Interquadrant row crosstalk

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1.0 Illumination of the complete row

Several images taken during the SOFI and ISAAC tests have been re-analyzed to further examine one peculiarity of the array which we call interquadrant row crosstalk. The effect is apparent when part of the array is exposed to bright illumination and faint objects have to be detected on the same rows which are exposed to the bright illumination. One has to account for this effect in spectroscopic applications, when faint lines have to be detected between bright OH lines or the continuum to line ratio is of interest.

Figure 1 and Figure 2 show the shading effect with a long slit oriented parallel to the rows of the detector. The slitwidth is 2 arcseconds on the sky. The image shows the spectrum of ambient background radiation observed with the narrow band CO filter and the red grism of SOFI. The dispersion of the grism is 10.22Å/pixel. The peak flux in the center of the slit image is $1374 \text{ e/sec/pixel}$. The calculated photon flux for the given instrument setup is $1846 \text{ photons/sec/pixel}$. The rows in quadrants III and IV near row 798 which have increased intensity but do not receive any photons, are read out at the same time as the rows close to row 286, which are illuminated by the slit. The intensity of row 798 is $1.5\%$ of the intensity of row 286.

FIGURE 1. Shading effect with long slit oriented parallel to rows of the detector. Rows in quadrants III and IV read out at the same time as rows illuminated by the bright slit show increased intensity.
This interquadrant row crosstalk is a detector anomaly assigned to the multiplexer. The effect is poorly understood and not negligible at all when a complete row is illuminated.

In imaging mode the Wollaston prism produces two much brighter images of the slit. The long slit was tilted along the diagonal of the lower rectangle shown in Figure 3. The bright stripe produced by interquadrant row crosstalk is marked by the upper rectangle in Figure 3 and has the same width as the lower rectangle. In each row inside the lower rectangle a few pixels are illuminated by the slit and result in the corresponding intensity increase of the row inside the upper rectangle.

2.0 Illumination of a small fraction of a row

A second test was performed to measure interquadrant row crosstalk when only a fraction of the pixels in a row is illuminated as can be seen in the image shown in Figure 4. The echelle slit of SOFI is imaged on 82 pixels in a detector row generating a peak signal of 26332 electrons/sec/pixel. It is remarkable that pixels being addressed prior to the brightly illuminated pixels show crosstalk at the same level as pixels being addressed later than the bright source. The crosstalk generated in the row of the quadrant containing the slit image and on rows in the remaining three quadrants being read out at the same time has a uniform intensity of 30 electrons/sec/pixel which is 0.113% of the intensity of the slit image.
FIGURE 3. Tilted slit showing interrow crosstalk. The diagonal of the lower rectangle is illuminated by the tilted slit. The intensity is much higher than the cut levels of the image. The dark stripe in the middle of the bright slit is due to double correlated sampling of saturated pixels. The upper rectangle shows a bright stripe produced by crosstalk of the tilted slit.

FIGURE 4. Short echelle slit showing interrow crosstalk. Pixels being addressed prior to the brightly illuminated slit show crosstalk at the same level as pixels being addressed later than the bright source. Crosstalk in all four quadrants is $1.46 \times 10^{-5}$ times the integrated intensity along the row.
By scaling the crosstalk to the number of bright pixels measurements obtained with the short slit (Figure 4) and the long slit (Figure 1 and Figure 2) yield the same crosstalk. With the echelle slit and with the long slit the crosstalk is $1.39 \times 10^{-5}$ and $1.46 \times 10^{-5}$ times the integrated intensity along the row respectively. The interquadrant row crosstalk is uniform and depends linearly on the integrated intensity in a row.

A second image of the echelle slit was taken with increased photon flux saturating the detector pixels. Since double correlated sampling was used, saturated pixels in the center of the echelle slit appear dark in Figure 5. The trace perpendicular to echelle slit shown in Figure 5 and the trace perpendicular to the associated row crosstalk which is shifted by 512 rows is shown in Figure 6. Both the image of the slit and the interquadrant row crosstalk show the saturation of pixels as reduced intensity which is expected for double correlated sampling.

