KAON 864

HAWAII-II RG
Self-Heating Report

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Document Revision History

Revision Number	Revision Date	Summary of Changes	Author
1.0	03/31/2011	first draft	D. Hale
1.1	04/26/2011	include differential multi-accumulate data	D. Hale

Table of Contents

1 Overview

The purpose of this document is to describe the measurement procedure and analysis of the H2RG Self-Heating study.

1.1 Self-Heating Defined

Transistors in the unit cell (pixel) of the HAWAII-2RG detector dissipate power only when addressed. Therefore as the detector is read out the pixel power dissipation point is rastered across the multiplexor, causing a slight variation in pixel temperature over the array. The H2RG signal offset exhibits temperature dependence for uniform heating that ranges from 500-800 e-/K. This is in fact the difference in temperature coefficients of the pixel buffer the current source load (at the edge of the multiplexor) and the output amplifier. The temperature sensitivity of the pixel buffer alone is likely to be greater than this. Fixed patterns are removed by the subtraction of initial from final frames but thermally induced offset changes occurring during the exposure time are not. Thus it is important to maintain a constant self-heating by maintaining the same spatial pattern and timing for addressing the pixels.

When reading a small region of interest (ROI), even with constant-cadence clocking, only a relatively small number of pixels are being addressed and hence dissipating power, while the surrounding pixels are cooler. An example of this effect is shown in Figure 1.

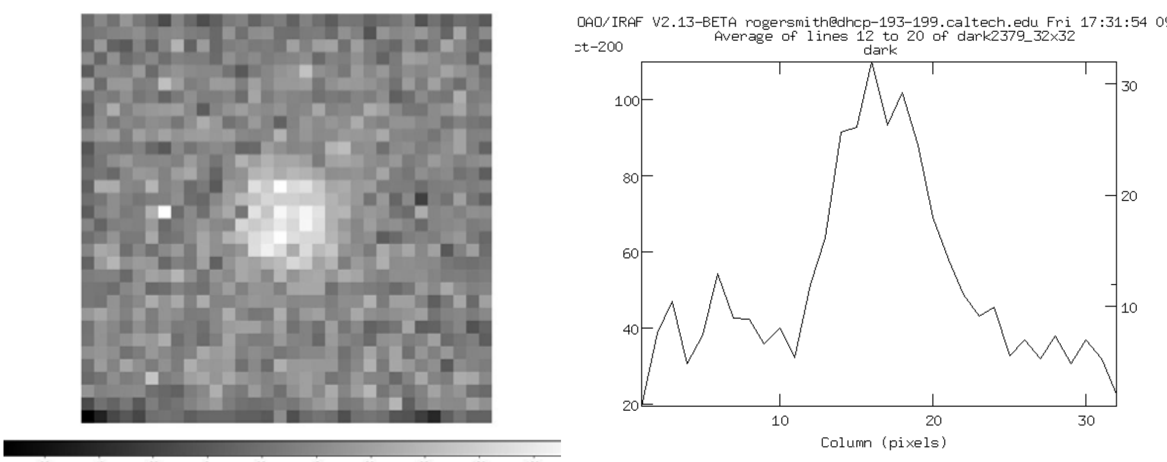

Figure 1. At left, evidence of rastering an 8x8 window is seen in a 32x32 window taken immediately after the smaller ROI. At right is a profile taken through the middle of the left-hand image. This is an extreme case where 480,000 8x8 frames (475µsec frame time) were recorded prior to the 32x32.

1.2 Motivation

The motivation behind this work was to quantify any possible impact self-heating might have on the determination of centroids in a recently moved window.

2 Experiment

2.1 Setup

This experiment used a 1.7μm cutoff H2RG detector, serial number H2RG-102 mounted in the ELEKTRA test dewar. All data were taken in the dark. The waveform file (`TRICK.20110225.MWM/tim.lod`) was optimized for 6.04 μsec pixels, with a measured 4x4 window frame time of 163.1μsec.

2.2 Procedure

Data were acquired in "filmstrip" mode where frames are taken as quickly as possible and stored sequentially in a single FITS file; that is, each file contains a time series (I.E. "filmstrip") of image frames. Only one reset is made at the beginning of the series. (NB. This is analogous to sample-up-the-ramp except that every frame is stored in a single file, and there is typically no inter-frame delay.) A programmable number of frames are read and then the window is repositioned by one pixel in the horizontal direction (to the right). This process is continued until after the third position is completed when the window is reprogrammed to the starting position. The entire process is repeated 10 times. This procedure is described in the pseudo-code in Figure 2, and graphically in Figure 3.

```
RESET H2RG
DO 10 SEQUENCES
   SET INITIAL WINDOW COORDINATES
   DO 3 positions
      DO 7500 frames
         READ H2RG
      ENDDO
      INCREMENT WINDOW POSITION
   ENDDO
ENDDO
```

Figure 2. Pseudo-code describing the moving window filmstrip mode. This code will produce 225000 frames in a single FITS file.

