pnCCD test

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1 Scope

This technical note describes the tests performed on the pnCCDs[3] used as camera for the Shack-Hartman ARGOS 's WFSs.

2 Introduction

The pnCCD is the detector of the Shack-Hartmann ARGOS 's WFSs.

Table 1: General characeristics as provided by HLL/pnSensor.

Parameter	**Value**
Type of CCD	Column-parallel, split frame transfer
Total number of pixels	69696
Pixel size	$48\,\mu m \times 48\,\mu m$
Pixel in image area	248 × 256 pixels
Reference pixels	8 columns and 4 lines per CAMEX
Image area	$11.9 \times 12.2\,mm^2$
Quantum efficiency at $532\,nm$	>98%
At $[500\,nm,\,800\,nm]$	>90%
Charge Transfer Efficiency	>0.99999
Full well capacitance	>50 000 e^-
Dark current $-50\,C$, $100\,fps$	$0.196\,e^-\,pixel^{-1}\,s^{-1}$
Hot pixels	No hot pixels at 20 fps
Dark pixels	No dark pixels at 900 fps
Operating frame rate	$10\,Hz \div 1000\,Hz$

3 LBT#2

Gain and Read Out Noise of the camera LBT#2 had been measured taking images of a flat field with a different flux of light.

For every flux of light, 1000 images at 1 kHz (tracking number from `measure/SX/20130718_091746` to `measure/SX/20130718_094555`) and 25 Hz (tracking number from measure/SX/20130705_143009 to measure/SX/20130705_150353) were acquired, and time-average and variance of each pixel were computed.

The gain is the slopes of variance (s^2, on y-axis) vs. time-average for each pixel (on x-axis), the gain was computed by a linear fitting, as show in Figure 1.

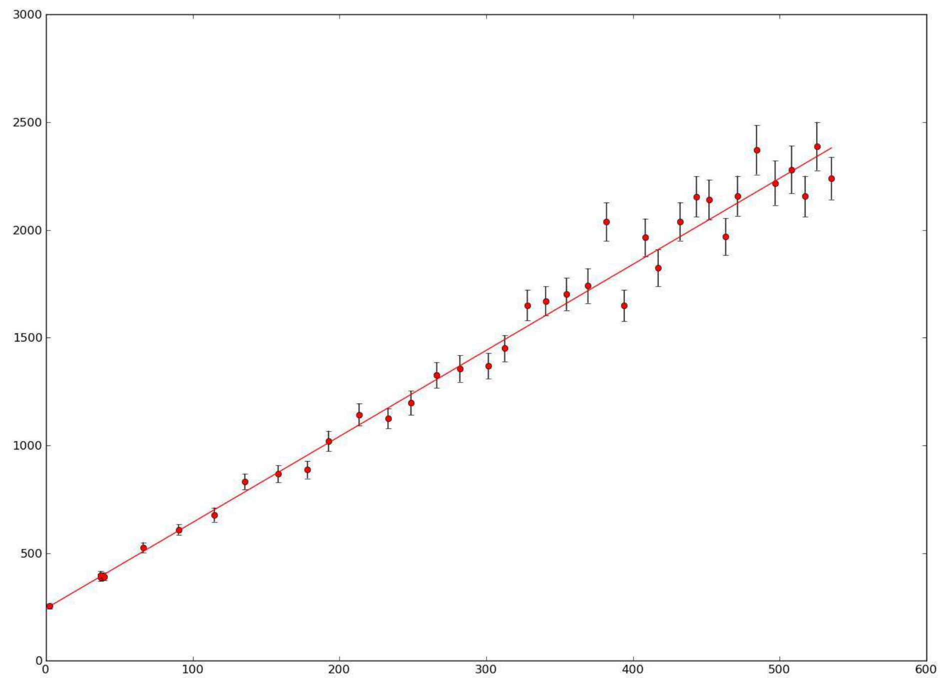


FIGURE 1: On x-axis the mean flux on a pixel expressed in ADU, on y-axis the variance s^2 on a pixel and relative error bars(δ_{s^2}), expressed in ADU^2.

The error of the variance (δ_{s^2}, error bar in Figure 1) is computed from the variance of the estimator of the variance[1], s^2:

$$V[s^2] = \frac{1}{n}\left(\mu_4 - \frac{n-3}{n-1}\mu_2^2\right); \qquad \mu_k \simeq \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^k; \qquad \delta_{s^2} = \sqrt{V[s^2]}$$

where μ_k is the k-th central moment, x_i is the i-th value and $\bar{x}$ the mean on the n events.

