Crosstalk Measurements in the DES Multi-CCD Prototype Camera

Juan Estrada (*Fermi National Accelerator Laboratory, Batavia, IL, USA*)
&
Andrés Plazas (*University of Pennsylvania, Philadelphia, PA, USA*)

August 2007

1 Introduction

In a previous document [1], we presented the results of a characterization of the crosstalk problem that has been found in the back-illuminated fully depleted 250 μm thick CCDs that are being testet at the *Silicon Detector Facillity*, SiDet, in Fermilab for the Dark Energy Survey (DES) project. For reference, we show the main results we obtained that time in Tables 1 and 2. We now present the results found from measuring the crosstalk in the multi-CCD prototype camera (Figure 11) that is located in the CCD testing room of SiDet. These CCDs are now mounted the *science (pedestal) package* (Figure 2) that will be used in the real DECam (unlike the CCDs analysed in [1], which had a *picture frame package*, see Figure 1). As is found in the literature [2], crosstalk is defined as the (undesired) coupling of energy between two circuits or parts of them by means of electric or magnetic fields. This means that we can model crosstalk contributions as coming from a capacitive part and an inductive part which, in general, have no constant impedances (frequency dependent) . It is important therefore to make the measurements again with the CCDs having this new configuration (which by the way is a more realistic one), in order to make a better characterization of the problem and be able to correct for it.

We used a laser pulse to create the image of a "fake star" on one side of the CCD and measure its crosstalk on the other channel. In this way we are

able to controle the intensity of the light pulse we send, so can make a better measurement of crosstalk (last year results were calculated from the crosstalk generated by intrinsec unsaturated light bulbs in the CCD). In some cases crosstalk was found to be so small that it was necessary to send several pulses for creating a measurable crosstalk.

From the results of [1] we know that we can study for separate the CCD and stuff (cables, amplifiers, etc) contribution to crosstalk from that one from the board (this is because crosstalk between channels 0 and 7 -those physically separated the most- is very small, so we can put the two readout channels of the CCD in these two in order to study the crosstalk in it). Crosstalk was measured in the multi-CCD system and for the CCD with a science pckage mounted in a dewar cube for different readout speeds (capacitive and inductive impedances both depend on frecuency and in fact crosstalk was found experimentaly to have a dependence on this variable in the previous measurements [1]). All results are presented and sumarized in Table 2. For most cases, many CCD images were taken and their mean image [1] used for making the analysis. Some examples of these images and plots are shown.

In general, it was found that the crosstalk in the CCDs studied satisfies DES technical requirement for crosstalk of a ratio less than 10^{-3} [4]. Nevertheless, we note the strong sensitivity of crosstalk with each particular electronic configuration, making its complete characterization a non-trivial problem and making it necessary to measure it again in the real camera in ordert to correct for it.

Finally, a test of one of the correction factors measured (0.006 for a science package with preamplifier and no JFET at 3.7 μs/pixel, see Table 2) was made by Donna Kubik (Fermilab). This is shown in Figures 14 and 15. We can appreciate that in this case the crosstalk value is close to optimal.

[1] IDL procedure MedianAndMean created by Donna Kubik (Fermilab employee) was used.

Crosstalk in physically opposite channels of the board	$\approx 0.08\%$
Crosstalk in physically non-opposite channels of the board	$\approx 0.006\%$
Crosstalk due to the CCD and stuff (cables, amplifiers,...)	$\approx 0.07\%$

Table 1: Summary of previous results [1]

2 Crosstalk Measurements in the Dewar Cube

2.1 Picture frame package

We put a CCD in a picture frame package (Figure 1) in a test dewar cube. We studied crosstalk between the channels of the CCD by connecting its two video outputs to channels 0 and 1 of the Monsoon ACQ board SN 021 (which was one of the boards we used in our previous measurements). Two different readout times were tried (3.7 and 6.2 μsec/pixel). A source follower circuit (JFET)located at the output of the CCD and a 3 ADUs/e^{-1} gain preamplifier were used. It is worth to keep in mind that this time floating channels did not have 5-kΩ resistors like in [1].

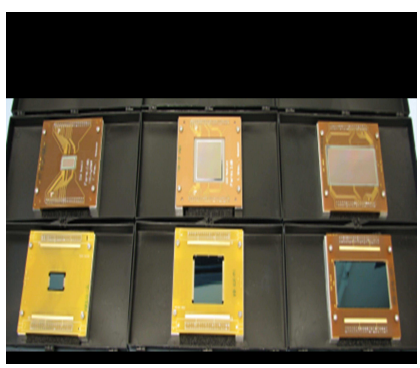

Figure 1: Picture Frame package for different CCD sizes. Top: front illuminated CCDs. Bottom: back illuminated.

