Nuclear Instruments and Methods in Physics Research A 622 (2010) 288–294

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

Technical Note

Frequency analysis of the noise in the Fowler(n) sampling of a H2RG(2K × 2K) near-IR detector

G. Smadja [a,*], C. Cerna [b], A. Castera [a], A. Ealet [b]

[a] Institut de Physique Nucléaire de Lyon, Université de Lyon/IN2P3-CNRS, Lyon 1, 4 r. E. Fermi, 69622 Villeurbanne Cedex, France
[b] CPPM, Aix-Marseille Université, CNRS/IN2P3, 163 avenue de Luminy Case 902, 13288 Marseille Cedex, France

ARTICLE INFO

Article history:
Received 29 April 2010
Accepted 23 June 2010
Available online 1 July 2010

Keywords:
Near infrared detectors
Noise power spectrum
Wiener–Khintchin

ABSTRACT

The readout noise of a H2RG HgCdTe NIR detector from Teledyne is measured at a temperature $T = 110$ K. It is shown that a Fowler mode with $n = 240$ allows to reach a noise of 2.63e (single read). A description of the power spectrum in terms of three parameters reproduces the variation of the noise as a function the number of Fowler samples as well as its dependence on the periodicity of the sampling. The variance of the noise decreases with frequency with an effective power of 0.62 in our measurement domain. The behaviour of the detector under different experimental conditions can then be predicted.

1. The apparatus

The measurements described in this paper were carried out in a dedicated setup built to evaluate Hawaii 2RG (HgCdTe) detectors from Teledyne. The detector was on loan from LBNL in view of the evaluation of its performance when used in a spectrograph for the JDEM project [1]. The cryostat can be operated in a range of temperature extending from 110 to 160 K with fluctuations smaller than 0.1 K, and its equilibrium temperature in the absence of heating is about 110 K. The polarisation of the substrate was chosen as $V_{sub} - V_{reset} = 0.4$ V in all the data analysed in this work. Additional experimental details are provided in a previous paper [2] where the conversion factor of our setup (e/ADCU) at $T = 110$ K was evaluated to be 2.042e/ADU for a single pixel. The goal of the present measurements is to lay the ground for a determination of the frequency distribution of the noise, so as to be able to predict the behaviour of the detector in different experimental conditions (Fowler samplings, interval between groups, etc.). The merit of the power spectrum analysis is also the link it provides with the physical processes in the CMOS semi-conductor, such as the trapping and detrapping of electrons with a distribution of time constants.

2. The measurement method

In the 2K × 2K H2RG detector, a window of 31 × 31 pixels has been selected. The clock frequency is 100 kHz, as anticipated in the SNAP-JDEM project, and the time needed for the readout of 1 frame of 30 × 30 pixels is $\delta = 17.5$ ms. The non-destructive frame readouts are organised into 'groups' of 250 frames, read at the clock frequency of 100 kHz and separated by a time interval which can be tuned, with the clocking of the pixels stopped. Taking into account the readout of the frames, the periodicity of the readout of a given pixel between two consecutive groups varies from 5 to 13 s. The selection of a small window allows to reach a higher repetition rate for the frame readout, and to save on the overall measurement time as well as on computing resources. All the frames are stored on disk for further analysis. The noise is characterised by two variance measurements:

- the frame to frame variance, with the readout interval of $\delta = 17.5$ ms for a 'window' frame 31 × 31 as considered here, is convenient for a calibration of the detector and its readout. It was studied in Ref. [2].
- the Fowler(n) group to group variance measured by the spread of the difference of the averages of two consecutive groups for a given pixel will allow to characterise the noise performance of the H2RG on longer time scales, and will be investigated here.

The Fowler(n) noise is evaluated in each pixel from the differences D_k of the average signal in groups k and $k-1$:

$$D_k = \frac{1}{n}\sum_{i=1}^{i=n} s(t_0 + k\Delta + i\delta) - s(t_0 + (k-1)\Delta + i\delta). \quad (1)$$

In this relation, δ and Δ are the frame to frame and group to group periodicities. The number of frames is 250 in the acquisition, but will be varied from 1 to 240 in the offline analysis as the first 10

* Corresponding author. Tel.: +33 4 7244 8318; fax: +33 4 7244 8004.
E-mail address: g.smadja@ipnl.in2p3.fr (G. Smadja).

0168-9002/$ - see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.nima.2010.06.271

frames of each group are always ignored. The noise is measured by the average of $D_n(\Delta)^2$ over the $N+1$ groups stored during the exposure. The number of groups in the on-line acquisition was actually 200 in the exposures studied here, but the first 10 groups were eliminated from our investigation

$$\sigma^2 = \frac{1}{N-1}\left(\sum_{k=1}^{k=N}(D_k - \langle D_k \rangle)^2\right) \tag{2}$$

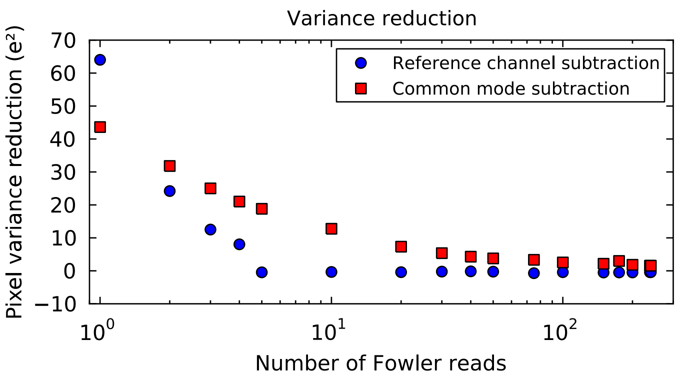

Fig. 1. Noise reduction from reference channel and common mode subtractions. The second one is applied on top of the first one.