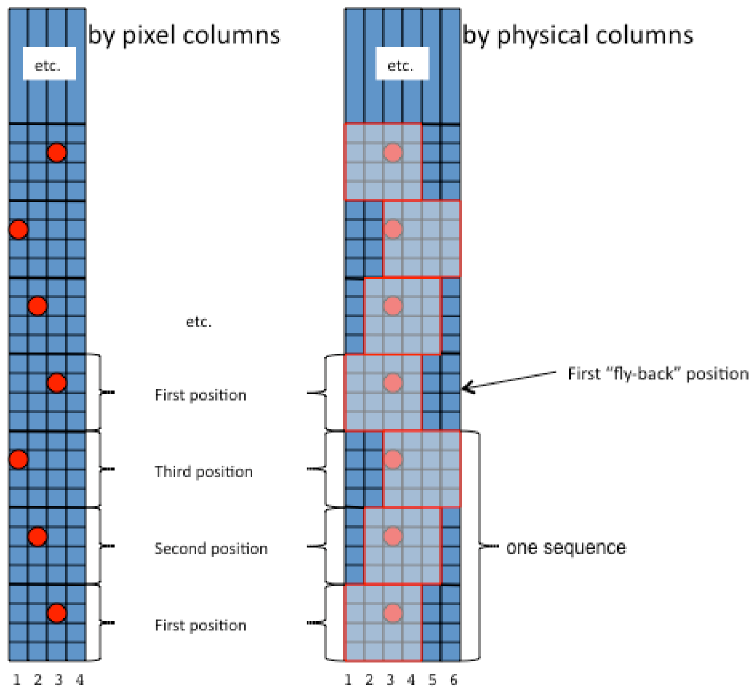

Figure 3. Graphical snapshot of the moving window filmstrip data for a 4x4 window. The red dot is a marker for illustrative purposes only, to make the moves visible in the figure. 7500 frames were recorded at each of three window positions (whereas only one frame per position is depicted in this figure), ten sequences of which were recorded in a single FITS file.

3 Analysis

Data were analyzed with Matlab; a filmstrip FITS file is read from disk into RAM where the frames can be quickly processed and ordered as desired.

3.1 Raw Data & Calibration

Raw data for the first five positions are shown in Figure 4. The pixels in a position will be at their most stable value at the end of a position, just before the ROI window is moved. Thus, the last 128 frames of a position are averaged together and this average value is subtracted from the previous frames for that window position. These same data with the equilibrium column subtracted are shown in Figure 5. The equilibrium-subtracted columns are shown individually for the four pixel columns in Figure 6.

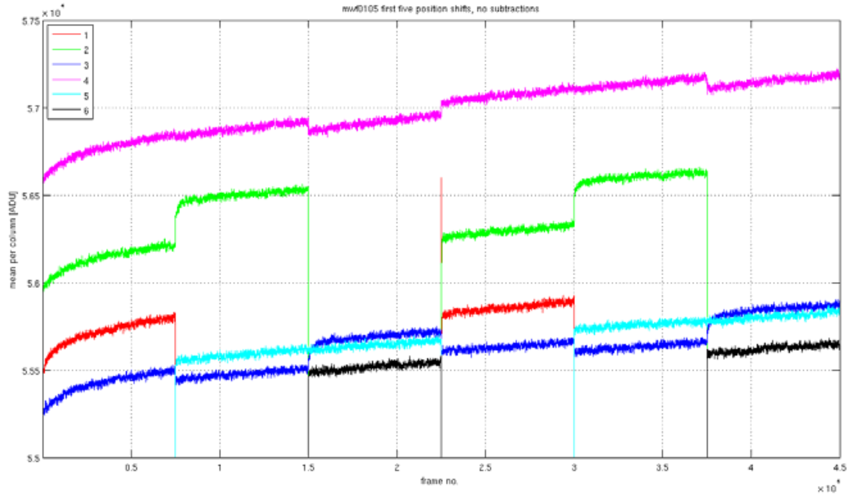

Figure 4. Raw data for the first five position shifts. The columns are treated independently; each trace is the mean pixel value in a column, shown as a function of frame. The six traces refer to the six physical columns depicted in **Figure 3**. Gaps for some columns correspond to time that the ROI did not fall on that column.

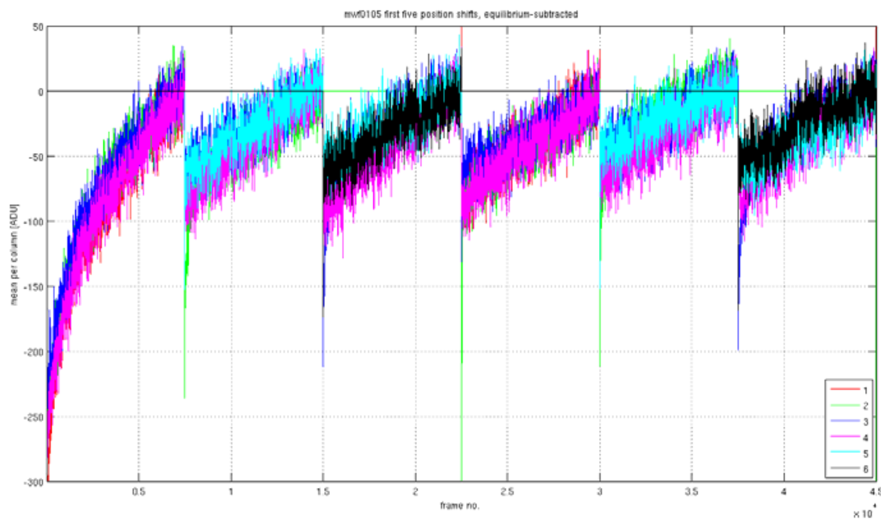

Figure 5. Data of **Figure 4** with equilibrium frame subtracted. The equilibrium frame is a mean of the last 128 frames before the window is moved.

