Ivan Cindrich

Ⓐ

SENT TO ERIM

From.
Robert W. Harrison.

29 July 1976.

29 July 197

"Major Detection Considerations," Trade-offs, etc. Concerning Detector Choice for the NRAO Optical Processor

R. Harrison

① A major problem affecting CCD detectors (but not the Reticon devices) is that of charge transfer efficiency, η which is defined as the fraction of charge actually passed in a given transfer. About the best we could hope this number to be for the Fairchild devices is 0.99999 [this is the best value obtained for any CCD to my knowledge but a much more realistic value would be in the range 0.99997 to 0.99995, which are values actually measure on Fairchild CCD121's (1728 elements)] 1

The effect of these numbers is not negligible in the case of data shifted from the far end of a Fairchild CCD131, with 1024 elements. Even though the charge packet from the most distant photocells travel through a register of only ~ 512 cells, the register is two phase, (i.e. two transfers per cell) implying ~ 1024 transfers all tolled.

The effect of various values of $\epsilon = 1-\eta$ are shown in Fig. 1. Suppose we initially start with the normaliz charge distribution across 7 photocells as shown by the solid This pattern corresponds roughly to the main lobe of a sinc function, with 6 photocells between first zeros. Now tran this pattern from the far end of a CCD131 (direction of transfer is to the right) and then superimpose the transfe and original patterns to show the degredation.

The dashed line represents the transferred patte with $\epsilon = 5 \times 10^{-5}$, the dotted line with $\epsilon = 1 \times 10^{-5}$ (Necon

29 July 1976

was taken of the fact odd and even photocells have differ
shift registers)

Note the following:

① The sizes of the errors (each box represents 2%
the maximum original signal).

② The errors are systematic, and will be in addit
to uncertainties due to noise (which has been ignored
in the above problem)

⑬ The errors are signal dependent, even if ε is
independent of signal.

It is clear ε in general, will depend on signal, and a
though a strong dependence of ε on signal has been dispro
the data could not rule out weak dependences of, say,
$\lesssim$ 10%, which would further complicate matters.
It should be investigated if going to a shorter CCD cures the pro
sufficiently.

⑫ As far as a problem with Fabry-Perot type fringing
in layers above the photosites, more problem might be
encountered with Fairchild, because instead of having a sing
layer of SiO_2, they have two layers of SiO_2 with a polysil
photogate layer sandwiched in between.

⑬ Blooming (the spilling of a over-saturated signal from one
photosite to another) is apparently much more prevalent
in CCD's than in photodiode arrays, because of spillage
from an overexposed cell over the potential barrier into
adjacent shift register.

ⓒ

28 July 1976

④ The major cause of nonlinear response (w.r.t. exposure of both CCD's and photodiodes appears to be in the amplifying electronics, and not the photosensing process itself. In the case of Fairchild, we have to take the on-chip preamp they give us. On chip preamps of this type have been known to give trouble.[2] No one to my knowledge has done sufficiently accurate linearity measurements on the Fairchild devices to check the problem at a level we would b interested in.

It is also important to consider the possibility that the reciprocity between time and intensity is good enough for our purposes (i.e., is exposing for time t at intensit I the same as exposing for time t/c at intensity (cI). Many linearity measurements are done by varying t to cha the exposure (keeping I constant) because it is much easier to do than the other way), but for our device, all integration times will be the same, with a change in I the thing we measure.

ⓑ The dependence of S/N ratio on exposure is significantly different for the Reticon and CCD devices. This arises from the fact photon noise plays a more significant role in the noi of the CCDs than the photodiode arrays. At saturation, the CCD's can "hold" only about 10^6 photons, while the Reticon devices "hold" about 10^7.

ⓒ The Fairchild CCD's make more efficient use of lase energy because

Ⓓ

29 July 1976

(a) The cells cover a smaller area

(b) The noise-equivalent exposure is lower in the Fairc CCD than the Reticon devices.

Because of these two effects roughly 17 times as much energy m be spent overcoming detector noise in Reticon RL1872F as comp with the Fairchild CCD131

⑦ The CCD has a more efficient scan method due to the parallel transfer of integrated photosite charge to the analog shift registers as opposed to serial readout

⑧ I have not yet found anyone who has tried to measure precisely the photometric properties of the *current* Fairch devices, or tried to use them for radiometry.

Reticon, on the other hand, has several customer who have evaluated their devices for such considerations.

⑨ Thought should be given to the use of GE CID's a detectors.

⑩ See list of obvious important detector parameters, things to be tes for, etc.

References:

1 Michael Vicars-Harris, "Slow Scan Operation of Long Linear CCD Arrays," *Proceedings: Symposium on Charge-Coupled Devic Technology for Scientific Imaging Applications.*" Date of Publ. 10 Ju date of Symposium: 6-7 March '75

N 75-28824 thru N75-28844

Contract NAS 7-100

29 July 1976. Ⓔ

Refs. cont'd

2 C. H. Séquin and M. F. Tompsett, Charge Transfer Devic
(Advances in Electronics and Electron Physics, Supplement 8, 197

© 1975, Academic Press, pp 126, 127

---

① Existence of Fabry-Pérot type fringing; its dependence o
λ and angle of incidence. Can it be calibrated out as a "fixe
sensitivity variation for our application?

② $(\text{Dynamic Range})_1 \equiv \dfrac{\text{saturation output}}{\text{RMS noise on ave. pixel in dark}} \equiv DR_1$

Does not include sensitivity variations, dark current non-uniformities, or other fixed pattern "noise."

$$(\text{Dynamic Range})_2 \equiv \frac{\text{saturation output}}{\text{amp. of fixed pattern "noise"}} = DR_2$$

③ Can fixed pattern be removed by calibration and filtering and/or current integration so that

$$DR_1 \approx DR_2 \quad ?$$

④ Device capacity (ie # photons a single pixel can record, as determined by its saturation charge)

⑤ Geometric arrangement of photoelements. Existence of crosstalk between adjacent photoelements. Dependence on λ. With what fidelity (defined in an appropriate manner) does device reproduce the intensity pattern sensed.

29 July 1976 (F

⑥ What is dark current, its nonuniformities, and depend
on temp.?

⑦ Are nonuniformities in sensitivity from photoelement
photoelement independent of intensity, and thus can be calibrate
out?

⑧ How good is the temporal stability of key device
parameters, and what are the effects of any changes or
device calibration?

Is it necessary to regulate the temperature to obt
sufficient stability for resonable calibration?

⑨ If cooling is necessary for reduction of dark curren
what are the effects on device operation as a whole?

⑩ Whether or not "blooming" occurs with photoelements
exposed beyond saturation. How bad?

⑪ Whether or not there is a "threshold" exposure level.

⑫ How fast and slow can the array be scanned? What is
mode of scanning?

⑬ How is linearity of output w.r.t. both intensity and tim
Is there a reciprocity failure analogous to photographic
film? If nonlinear, can it easily be corrected for to
better than 1% cummulative error over 3 orders of mag.
in intensity?

⑭ Be aware of possible nonlinearities in readout electroni

29 July 1976 Ⓖ

⑮ How complete is the readout? Is it a func. of clock freq. or exposure level? How is linearity affecte