2.2 Science package

We also measured crosstalk between the two CCD readout channels in the case of a science package (Figure 2). Different electronics configurations (JFet and preamplifier, no JFET and no preamplifier, no JFET and preaplifier) and

readout times (3.7 and 6.2 μsec/pixel) were studied in order to characterize crosstalk. This type of packaging is the one that is used in the protoype multiCCD camera.

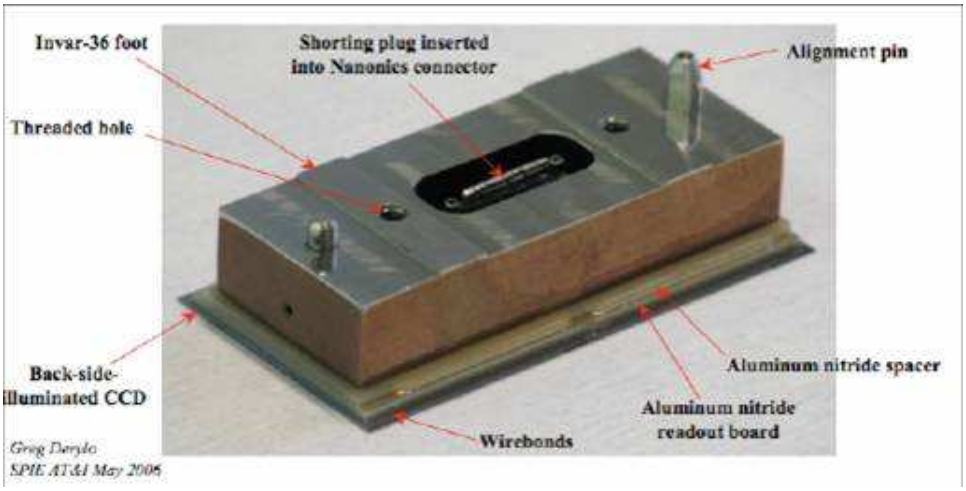

Figure 2: Science package of the CCDs that is used in the prototype camera in SiDEt and will be used in the real DECam.

3 Crosstalk measurements in the MultiCCD prototype camera

3.1 Crosstalk in a single CCD

In the multi-CCd prototype camera there are currently four 2k×4k science packaged CCDs. Their arrangement is as shown in Figure 11. Measurements were made at three different readout speeds (3.0μs/pixel, 3.7μs/pixel, 6.6μs/pixel). Crosstalk in these three cases was found very difficult to see and measure, so in all cases was necessary to send several laser pulses in order to be able to measure crosstalk (even so, in the case of 3.7 μs/pixel we could only make an estimate of crosstalk given that its value was very small).

3.2 Crosstalk between CCDs

Crosstalk was also measured between different CCDs in the multi-CCD array. More precisely, crosstalk was detected between right channel of CCD 2 (where the laser pulse was sent) of the array and channels 1 and 2 of CCD number four (Figure 12).

4 Results

SUMMARY OF CROSSTALK RESULTS (Ratio of crosstalk to laser signal)		
Tests in Dewar Cube		
Features	**3.7 μs/pixel**	**6.6 μs/pixel**
Science Package		
JFET, Preamp.	0.000267 $\pm$0.000013	-0.000393 $\pm$ 0.000012
No JFET, no Preamp.	0.00802 $\pm$0.00046	0.005451 $\pm$ 0.000065
No JFET, Preamp.	0.006261$\pm$0.000044	0.001668 $\pm$0.000017
Picture Frame Package		
JFET, Preamp.	0.00016 $\pm$0.00005	0.000196 $\pm$ 0.000015
Tests on Multi CCD prototype camera-Single CCD		
3.0 μs/pixel	**3.7 μs/pixel**	**6.6 μs/pixel**
0.00012 $\pm$0.000046	$\leq$ 0.00001$\pm$0.00001	-0.00003$\pm$0.00001
Tests on Multi CCD prototype camera-Crosstalk between CCDs 3-4		
3.7μs/pixel		
0.000141$\pm$0.000005		
Results of previous measurements (DES doc 207-v1)		
Features	**Location**	**6.6 μs/pixel**
No JFET, preamp.	Physically opposite channels (board)	$\approx$ 0.0008
No JFET, preamp.	Physically non-opposite channels (board)	$\approx$ 0.00006
No JFET, preamp.	CCD and stuff (cables, amplifiers,...)	$\approx$ 0.0007

Table 2: Summary of crosstalk measurements. The errors shown are statistical.