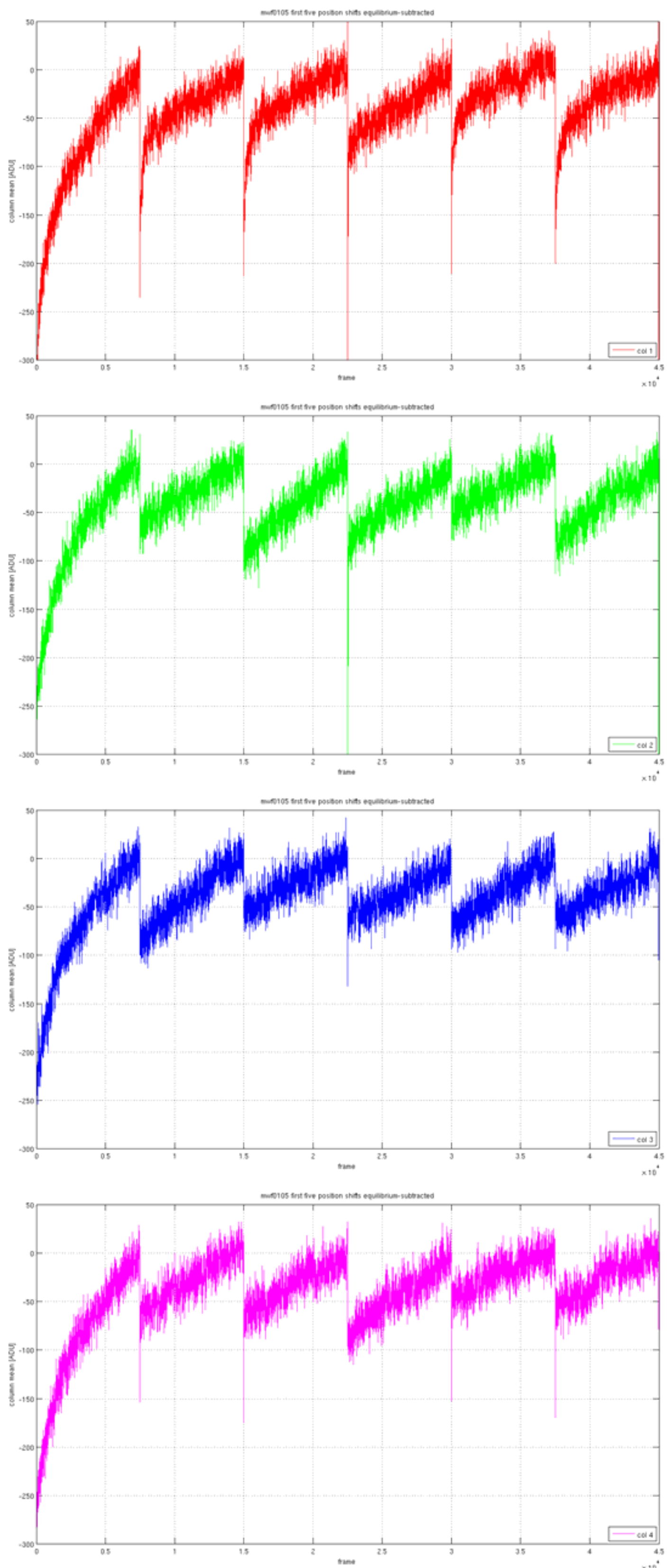

Figure 6. Equilibrium-subtracted columns (averaged per frame) for the four pixel columns.

3.2 Slopes

Errors in centroid position will be primarily caused by thermally induced gradients across the ROI, rather than common mode offset (although this can affect gain). It seems apparent from Figure 6 that each column has a unique slope from left to right and possibly a settling time after a horizontal window position change. The most stable condition will be immediately before a window position change. If we look at the mean pixel column value of the last 10 frames before a move, we see in the left panel of Figure 7 that the slope is about zero for all 30 window moves. However, the average of the first 10 frames after a window move shows clearly that there is a slope (right panel of Figure 7).

To quantify the slope change, a slope was calculated for each frame by fitting a linear curve of the form `y=mx+b` to the four mean column values in each frame. These slopes are plotted as a function of time in Figure 8 and Figure 9. (Here the time axis replaces frame number using a measured 163.1µsec per frame, but the position changes are clearly identifiable.)

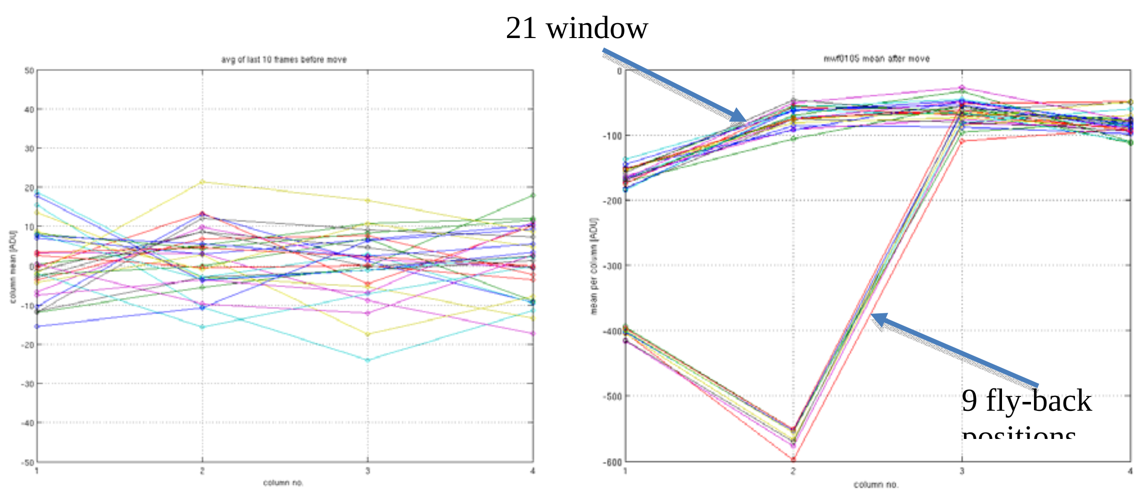

Figure 7. Column averages of last 10 frames before and first 10 frames after each window re-positioning. “Fly-back” is when the window moves from position 3 to position 1 again.