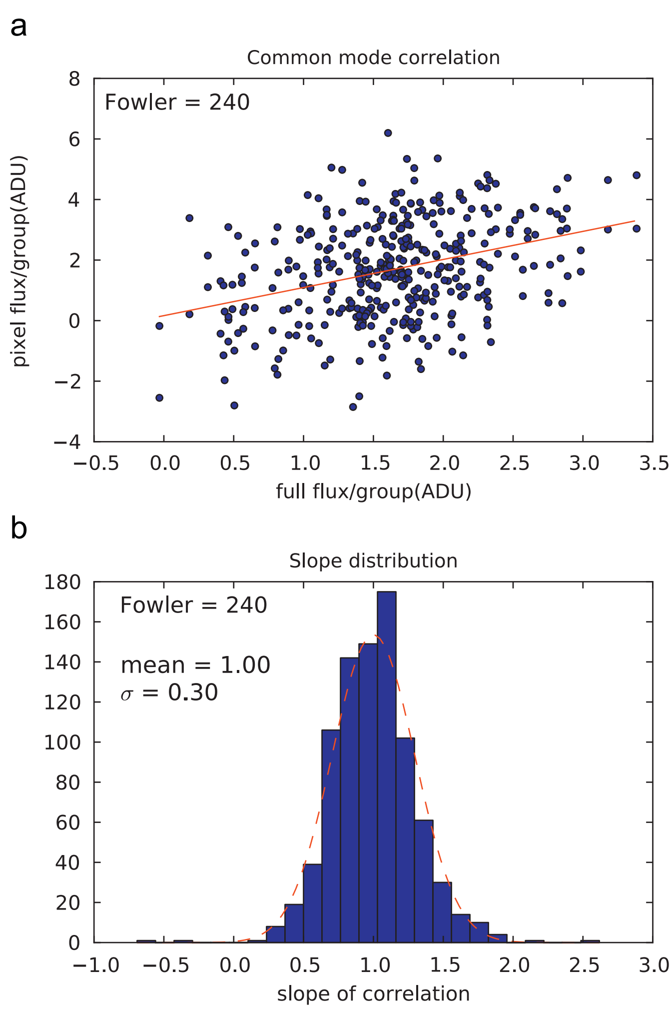

Fig. 2. (a) Group to group correlation between pixel flux (Fowler=240) and full flux: two pixels have been selected at random. (b) Distribution of the correlation slope (Fowler = 240) found for all pixels.

with

$$\langle D_k \rangle = \frac{1}{N}\left(\sum_{k=1}^{k=N} D_k\right). \tag{3}$$

The subtraction of the reference channel, which follows synchronously the level of a fixed capacitance, and corrects possible bias changes reduces the variance when the number of Fowler samplings $n<10$, as shown in Fig. 1 for a group periodicity of 5.23 s. For larger numbers of reads, the variance of the noise is, however, slightly increased, by typically 0.1 ADU^2. We attribute this to low frequency voltage offsets, which are at least partially cured by the next step.

3. Common-mode subtraction at low frequency

The reference channel subtraction takes out most of the high frequency common modes, but we still observe the impact of common modes remaining at lower frequencies in Fig. 2(a). This figure shows the remaining correlation between the differential flux observed for two randomly selected pixels between two consecutive groups (in the absence of any illumination), and the differential flux of the sum over all pixels. Both are averaged over the 240 Fowler acquisitions of the group, and the 200 groups of the exposure are shown. The value of the slope of the correlation is stored for each pixel, and its distribution is shown for all pixels in Fig. 2(b), where it is seen to be compatible with unity within the measurement errors from the noise. A 'common' offset for each group is then obtained from a second straight line fit throughout the 'full' (integrated over all pixels) observed fluxes of all 200 groups as a function of the group number. The resulting variance reduction is shown in Fig. 1 as a function of the Fowler number n, and the resulting distribution of the 240 corrected flux differences D_k is shown in Fig. 3, for a typical exposure at 110 K with Fowler samplings $n=240$. The rms of the distribution is four electrons. As this value arises from the difference between the averages over two (consecutive) groups of 240 frames, it can then be considered that the noise in a single Fowler readout is 2.85 electrons. We shall see in Section 5 that part of this noise can be assigned to a parasitic photon flux, and that the actual performance reached is better.

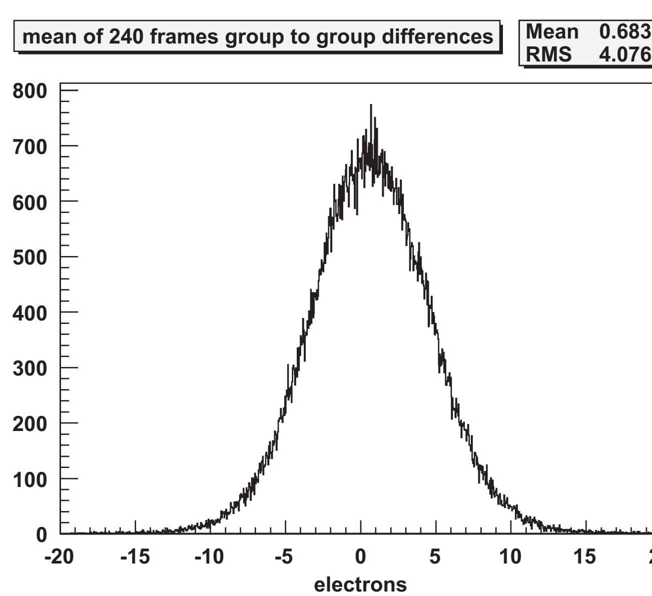

Fig. 3. Group to group difference distribution for Fowler(240).