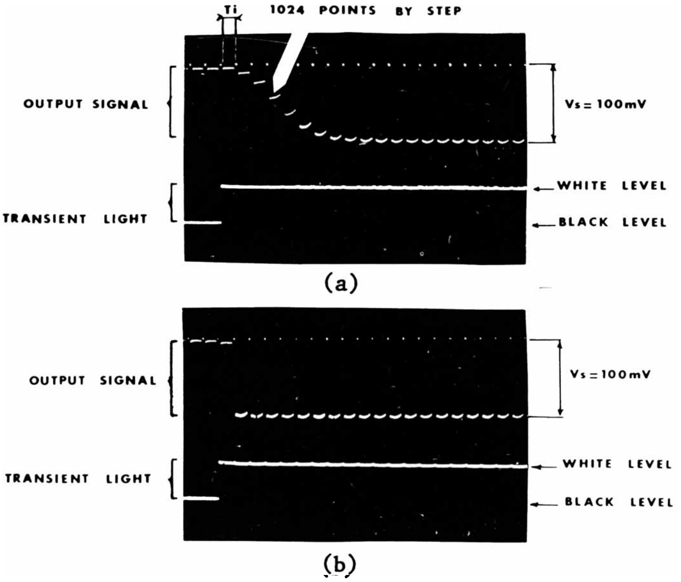

Fig. 2 - Response to a transient light, (a) without a bias charge, (b), with a bias charge. Each step represents the read signal on one output at the integration time repetition.

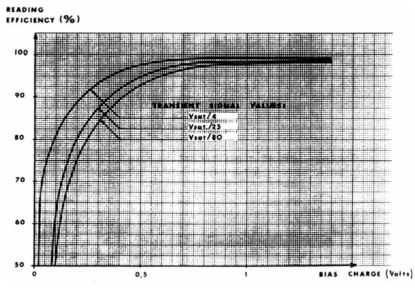

Fig.3 - Reading efficiency for several signal levels v.s. the bias charge

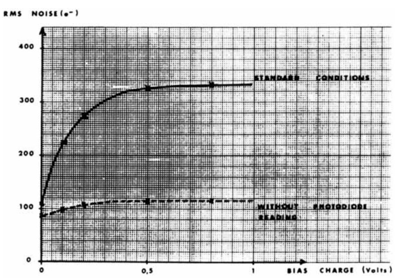

Fig. 4 - RMS noise variation v.s. the bias charge

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