For each pixel the intercept of the linear fit is the variance of signal without light, so the square root divided by the median gain is our measure of the Read Out Noise (RON). From the covariance matrix of the linear fit we computed for each pixel the error of Gain and RON, in Table 2(a) are show the mean value and the mean value of the errors for each parameter. We define bad pixels as pixels where the linear fit doesn't converge, or where the computed gain is outside the 6σ interval.

A histogram of the gain value is shown in Figure 2(b), a histogram of the RON value is show in Figure 2(f), with this data we computed the values show in Table 2(b), Gain and RON are the median of the values and σ are the standard deviation of this values.

The standard deviation σ of Gain and RON are smaller than the error ε due to the linear fit, so our analysis is consistent and the deviation of gain between pixel is greater than the measument error.

TABLE 2

(a) Gain and RON values for LBT#2 @ 1 kHz, computed from linear fit.

Parameter	Value	Unit
Gain	3.89	ADU/e^-
ε_{Gain}	0.05	ADU/e^-
RON	4.18	e^-
ε_{RON}	0.06	e^-

(b) Gain and RON values for LBT#2, computed from the histogram.

Parameter	Frequency	Value	Unit
Gain	1 kHz	3.89	ADU/e^-
σ_{Gain}	1 kHz	0.11	ADU/e^-
RON	1 kHz	4.16	e^-
σ_{RON}	1 kHz	0.13	e^-
Gain	25 Hz	3.83	ADU/e^-
σ_{Gain}	25 Hz	0.32	ADU/e^-
RON	25 Hz	5.32	e^-
σ_{RON}	25 Hz	0.21	e^-

3.1 Cosmic

During the data acquisition we saw some strange frames from the camera LBT#2, randomly a group pixel was saturating, without a specific pattern, as show in Figure 3.

Durig an acquisition of 40000 frames at 1 kHz the integrated flux of cosmic radiation expected[2] for high energy muons ($E_\mu > 1\,GE\text{v}$) is $I = 1\,cm^{-2}\,min^{-1}$, the total time of acquisition is $t = 40\,sec = 0.67\,min$ and the maximum surface of the detector (detector in horizontal position) is $S = 1.19 \times 1.22\,cm^2$, so the number of expected cosmics events is

$$N_{\text{cosmic}}^{\text{expected}} = I \times S \times t < 1$$

The measured flux is higher, $N_{\text{cosmic}}^{\text{measured}} = 13$ events with the detector in vertical position.

4 LBT#1

Gain and RON of the camera LBT#1 has been measured with the calibration unit of the WFS, and the array of micro lens mounted in front of the LBT#1, so it was impossible take image of flat field as we done with LBT#2. The analysis was computed with the subaperture definition, analyzing the group of 64 pixels of a subaperture as one pixel with value equal to the mean value of the 64 pixels (the mean flux in the subaperture).

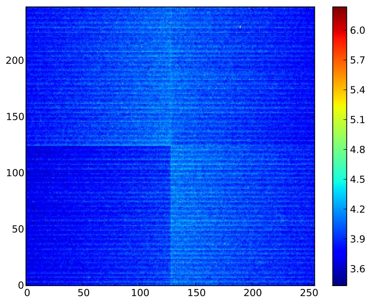
For every flux of light, 1000 images at 500 Hz (tracking number from `measure/DX/20130701_165453` to `measure/DX/20130701_170650`) were acquired, and time-average and variance of each subaperture for were computed. The analysis is the same of the LBT#2, but with the subapertures instead the pixels, so with groups of 64 pixels.

For each subaperture the intercept of the linear fit is the variance of signal without light, so the RON is equal to the variance divided by 64 (the number of pixel in a subaperture), squared root and divided by the median gain.

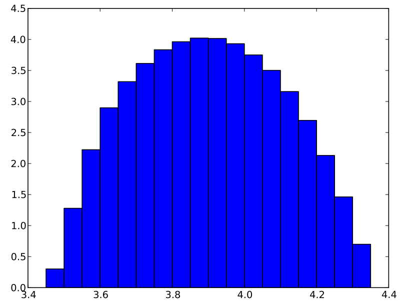
As we can see in Figure 4(c), the RON is different between camex and the histogram of the RON has two peak, one for each camex.