5 Discussion and Conclusions

As a general feature, we can see that almost all crosstalk values measured satisfy the preliminary DES technical requirement TP-2 [4] of 10^{-3} for crosstalk (ratio between crosstalk and original signal). The only values that are one order of magnitude above this requirement are those obtained when the source follower JFET (located between the science package and the ACQ board) was not there. Therefore we can say that the introduction of the JFET diminishes crosstalk (one could say that the large input impedance of the JFET prevents the current from the science package to flow to the ACQ board, lowering in this way the inductive coupling, or, artenatevely, one can think also in the possibility of the low output impedance of the FJET allowing current to flow from the package and with that diminishing capacitive coupling; we would need to have a detailed knowledge of the actual configuration of the system and make a more deeper analysis). Taking this into account we can see an agreement with the values shown in the previous report (see last row of table 3, "CCD and stuff"). The JFET source follower is also used in the multi-CCD camera, so this could help to explain the low values of crosstalk seen in the multi-CCD vessel. In fact, it was very difficult to measure theses values, and systematics errors (the errors shown in table 3 are only statistical) may be present. We can also appreciate the way in which crosstalk depends on frequency. Given that the impedance depends on this variable, we expect crosstalk to change according to the different electronic configurations. This makes crosstalk problem a non-trivial one and brings the necessity of mearuring it again in the actual final conditions (i.e, in the real DECam).

References

[1] **Estrada**, Juan ; **Plazas**, Andrés. *Crosstalk Measurements for DES CCDs and Monsoon Boards*, DES document 207-v1.

[2] **General Services Administration**, emphTelecommunications: Glossary of Telecommunications Terms, Federal Standard 1037C.

[3] **Horowitz**, Paul; **Hill**, Windfield. *The Art of Electronics*, second edition.

[4] *Comparison of DECam engineering CCDs with DES technical requirements*, DES document 479-v5.

[5] **Scarpine**, V. *Laser Pattern on CCD - Fresnel Diffraction*, DES document 756-v1.

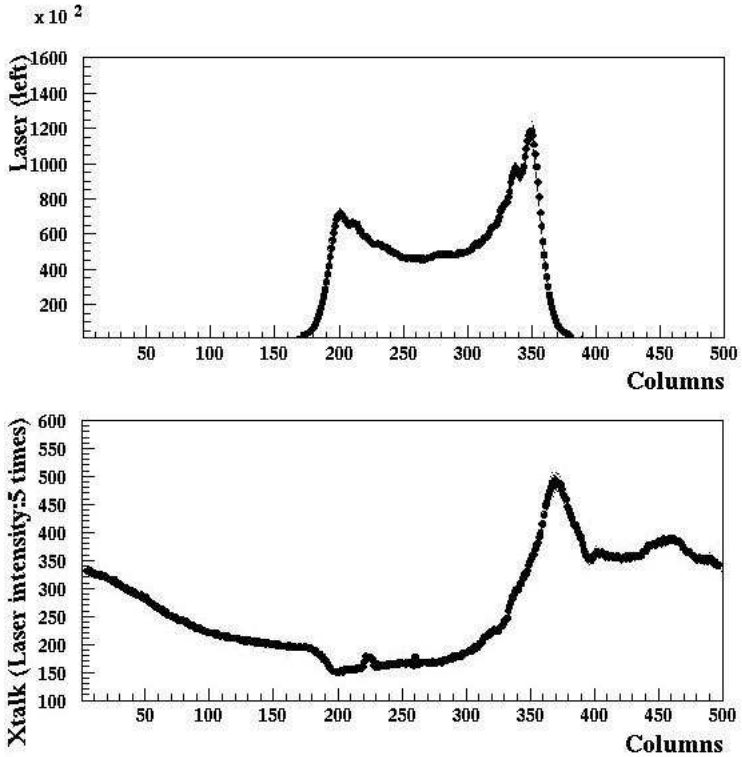

Figure 3: Picture frame package. JFet and preamp. Crosstalk in a single CCD at a 6.2μs/pixel rate. A laser pulse was used and its crosstalk measured in the other CCD readout channel (right hand side, RHS). The crosstalk in the bottom plot corresponds to a laser pulse 5 times brighter than the pulse shown in the top plot (given that it was difficult to see we had to send several pulses).