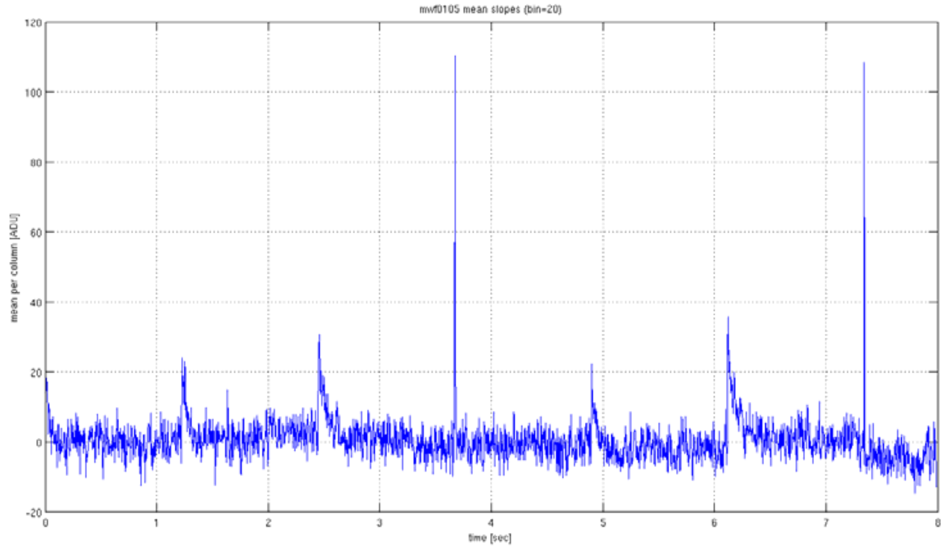

Figure 8. Mean slope (bin=20) across frame as a function of time, fitted using four column averages per frame. The two largest, narrow peaks are fly-back positions. The position change around 2.5 seconds is shown enlarged in **Figure 9**. Note this is for raw data in the nth frame minus the last frames, a time span much greater than for the actual exposure duration.

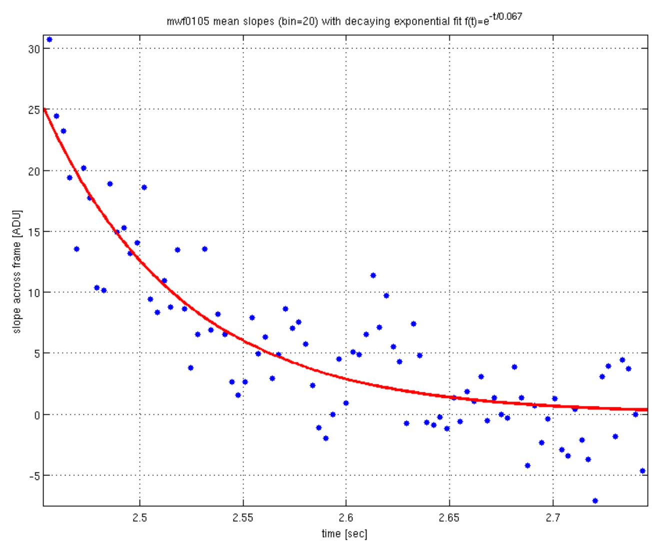

Figure 9. Enlarged view of region of **Figure 8** (mean slope across frame as a function of time). An exponential curve is fit to this region with an exponential decay time constant of ~ 70msec. For exposure times much less than this characteristic time constant the effect will be significantly attenuated.

3.3 Differential Multi-Accumulate

The preceding data are raw apart from subtraction of equilibrium frame measured at a much later time. By contrast, typical processing would employ some method of multiple sampling to beat down the read noise and frame differencing on 1-10ms time scales which are much shorter than the settling time shown in Figure 9. A method previously described elsewhere[1] and tested in our laboratory synthesizes exposures by co-adding groups of samples and differencing them; the group of samples representing the end of one exposure becomes the reference level for the next exposure. See Figure 10. This method was used on these data to synthesize 100Hz and 1kHz frame rates. Within each window position a group of frames were co-added to yield the desired frame rate per position. For example, given the 163.1μsec frame time, a group of *n* samples will achieve the desired 100Hz frame rate:

$$1 / (n \cdot 163.1\mu s) = 100Hz$$
$$n = 1 / (100 \cdot 163.1 \times 10^{-6})$$
$$n \approx 60$$

Thus, approximately 60 samples would result in a synthesized frame rate of 100Hz (and similarly, ~ 6 samples produces a 1kHz frame rate). Now, instead of having 7500 frames per ROI position there will be *7500/n* synthesized frames per position.

