ON HIGH SIGNAL TO NOISE SPECTROSCOPY WITH CCDs

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ABSTRACT : This communication presents a very quick overview of major trends in CCD development and somes ideas on how to use a CCD for spectroscopy with H.S.N. ratio.

1. INTRODUCTION

A lot of reviews have been devoted to CCDs in the past 10 years. The two most recent and complete contributions on the subject are probably the publication of the ESO/OHP Workshop on the optimization of the use of CCD Detectors in Astronomy [1] and the three new books on CCDs : theory, manufacturing and application by J. Janesick [2. 3. 4]. Reading these publications immediatly shows that CCDs were up to now rarely used for spectroscopy with S/N ratio above 200. The reason is quite evident : for such observations the read-out noise of the detector is negligible compared to the photoelectronic shot noise. The main performance of the detector becomes the maximum capacity of charge storage per pixel. In this respect, good Reticon cameras with a read-out noise below 400 electrons : $pixel^{-1}$ and a storage capacity of several billions of charge definitively out perform CCD cameras. (cf. paper by M. Walker in this conference).

The advantage of CCDs in this field of application may only come from their twodimensional format necessary for long slit spectroscopy of extended objects or cross-dispersion spectroscopy.

In this respect, in this -very short- communication we have chosen to briefly list the new trends in CCD development and some ideas on how to use a CCD for H.S.N. spectroscopy. Although the author is familiar with CCD, he has only used them in extragalactic spectroscopy. Therefore this paper reflects more the theoretical view of a CCD camera maker than that of an expert astronomer in H.S.N. Spectroscopy.

G. Cayrel de Strobel and M. Spite (eds.), The Impact of Very High S/N Spectroscopy on Stellar Physics, 49–53.

II. MAJOR TRENDS ON CCD DEVELOPMENTS FOR THE VISIBLE SPECTRAL RANGE

The possibility to run CCDS with very low read-out noise, 6 to 10 electrons r.m.s. per pixel and per reading, has now been successful in many laboratories, and on telescopes. Various small photometric defects are also being cured, that we do not comment here because most of them are significant at very low flux [4]. Finally the two major efforts which are being made concern the increase of quantum efficiency in the UV and the attempt to have large pixel formats.

Obtaining a high UV response

In the UV, the opacity of Silicium is high and the photocharges are created very close to the surface, where they have a great chance to be recombined and trapped by impurities before being collected in the depletion layer. One possibility to collect these charges efficiently is to use a thin CCD with a potential curve which makes the charges drift to the potential pit.

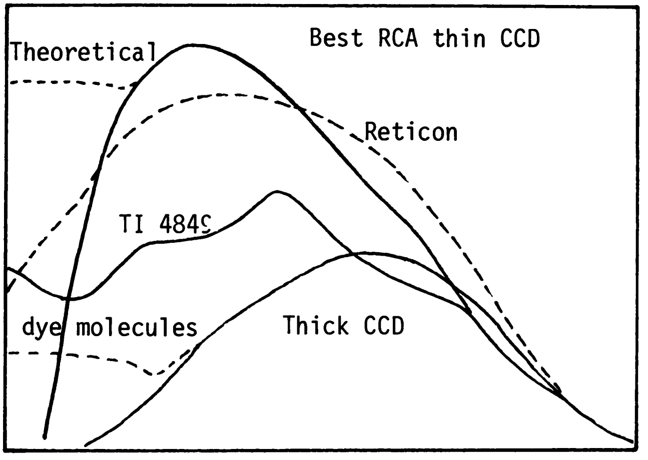

Fig. 1 : Typical responsive efficiency of CCDs.

Many solutions are investigated and discussed by Janesick et al. [3].

a) coating with dye molecules which convert UV photons to red photons detected by a thick CCD [5].

b) P+ diffusion in a thick epitaxial SiO_2 layer followed by an optimum thinning of about 200 nm [2].

c) direct ionic implantation of Boron P+ on an optimum thin CCD [6].

d) Backside charging of the thin CCD by gas absorption corona discharge or UV flooding [2.3].

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e) the so-called "flash gate technology" which consist in coating the backside with a thin platinum layer [2. 3].

Solution a) is presently working very well but should be supplanted within a few years by one of the promising technologies b, c, d or e. (Fig. 1)

We should also note that such an effort is accompagned by an attempt to minimize fringing effect on thin CCDs, and Fresnel losses at the SiO_2/ air interface.

- Increasing the size of frame-transfer CCDs

Up to now the standard size of CCDs does not allow us to use the full field of a telescope without a field segmentation. This often produces an intolerable waste of large telescope time. Several efforts are being made to develop large size CCDs for 1988. Two approaches are considered : the first is to build large monolithic CCDs, [2] the second is to use buttable CCDs for making mosaics [2] (see Fig. 2).