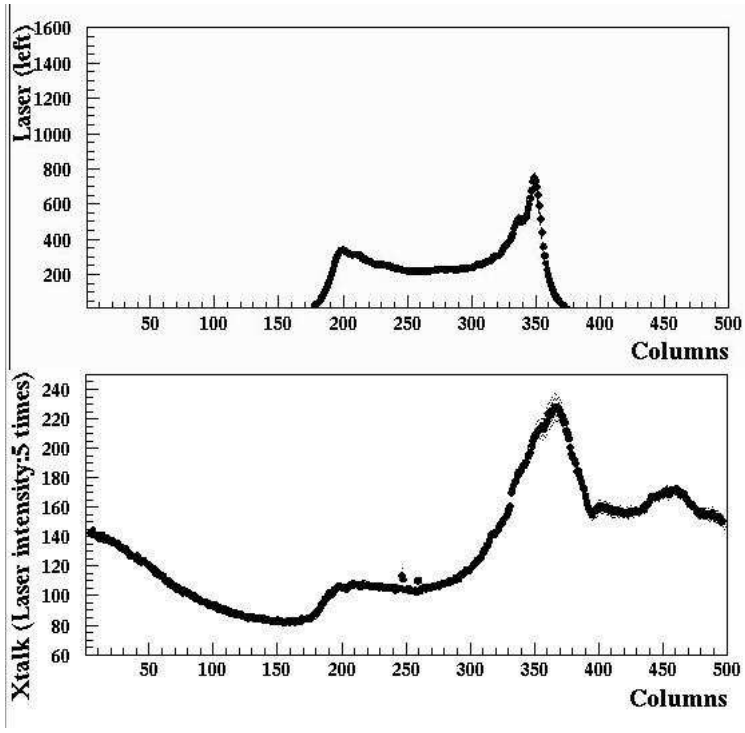

Figure 4: Picture frame package. JFET and amplifier. Crosstalk in a single CCD for a 3.7μs/pixel rate. A laser pulse was used and its crosstalk measured in the other CCD readout channel. The crosstalk in the bottom plot corresponds to a laser pulse 5 times brighter than the pulse shown in the top plot.

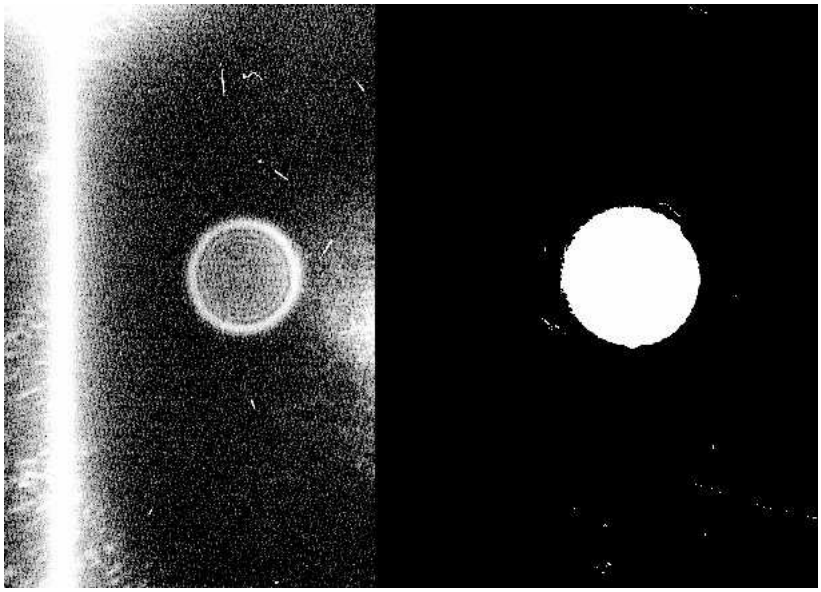

Figure 5: Example image of crosstalk. Science package in a dewar cube. 6.6μs/pixel readout rate. A laser pulse was used (right) and its crosstalk measured in the other CCD readout channel. Preamplifier used, source follower (JFET) not. The laser exhibits a Fresnel difraction pattern (curved wavefronts of light reaching the aperture of the laser, see [5]).

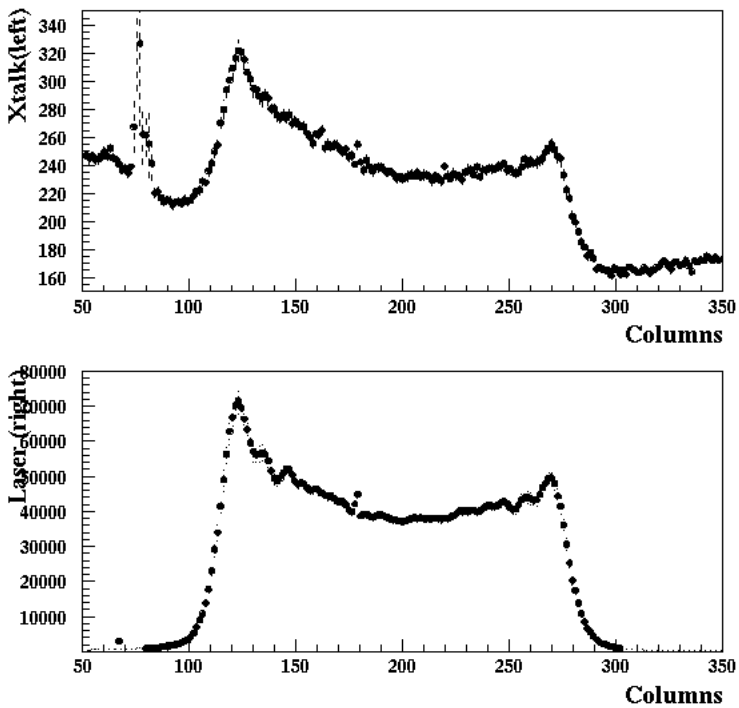

Figure 6: Plot of the pixel values of the laser signal and crosstalk shown in the previous ds9 image. 6.6μs/pixel rate. Test made on dewar cube with a CCD in a science package. Preamplifier used, source follower not. For all the cases cited in the table of results (Table 2) we created similar plots in order to quantify crosstalk.