4.1 Cosmic

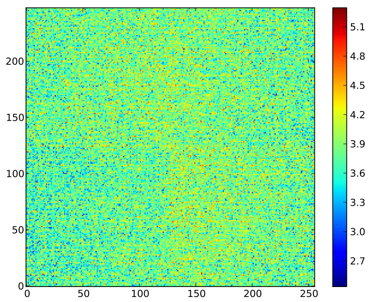
In 2 package of 25000 frames (on *dx-lgsw* `/home/argos/Documents/2013091612000.fits` and `/home/argos/Documents/2013091612000.fits`) acquired @ 1 kHz we found $N_{\text{cosmic}}^{\text{measured}} = 9$ cosmic events, the number of events expected in time $t = 0.83\,min$ is $N_{\text{cosmic}}^{\text{expected}} = I \times S \times t \sim$



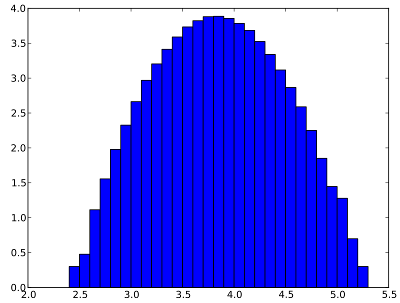
(a) Gain map (1 kHz).



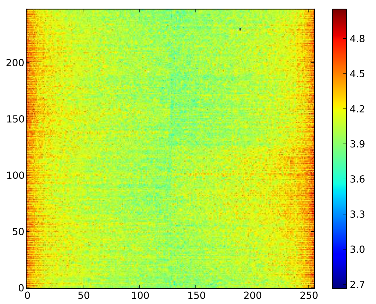
(b) Histogram of gain (log scale, 1 kHz).



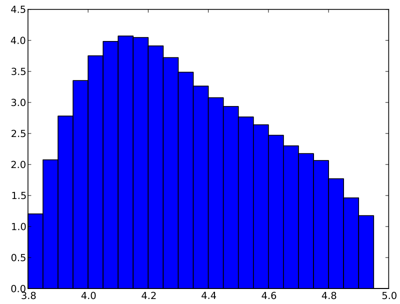
(c) Gain map (25 Hz).



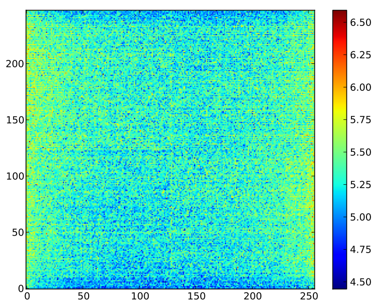
(d) Histogram of gain (log scale, 25 Hz).



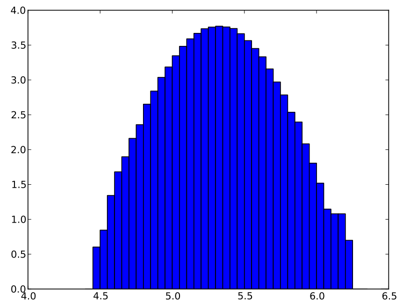
(e) RON map (1 kHz).



(f) Histogram of RON (log scale, 1 kHz).

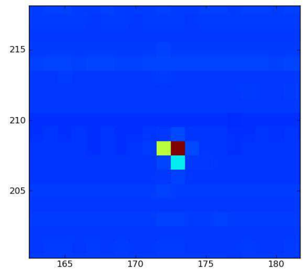


(g) RON map (25 Hz).

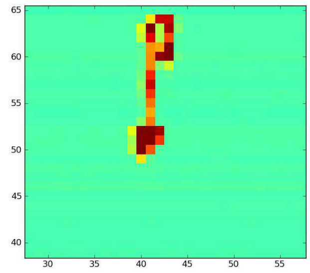


(h) Histogram of RON (log scale, 25 Hz).

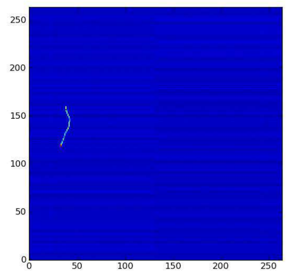
FIGURE 2: LBT#2 Gain and RON



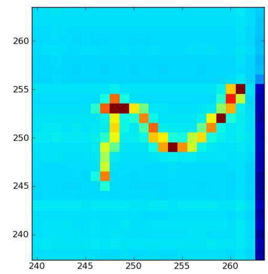
(a) LBT#2, single pixel on DSP1, 20130718_091916, frame 882.