![Echelle slit with saturated pixels. Crosstalk rows also show saturation of detector (see trace perpendicular to slit and crosstalk rows in Figure 6).](image)

**FIGURE 5.** Echelle slit with saturated pixels. Crosstalk rows also show saturation of detector (see trace perpendicular to slit and crosstalk rows in Figure 6).
3.0 Illumination of a large area

In ISAAC the dispersion direction is parallel to the row direction of the detector. In the low resolution spectroscopic mode a blackbody source at a temperature of 130°C viewed through the K band filter illuminates a larger area of the detector as can be seen in the left image of Figure 7. Reducing the cut levels in the right image of Figure 7 makes visible the interquadrant row crosstalk, which appears as darker and brighter stripes outside the K-band spectrum where the array does not receive any photons. At the top and at the bottom the array does not receive any light. The remaining intensity of ~100 electrons at the top and the bottom of the array is due to interquadrant row crosstalk of the rows in the corresponding upper or lower quadrants which are brightly illuminated. Each of the bright rows receives a total integrated intensity of 7.39 × 10^6 electrons during the integration time of 1.4 seconds. The rows of the two darker stripes in the center see crosstalk of the illumination incident on the row itself but no crosstalk from rows of other quadrants read out at the same time, since these rows are dark. The bright stripes in the upper and lower quadrants see interquadrant row crosstalk in addition to intrarow crosstalk within the row itself. The crosstalk of the bright stripes has twice the value of the crosstalk of the dark stripes. Since the bias pattern of the array is nonuniform and the trace perpendicular to rows as shown in Figure 8 is a superposition of bias pattern and row crosstalk, the discontinuity step at positions 1, 2, 3 and 4 was used to quantify crosstalk. The step size is 94.2 electrons yielding a crosstalk of 1.3 × 10^-5.
Integrated intensity in row is $1.324 \times 10^6$ ADU = $7.388 \times 10^6$ e

**FIGURE 7.** Low resolution spectrum of short K-Band filter taken with ISAAC shown with different cut levels. Left image: cut levels -1000/+7000 ADU. Right image: cut levels -20/+50 ADU. Dispersion direction is parallel to rows.

Integrated row intensity of K-band spectrum is $7.388 \times 10^6$ electrons. Peak intensity is 36270 electrons. Stripes outside the spectrum of K-band filter in right image are caused by interquadrant row crosstalk. The vertical line in the right image indicates the location of the trace shown in Figure 8.
4.0 Illumination with a point source

If all the light is concentrated in a single point source as in the 30 Doradus image shown in Figure 9, interquadrant row crosstalk can still be seen. The intensity of the point source on row 384 is shown in Figure 10. The integrated intensity of the point source in row 384 is 64170 e/sec/pixel. A trace perpendicular to the rows affected by interrow crosstalk is plotted in Figure 11. To increase the signal to noise ratio of the trace, columns 210 to 385 have been averaged. The intensity in row 896 is 0.87 e/ sec/ pixel. This yields a measured crosstalk of $\alpha = 1.35 \times 10^{-5}$. This reconfirms that the row crosstalk is proportional to the integrated intensity along a row.
FIGURE 9. 30 Doradus showing interquadrant row crosstalk for point source illumination. Integrated intensity of point source in row 384 is 64170 e/sec/pixel. Intensity in row 896 is 0.87 e/sec/pixel. Crosstalk is $1.35 \times 10^{-5}$.
FIGURE 10. Point source in 30 Doradus. Integrated intensity of point source in row 384 is $64170e/sec/pixel$.

FIGURE 11. Interquadrant crosstalk of point source in 30 Doradus. To increase signal to noise ratio of the trace in the row direction, columns 210 to 385 have been averaged. Intensity in row 896 is $0.87 e/sec/pixel$.
5.0 Swapping of fast and slow clocks

A further effort has been made to reduce the crosstalk by clocking the fast column shift register slowly and the slow shift register (row) fast. Figure 12 shows the image of a grid of holes applying standard clocking. The column shift register is running with fast clocks and the row shift register is running with slow clocks. The image in Figure 13 was taken under identical conditions but the clocks were swapped. The row shift register is running with fast clocks and the column shift register is running with slow clocks. The Holes at position 1,2,3,4 and 5 have trails shifted by one pixel in direction of slow clock. The trails at position 3 and 4 can hardly be seen in Figure 13 due to poor reproduction quality. The trails have uniform intensity and the crosstalk $\alpha$ is $2 \times 10^{-4}$. They are shifted by one pixel in the direction of the slow clocks. Not all point sources have a trails suggesting a kind of subthreshold effect of the addressing FET's. The standard clocking does not exhibit any trail at this level. Therefore swapping clocks is not recommended.