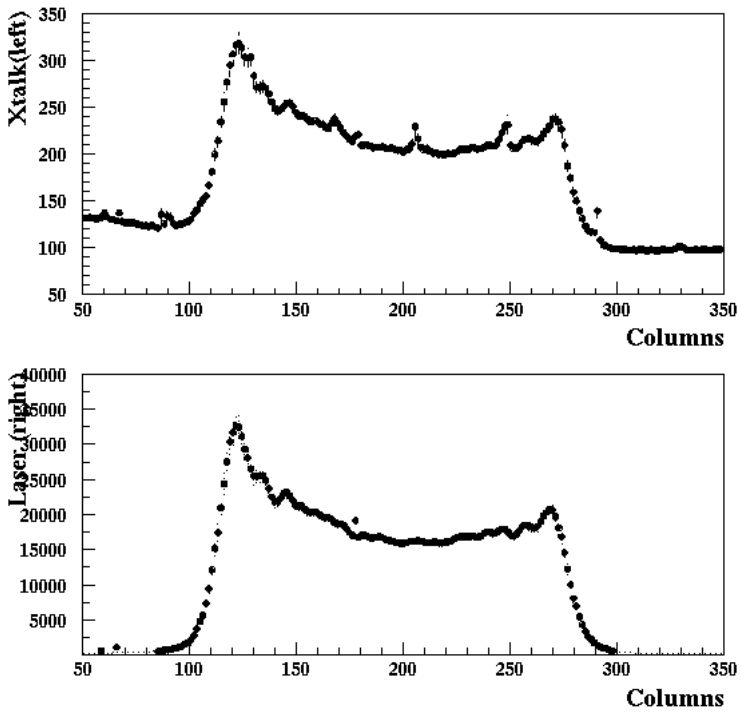

Figure 7: Same situation as in Figures 5 and 6 but for a 3.7μs readout time.

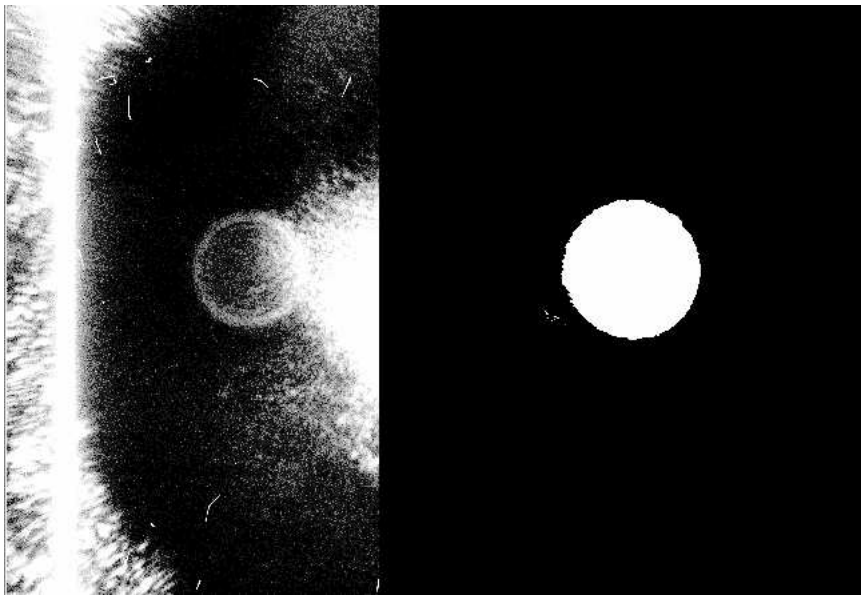

Figure 8: Another example of a ds9 image where crosstalk can be appreciated. Science package. 3.7μs/pixel readout rate. A laser pulse was used (right) and its crosstalk measured in the other CCD readout channel. Preamplifier and source follower used. The crosstalk measured is about 0.0026, as shown in Table 2.

