Harvard-Smithsonian Center for Astrophysics

Precision Astronomy Group

TECHNICAL MEMORANDUM

To:	Distribution	19 November 2001	TM01-06
From:	J.D. Phillips		
Subject:	Charge spreading: Charge in the central pixel as a function of FWHM.		

In a backside-illuminated CCD, photons of shorter wavelength are absorbed near the surface at which they enter, and the generated electrons travel to the buried channel near the other side. If the CCD is "fully depleted", i.e., an electric field drives the electrons during their entire travel towards the buried channel, then they get there with minimal lateral diffusion. If on the other hand there's an undepleted region, the electrons must first diffuse before being accelerated by the field in the depletion region. Diffusion results in some electrons being collected in neighboring pixels, a phenomenon known as *charge spreading.* At longer wavelengths, some of the light is absorbed closer to or within the depletion region, so there is less spreading.

Detailed measurements on an EEV (now Marconi) CCD have been taken by Tulloch [1998]. The results of illumination with a spot of a few microns, full-width at half-maximum (FWHM), can be modelled as a Gaussian with FWHM of 18 μm.

SAO simulations have found that spreading of 18 μm FWHM increases the photon-limited astrometric uncertainty by about 50%, for an earlier configuration of FAME. (The simulation will require some work if it is to be updated to correctly reflect the current FAME design.)

When LMCO and USNO tested an EEV CCD in 1999, they found no spreading to within a few microns FWHM. Given Tulloch's results, it would be valuable to test this parameter on all CCD's used. This information should be considered when allocating devices for use as astrometric, photometric, or spares.

Charge in the central pixel as a function of FWHM.

Treating the charge spreading as a Gaussian distribution in two dimensions, the intensity per unit area is

$$I(r) = \frac{1}{2\pi\sigma^2}\exp\left(-\frac{r^2}{2\sigma^2}\right) \qquad \textbf{(1)}$$

normalized to unit total intensity, where r is distance from the point at which light impinges on the CCD. The standard deviation σ is related to the full-width at half-maximum by

$$\sigma = \frac{\text{FWHM}}{2\sqrt{2\ln 2}} \approx 0.425\,(\text{FWHM}) \qquad \textbf{(2)}$$

To relate the parameters of the Gaussian model used here to the fraction of intensity captured in the central pixel, which will be tested, consider a pixel illuminated at its center by an infinitesimal spot. The fraction falling in the central pixel is

$$f = \int_{-w/2}^{w/2} \int_{-w/2}^{w/2} I(x,y)\ dx\ dy \qquad \textbf{(3)}$$

where x and y are rectilinear coordinates on the CCD, and w is the pixel size. For a pixel size of 15 µm, this expression is evaluated in Table 1.

Table 1. Fraction of light from a spot centered on a pixel captured in that pixel.

FWHM, µm	σ, µm	fraction
1	0.42	0.9999
2	0.85	0.9999
3	1.27	0.9999
4	1.70	0.9999
5	2.12	0.9992
6	2.55	0.9935
7	2.97	0.9769
8	3.40	0.9462
9	3.82	0.9030
10	4.25	0.8512
11	4.67	0.7950
12	5.10	0.7377
13	5.52	0.6818
14	5.95	0.6287
15	6.37	0.5791
16	6.79	0.5334
17	7.22	0.4916
18	7.64	0.4536
19	8.07	0.4191
20	8.49	0.3879

Reference

Tulloch, S., "The Measurement of Spatial Resolution in EEV4280 CCD Images", RGO Technical Note 118 (7-7-98), available at fame.usno.navy.mil, under Reference Literature, NOT under Technical Memoranda.

Distribution
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