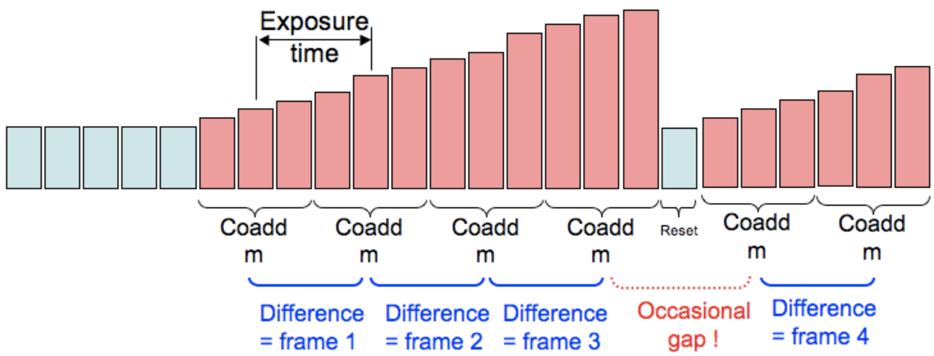

Figure 10. In “Differential Multi-Accumulate” readout mode the detector is reset only when necessary to avoid saturation to obtain ~100% duty cycle. Non-destructive reads are averaged and exposures are synthesized by differencing averaged frames.

3.3.1 100Hz Frame Rate

The first 10s of these data for *n=60*, representing a 100Hz synthesized frame rate, are shown in Figure 11 and a close-up of one of the “fly-back” position moves is shown in Figure 12. These figures display the mean pixel value per column per frame, plotted as a function of time. A few image frames are displayed in Figure 13. The average of the last 10 frames before and the first 10 frames after an ROI position change are shown in Figure 14. In the same manner as described in Section 3.2, a slope was fit to the mean column values in each frame. These slopes are shown as a function of time in Figure 15. Clearly these synthesized exposures are much more stable than the quasi-raw data shown in Section 3.1.

[1] Detectors for Astronomy Workshop, Garching, 2009-Oct-14

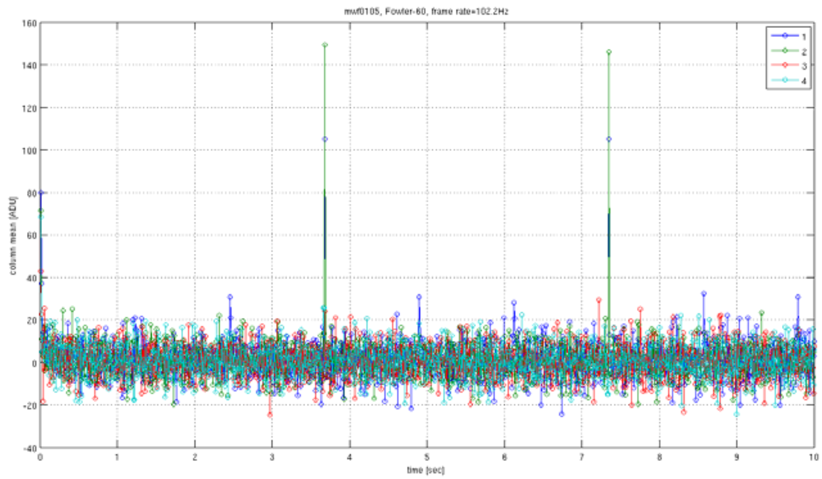

Figure 11. Column averages per frame for 100Hz synthesized frame rate for 10s of time that spans eight position changes. The moves at (approximately) 1.25s, 2.5s, 4.75s, 6.25s are barely visible but the “fly-back” moves at 3.75s and 7.5s are easily seen here.

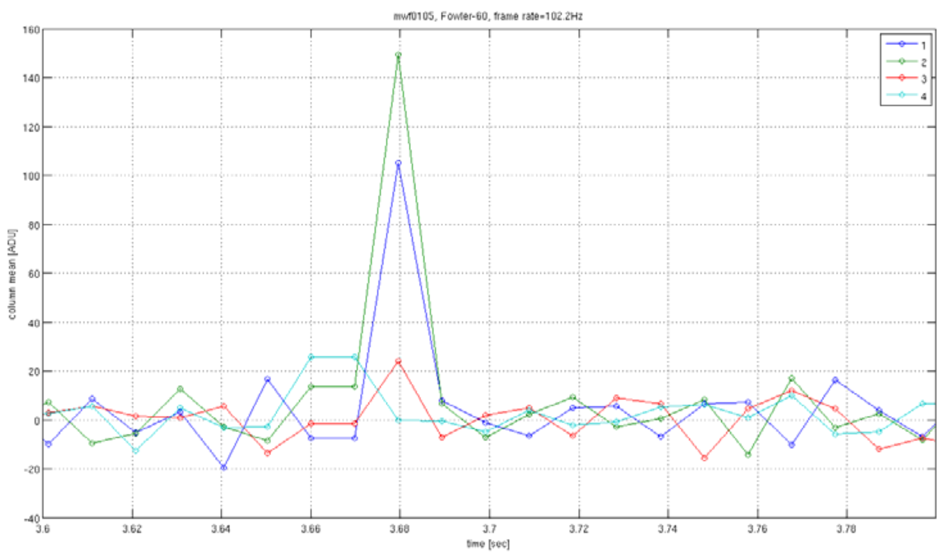

Figure 12. A zoom-in of one of the “fly-back” moves for 100Hz synthesized frame rate. From this it appears that only the first two columns are affected, and that they recover in only one frame time.