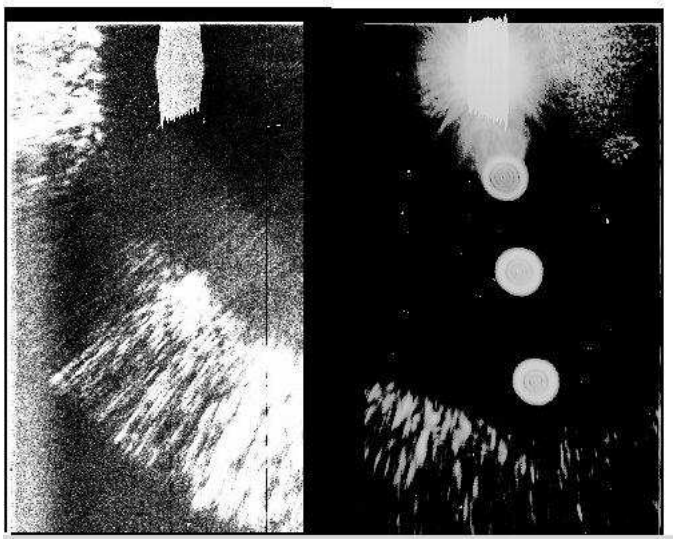

Figure 9: Crosstalk in the multiCCD camera (left) due to a laser pulse in the RHS. This is crosstalk in a single CCD (number 3, see Figure 11) for a readout speed of 3.0 μs/pixel. For this frequency crosstalk was easier to see than for 3.7μs/pixel and 6.6μs/pixel, as is quantified in Table 2, bringing into evidence the crosstalk dependence on frequency.

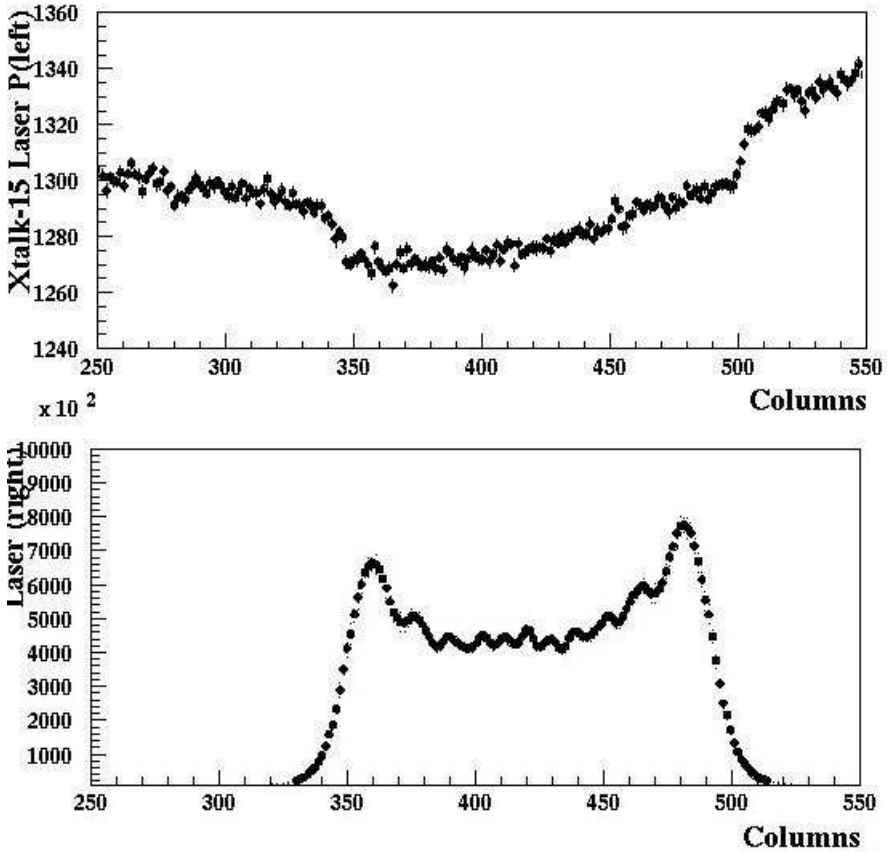

Figure 10: Crosstalk in a single CCD (number 3) of the multi-CCD vessel. The readout time is 6.2 μs.

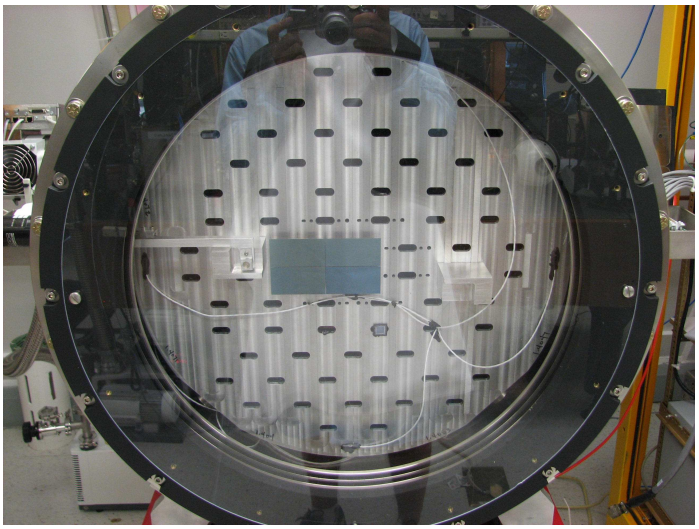

Figure 11: Image of the four CCDs mounted on the focal plane of the prototype DECam at SiDet. The numeration of the CCDs is as follows: CCD 1 (right,top), CCD 2 (right,bottom), CCD 3 (left,top), CCD 4 (left,bottom)