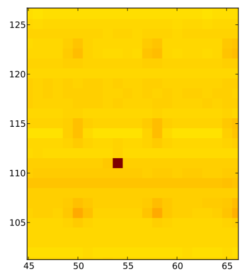
(b) LBT#2, key pattern on DSP0, 20130718_093352, 981



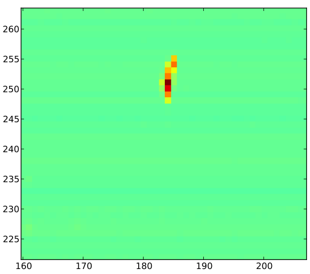
(c) LBT#2, intra Camex on DSP0, 20130717_1038399, frame 865.



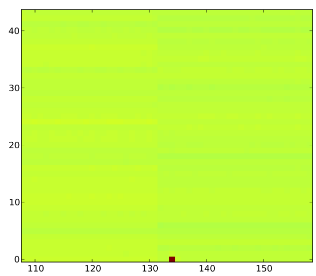
(d) LBT#2, curved pattern on DSP1, 20130718_092225, frame 612.



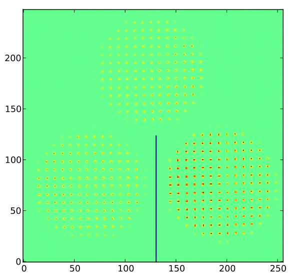
(e) LBT#1, single pixel on DSP0 with $\sim 43000\ ADU$, 20130916_130000.



(f) LBT#1, long pattern on DSP1, 20130916_130000.



(g) LBT#1, single pixel on common mode area, 20130916_130000.



(h) LBT#1, effect of single pixel on common mode area (see Figure 3(g))to 248 $\times$ 256 pixels.

FIGURE 3: Cosmic

1, so for LBT#1 the numbers are not comparable too with the expected value but the values between the two cameras are comparable.

TABLE 3: Gain and RON median values for LBT#1 @ 500 Hz, computed from the histogram.

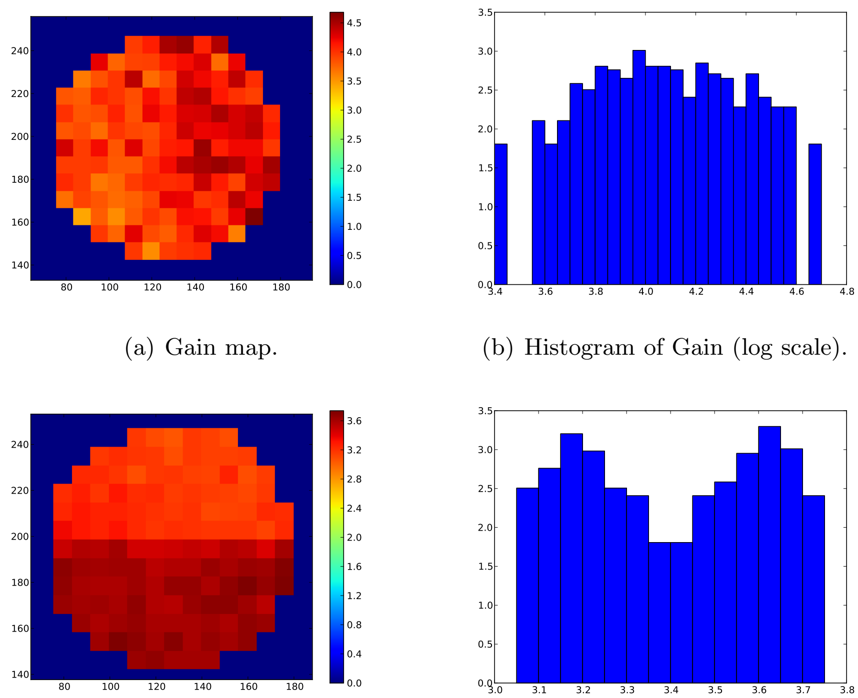
Parameter	**Value**	**Unit**
Gain	4.05	ADU/e^-
σ_{Gain}	0.25	ADU/e^-
RON	3.50	e^-
σ_{RON}	0.22	e^-

References

[1] Glen Cowan. *Statistical Data Analysis*. Oxford University Press, Oxford, 1998.

[2] K Nakamura et al. “Review of Particle Physics”. In: *Journal of Physics G: Nuclear and Particle Physics* 37.7A (), p. 075021.

[3] G. Orban de Xivry et al. “Wide-field AO correction: the large wavefront sensor detector of ARGOS”. In: *Proc. SPIE 7736* (2010).



(a) Gain map.

(b) Histogram of Gain (log scale).

(c) RON map.

(d) Histogram of RON (log scale).

FIGURE 4: LBT#1 Gain and RON @ 500 Hz.