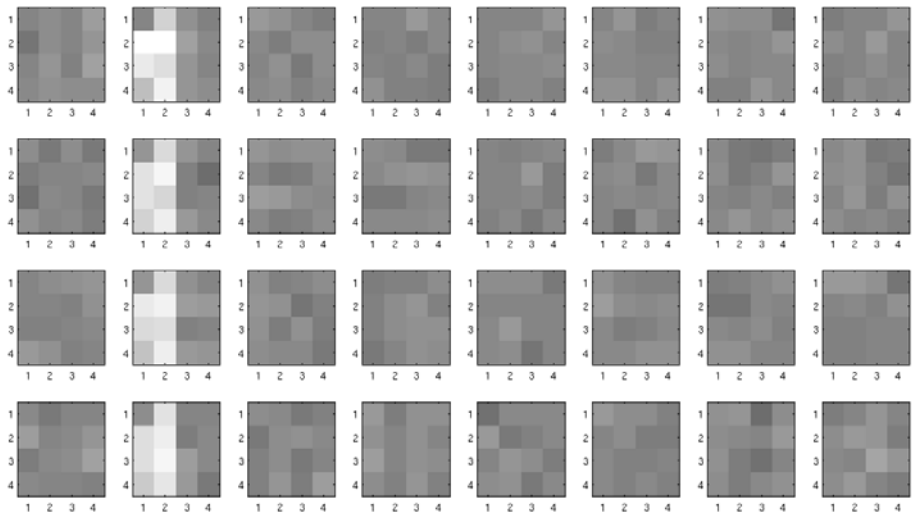

Figure 13. Snapshots of processed frames for a 100Hz synthesized frame rate. Time progresses from left to right, one frame time per column (9.786msec). The first column represents the last 100Hz frame before a fly-back move. The second and subsequent columns show the fly-back position and subsequent frames. The four rows are the first four fly-back positions of the recorded sequence of data. White indicates pixels are cooler than average.

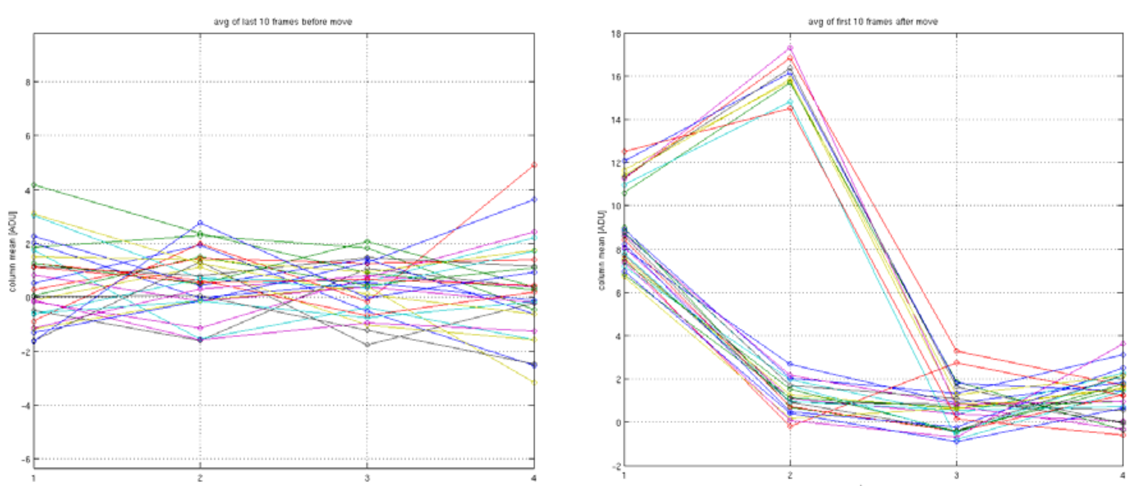

Figure 14. Column averages of last ten 100Hz synthesized frames before and first ten frames after a position change. The upper group in the right-hand panel represents the fly-back positions, with the greatest change (on average) being in the 2nd column.

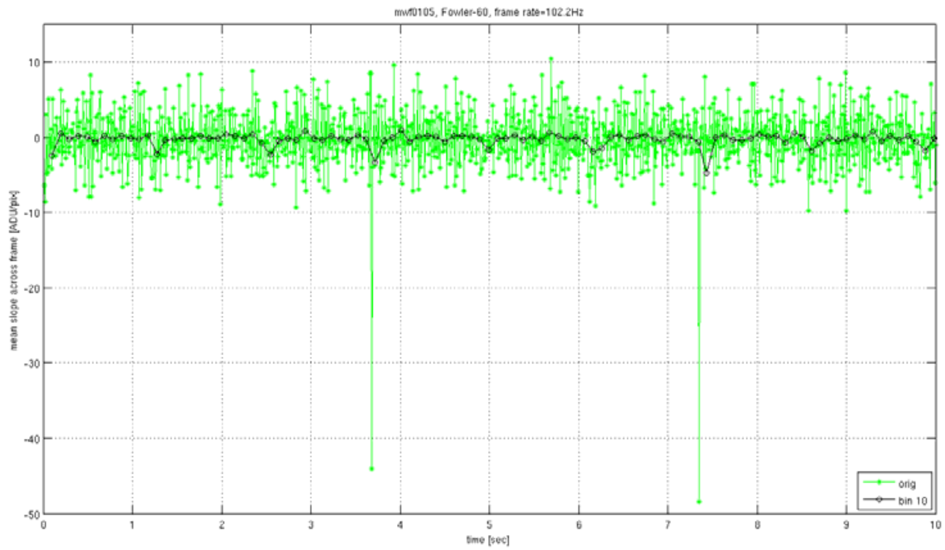

Figure 15. Mean slope across frame, per frame, shown as a function of time for the 100Hz synthesized frame rate. In green are shown the original data, 125 100Hz frames per position. A binning factor of 10 was applied, which is shown in black.

3.3.2 1kHz Frame Rate

The data for *n=6* representing a 1kHz synthesized frame rate are shown in Figure 16 through Figure 19.