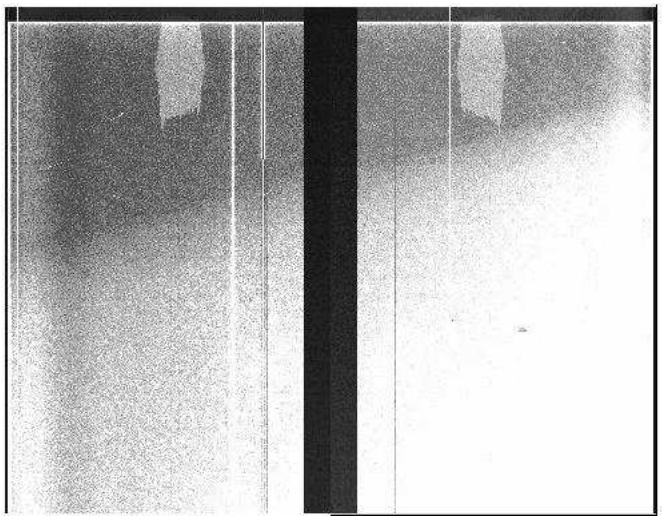

Figure 12: Crosstalk between CCDs in the multi CCD prototype camera. This vessel has four 2k×4k CCDs. Here is shown the crosstalk on CCD number four that is caused by the laser pulse that is shown in the right hand side of Figure 9, which in turn is on CCD number 3.

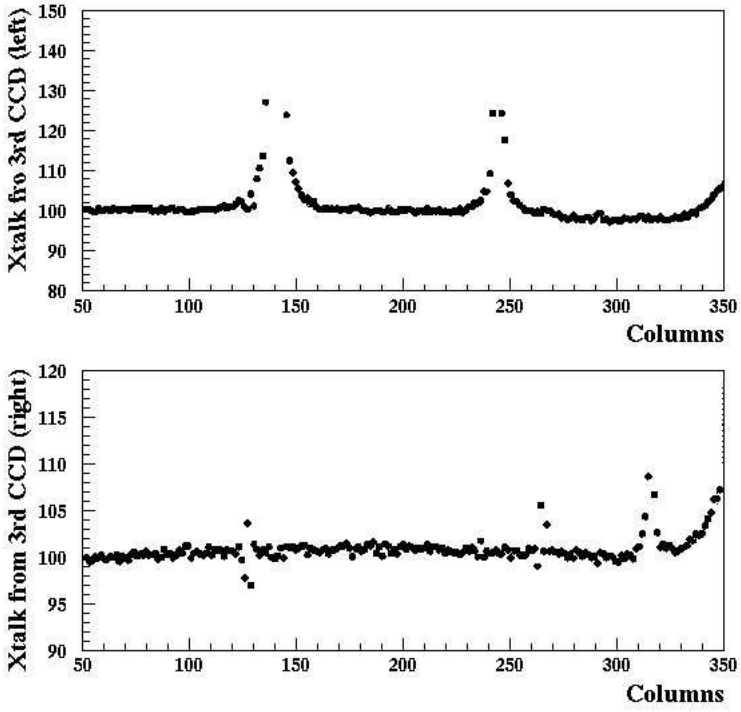

Figure 13: Profile of crostalk betwwen CCDs 3 and 4 in the multi-CCD vessel shown in previous plot. Notice that RHS crosstalk is almost unmeasurable, indicating probably that the RHS of CCD 3 (where the original laser pulse was sent) and this side are not so coupled. The crosstalk value between CCDs that's in Table 2 was calculated using the bottom part of this plot (i.e., crosstalk on the LHS of CCD number 4).