FIGURE 12. Image of hole mask applying standard clocking: column shift register running with fast clocks and row shift register running with slow clocks.
6.0 Model for row crosstalk

The row crosstalk is uniform within one row and does not depend on column index j. Let $I_{i,j}$ be the intensity of the pixel at row i and column j. Due to row crosstalk the observed intensity $I'_{i,j}$ is modified by the row crosstalk as described by equation 1.

$$I'_{i,j} = I_{i,j} + C_i + C_{i \pm 512} \quad \text{(EQ 1)}$$

The row crosstalk $C_i + C_{i \pm 512}$ consists of two terms, namely the intraquadrant row crosstalk $C_i$ and the interquadrant row crosstalk $C_{i \pm 512}$. Both terms depend linearly on the integrated intensity of row number i and row number $i \pm 512$ as described by the coefficient $\alpha$ in equation 2. The plus sign applies for indices $i \leq 512$, the minus sign for $512 < i \leq 1024$:

$$C_i = \alpha \sum_{k=1}^{1024} I_{i,k} \quad \text{(EQ 2)}$$

The intensity $I_{i,j}$ can be derived from the observed intensity $I'_{i,j}$ by subtracting the row crosstalk as shown in equation 3.
\[ I_{i,j} = I'_{i,j} - C_i - C_{i\pm 512} \] (EQ 3)

The result of this correction algorithm is demonstrated in Figure 14 and Figure 15 by comparison of the raw K-band spectrum of Figure 14 with the K-band spectrum modified by the correction algorithm using equation 3. The row crosstalk can be well removed. The correction algorithm was also applied to the 30 Doradus image. Row crosstalk can be removed without any degradation of image quality as shown by Figure 16 and Figure 17 with the raw and the corrected images of 30 Doradus.

FIGURE 14. Raw K-band spectrum showing row crosstalk


FIGURE 16. Image of 30 Doradus raw image showing row crosstalk caused by bright point source.

FIGURE 17. Image of 30 Doradus corrected for intraquadrant and interquadrant row crosstalk.


7.0 Conclusions

Even though interquadrant row crosstalk is not yet understood the following behavior of the effect has been observed:

- The crosstalk is uniform for all pixels in a row
- The crosstalk affects all rows in the other quadrants being read out at the same time with equal intensity. MUXSUB, CELLWELL and DSUB are the only bond pads which are shared by all four quadrants.
- Pixels being addressed prior to the brightly illuminated pixels show crosstalk at the same level as pixels being addressed later than the bright source.
- The intensity of the crosstalk is $1.3 \times 10^{-5}$ times the integrated intensity along one row
- The effect is 1.5% if a slit is oriented parallel to the row and all pixels are illuminated. This case is encountered when the dispersion direction is perpendicular to the rows and bright atmospheric lines illuminate the whole length of the slit.
- Saturation of brightly illuminated pixels is reproduced by interquadrant row crosstalk
- If the slow shift register is clocked fast and fast shift register is clocked slow the point source images exhibit strong trails confined to one quadrant, an effect not apparent with standard clocking.
- Spectroscopic applications will be adversely affected.
- If an explanation can be found design modifications on the 2Kx2K multiplexer should be made to suppress this effect
- An efficient and simple algorithm has been developed which removes the effect of row crosstalk without any degradation of image quality.

Further discussions should clarify whether the dispersion direction should be perpendicular or parallel to the rows of the array. If the dispersion direction is parallel to the rows all bright spectral lines of a point source add to row crosstalk. If the dispersion direction is perpendicular to the rows bright skylines (OH lines) which fill the complete length of the slit add to row crosstalk.

A simple alternative is offered by the algorithm described above which efficiently removes the effect of row crosstalk.