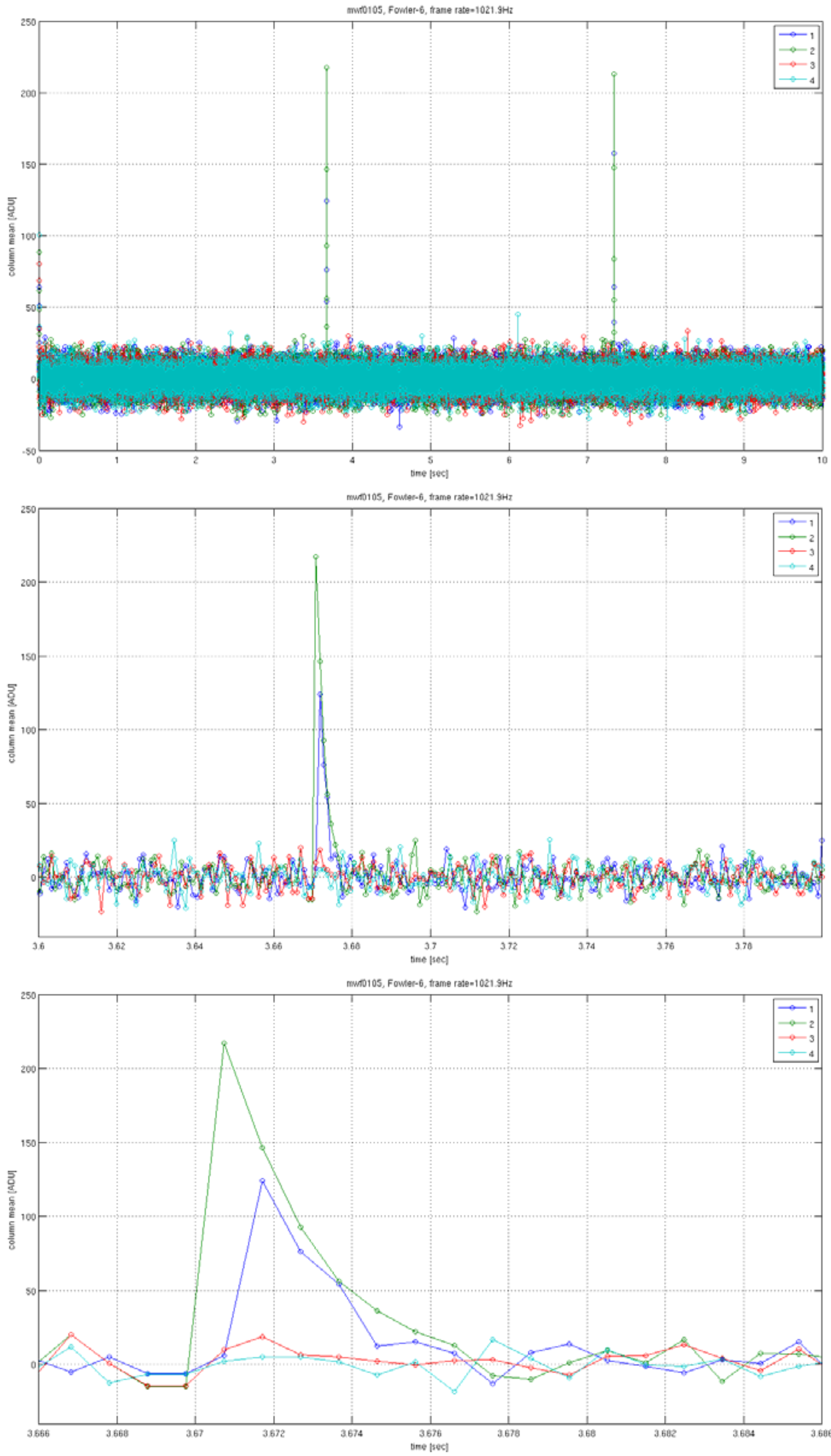

Figure 16. Column averages per frame for 1kHz synthesized frame rate. The top panel shows 10s of time and subsequent panels zoom in on the first fly-back. An exponential decay is apparent in the bottom panel, with a decay time of approximately 2.5 frame times. Note again that only the first two columns after a fly-back position are affected. These are the columns that were not addressed (and thus colder) prior to the fly back. The columns that are addressed before and after the fly-back show no change.

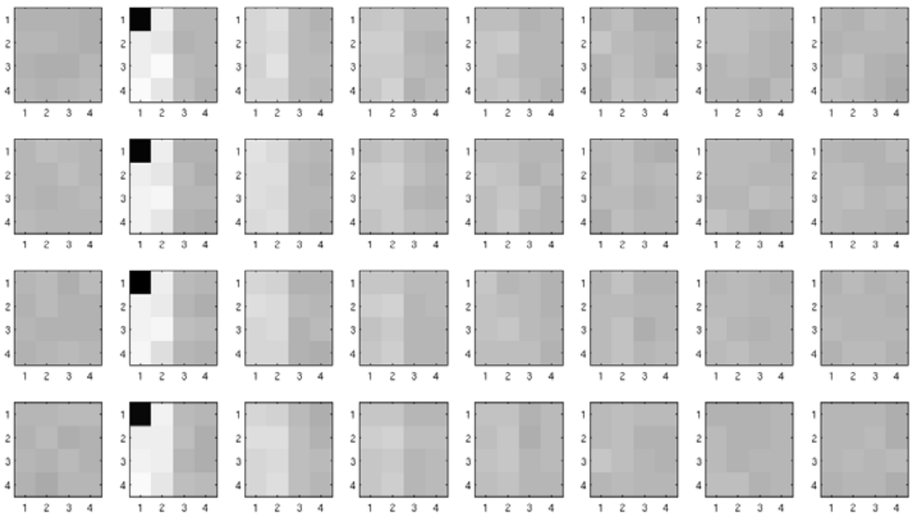

Figure 17. Snapshots of processed frames for a 1kHz synthesized frame rate. Time progresses from left to right, one frame time per column (978.6µsec). The first column of frames represents the last 1kHz frame before a fly-back move. The second and subsequent columns show the fly-back position and subsequent frames. The four rows are the first four fly-back positions of the recorded sequence of data. The dark spot at upper left is due to above average self heating caused by an inadvertent delay (tens of microseconds) between fly back and start of active rastering during which the initial pixel is heated continuously.