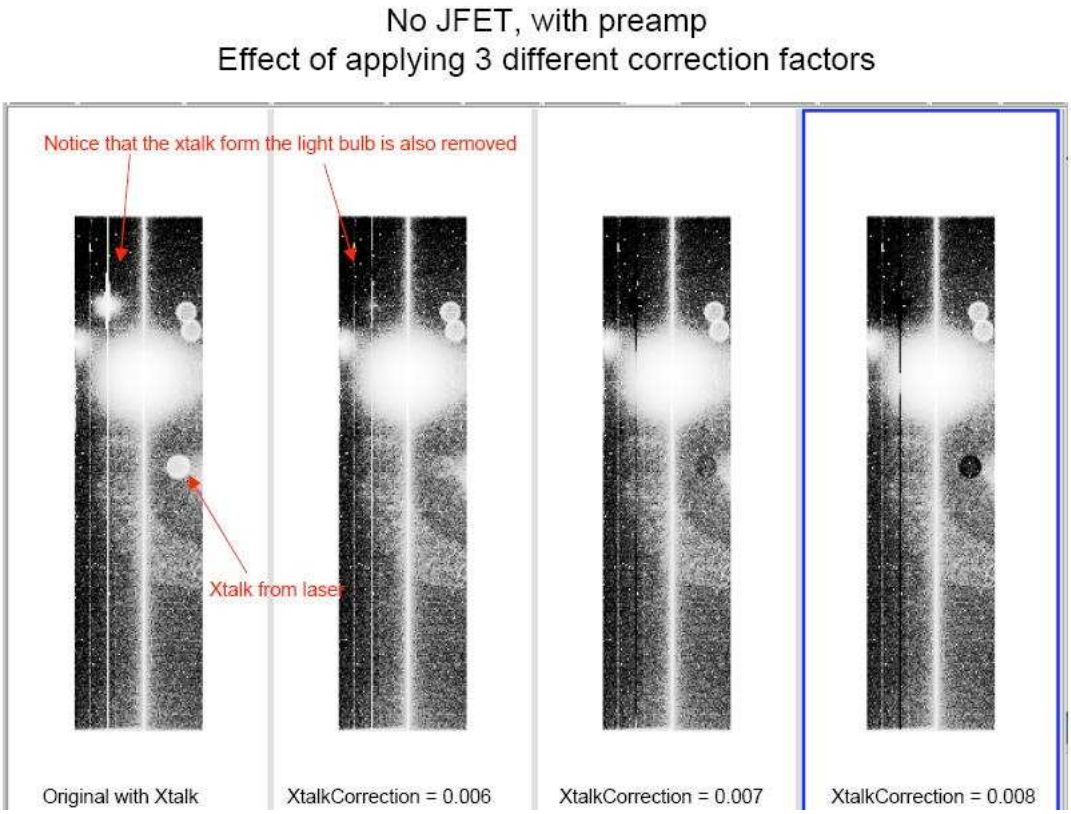

Figure 14: Crosstalk correction applied. The firts image shows the LHS of a CCD in a science package with no source follower (JFET) but with an amplifier at 3.7 μs/pixel . Crosstalk due to a light bulb and laser in the RHS (not shown) can be appreciated. For this case the crosstalk value measured was approximately 0.0006 (Table 2). This factor of correction, along with a factor of 0.0007 and 0.0008, was applied (images 2, 3, and 4). The factor that best corrects for crosstalk is 0.0006; the other ones overcorrect. Image and analysis made by Donna Kubik.

Correction factor = 0.006

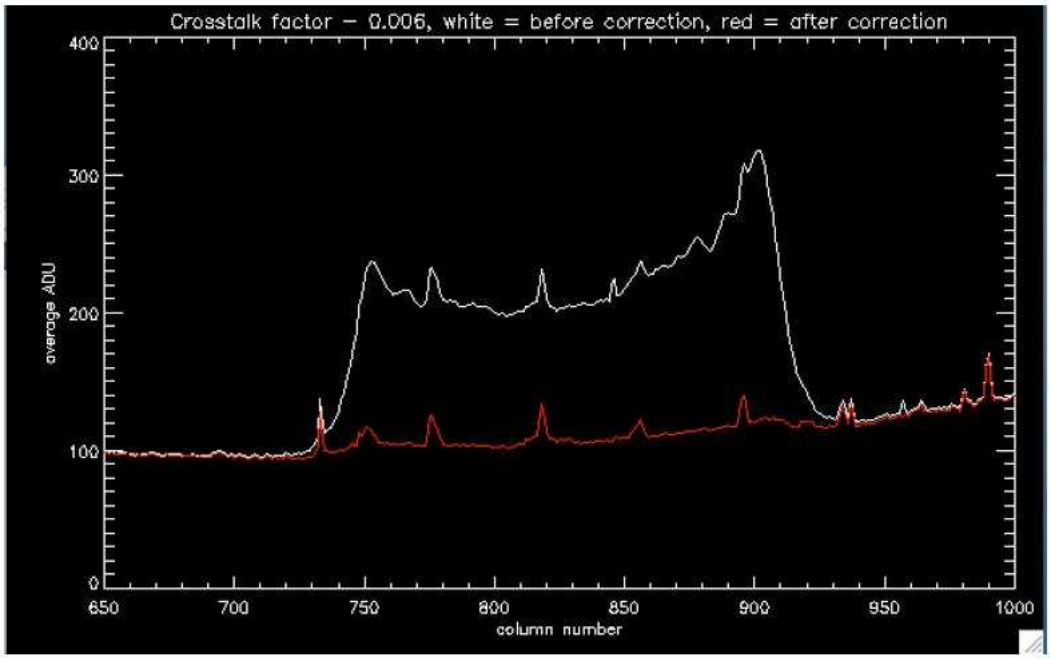

Figure 15: Profile of the second image of the previous figure. Crosstalk is almost eliminated (red plot). Systematical errors are still present (errors shown in Table 2 are statistical). Plot and analysis made by Donna Kubik.