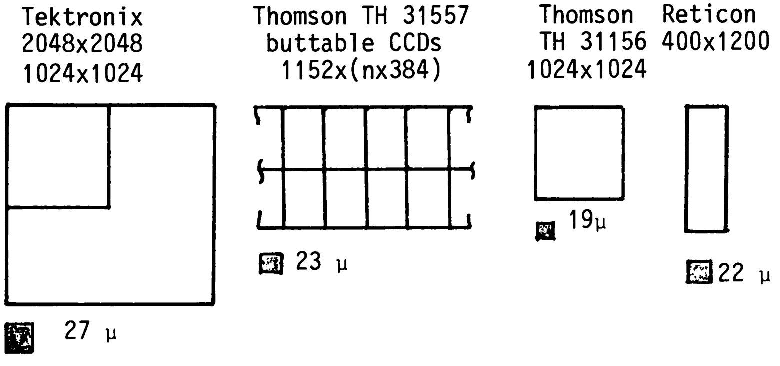

Fig. 2 : Relative size of futur large size CCDs. The shaded area represent the relative pixel size (ref. 9).

III. HOW TO HAVE HIGH S/N WITH A CCD

In this paragraph we summarize some steps that should be followed if we want to get a spectrum with signal to noise higher than 200.

1) The observer has to choose carefully the best place where he can record the spectrum. Even with the best scientific CCD, there always remains blemish defects, trapping effects etc..., which affect some pixels, on a chip.

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2) The long exposure necessary to get the total number of charge per pixel (say $5 10^5$ charge $pixel^{-1}$) has to be segmented in several shorter exposures which do not rise the continuum above a level of about 80 000 charges/pixel. This point is very important and needs to be quickly developed here.

For many CCDs, there is an optimum charge capacity close to 10^5 above which a small but real degradation of the MTF occurs. Some charges in a pixel spread to adjacent pixel. This is for example the case for the Thomson CCD [7]. A non linearity results for high spatial frequencies as well as a smoothing of the Flat Field response which can modify the line profile of absorption or emission lines, if poorly sampled. As the read-out noise is rapidly negligible as compared to the photoelectron shot noise it is then an imperative rule to stop exposures at the optimum charge level and then to co-add each of them. This also allows a better discrimination of cosmic rays glitches on the spectrum.

This rule of not trying to use a CCD above its optimum charge level, also holds for the Flat Field exposure. It has also to be done with a HSN level by co-adding many short exposures.

3) Even when working in this careful way it is difficult to avoid systematic errors, many of them coming from the residual in fringing effect correction. As an example the distribution of light through the slit is different for the calibration lamp and the star, and correspond to different flat field responses.

It is then of great importance to move slightly the grating between each individual exposure in order to average some systematic residual errors. The fringing effect is probably the most pervers one which prevents to get HSN in the far red. But in the green it is already possible to get S/N as high as 500 to 700 with a CCD. This is in fact illustrated by a curve derived from a table given by Bohannan et al. [8]

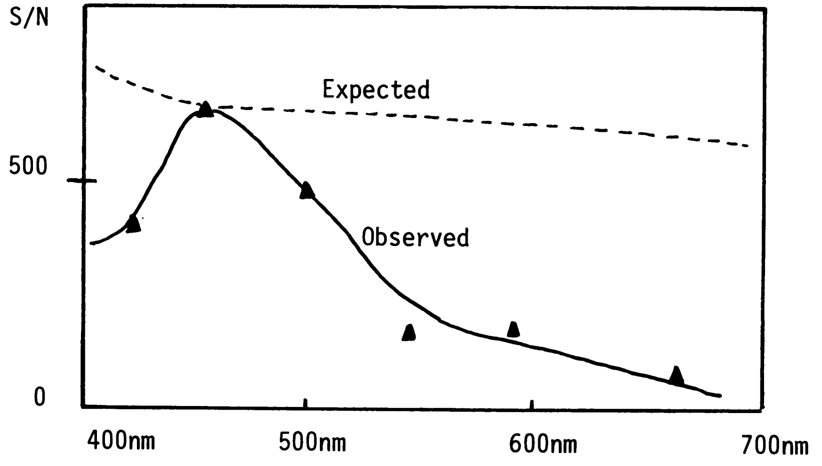

Fig. 3 : High S/N with the KPNO coudé feed spectrograph and a RCA2 thin CCD. 3 to 4 exposures with an optimum pixel charge : 87000e (ref. 8).

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