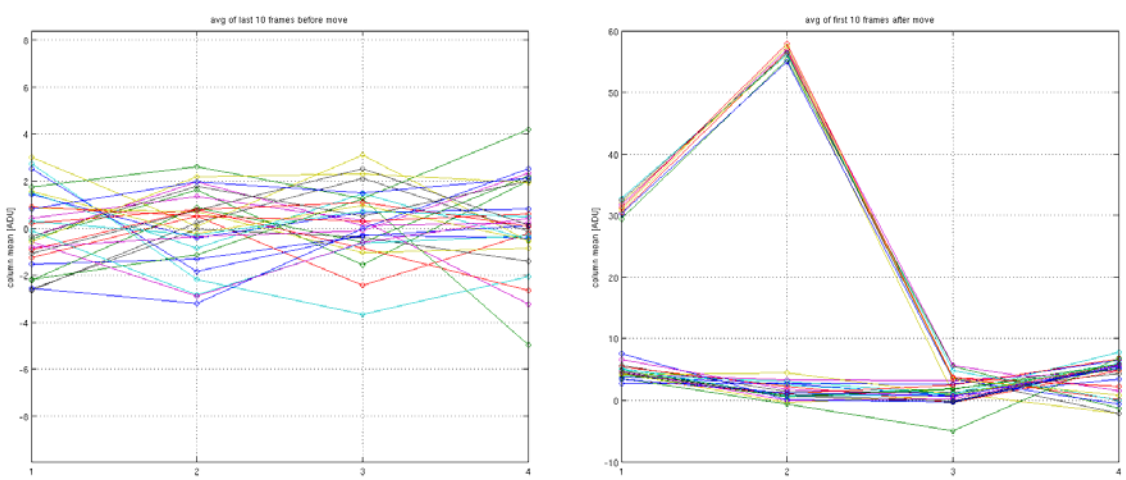

Figure 18. Column averages of last ten 1kHz synthesized frames before and first ten frames after a position change. The upper group in the right-hand panel represents the fly-back positions, with the greatest change (on average) being in the 2nd column.

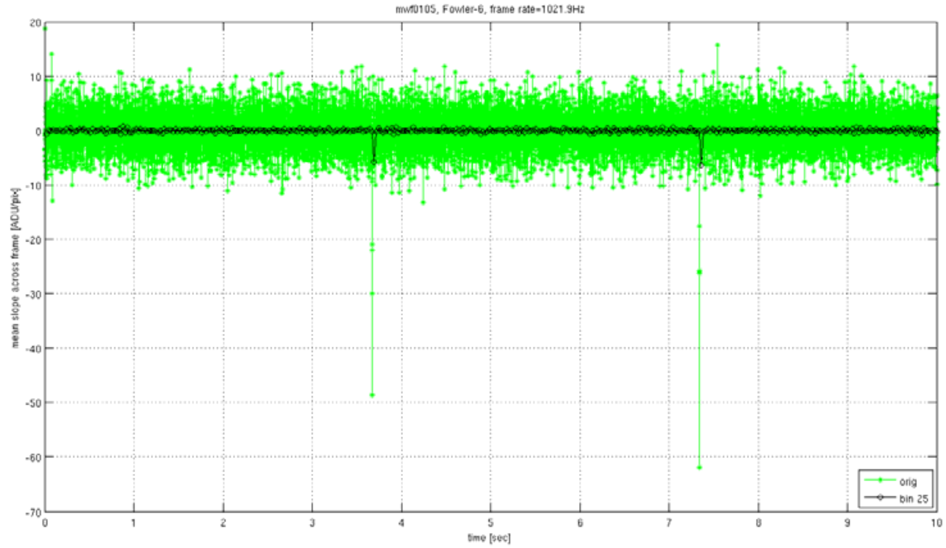

Figure 19. Mean slope across frame, per frame, shown as a function of time for the 1kHz synthesized frame rate. In green are shown the original data, 1250 1kHz frames per position. A binning factor of 25 was applied, which is shown in black.

4 Conclusions

When processed using the Differential Multi-Accumulate algorithm, a special case of Fowler sampling which has nearly 100% duty cycle, a small (1-pixel) window move is detectable as a sudden change in pixel counts. This magnitude of this change depends on how recently the pixels were visited. For a recently visited column the change is only a few ADU, and is thus negligible.

As seen in the so-called “fly-back” cases, when moving to a position that includes a column that has not been read for hundreds or thousands of frame times, there can be a change of a few hundred ADU. Only the edge columns are significantly affected. The self-heating effects in columns that are addressed before and after the move, while detectable in the raw data, are not significant in synthesized exposures in the 100-1000Hz regime.

For the edge columns where the self-heating is clearly detectable, the change in ADU is short-lived, decaying to the noise floor in six frame times for 1kHz synthesized frame rate and just one frame for 150Hz or slower.