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Report on Detector Optimisation

Peter Moore 2nd March 2001.

During the period 16th February to 1st March, investigations were carried out to identify and optimise certain operational characteristics of the INGRID detector. This report summarises the effect of this investigation. Principle objectives of this investigation were: -

1. Identify cause and eliminate anomalous dark current generation.
2. Reduce readout noise component.
3. Identify cause and eliminate hot pixel sites.

1. **Software version change**.
The result of this work has been the development of a new INGRID SDSU controller software version. The new version is 3.2 Beta. This version replaces and is compatible with the previous version 3.1. The upload code can be found at /ingrid/sdsu/V3_2_Beta/TIMING_INGRID_APPLICATION.lod

2. **Dark Current anomaly**.
After considerable investigation, the exponential character of the dark current is found to come from a leakage mechanism associated with the pixel sites. This leakage is general to all pixels and has the same character as that which causes hot pixels, but at a much reduced amplitude. Initial testing at the beginning of the investigation showed that the exponential portion dominates for the first 35 seconds of any integration and reaches an apparent signal level of approximately 360 ADU in this time. Further integration results in a linear increase of apparent signal with a slope of 1.5 ADU / sec / pixel. The leakage problem could not be resolved entirely, however, with version 3.2 Beta software these values have been reduce an exponential increase in dark current dominant in the first 30 seconds with an amplitude of 85 ADU followed by a linear increase of 0.75 ADU / sec / pixel. These values are based on a measured conversion factor of 5.3 e- / ADU.
<u>Technical note</u>.
Leakage from the pixel site can only be electrically described by a potential difference between the anode to cathode portion of the MgCdTl diode site. The anode is connected to substrate i.e. ground potential. The cathode however, is connected to the reset FET drain and the readout FET gate. A method was created to assure that the reset FET is completely switched off during all times except when actually reseting pixels. In addition a method was developed to minimise the current load through the readout circuit during integration and thus reduce any potential difference across the FET. The improvement in anomalous dark current is thought to come from these measures. However, given that the problem still exists it is likely that the considerable leakage still occurs within the MgCdTl diode itself. This is further confirmed by the continuing hot pixel problem.

3. **Readout Noise**.
Methods were implemented in an attempt to reduce readout noise originating from the detector itself. Initial tests gave a figure for an mndr = 1 readout of 8.5 ADU rms readout noise. Testing of individual electronic sub systems of the readout circuitry showed that the total noise contribution of the fanout board + cables + SDSU controller is 1.7 ADU rms. This is close to the theoretical of 0.71 ADU and dictated that most effort be spent on the noise component of the detector itself. Two areas were identified as being responsible for the first order noise sources. These are pixel clock feedthrough and amplifier drift during readout. The first source produces pixel to pixel variation by modulating the detector output with the pixel clock phase. On a single readout the amplitude of this modulation is of order 400 ADU. This amplitude was reduced by adjustment of the readout bias supply and

increasing the time allowed for signal stabilisation during readout. The second source of noise produces a gradient in the slow readout (or Y axis) direction due to localised heating of the electronics within the MUX circuitry. Many methods were tried to reduce this effect but without real success. Finally an optimised flush routine was used to pre-heat the readout circuitry and so produce the same degree of bias change for any readout. This methodology is not ideal but no other practical method could be found. After all of these efforts, the noise figure remains the same at 8.5 ADU rms. Testing of mndr readouts with values greater than one produce the theoretical reduction in noise as root n, where n = the number of readouts employed.

4. **Hot Pixel sites**.

Investigations carried out to determine a method were discussed in the previous paragraph on dark current. No significant reduction in number or amplitude of these pixels was achieved. However, since it is normal routine to subtract a dark frame of the same integration time as a science frame, the effect of hot pixels (and indeed dark current) only becomes significant when the available dynamic range of the pixel is compromised by the dark and / or hot signal itself.

5**. Gain, Linearity and Full Well**.

Initial tests showed linearity to be 12 percent over a dynamic range of 25,000 ADU Full Well. Initially, gain was measured as 5.3 e- ADU. No specific methods were implemented to optimise linearity. After adjustment of the Bias Power and Bias Gate supplies relating to noise reduction, linearity was tested and found to be nominally 4% between 2,000 and 18,000 ADU. Low count linearity is possibly compromised by the adjustments, however, the measured error of 30% between 0 ADU and 2,000 ADU needs to be confirmed as this may be attributed to measurement error in the timing. A photon transfer plot of the same data does not show the same low signal error. The measured gain with version 3.2 Beta remains at 5.3 e- / ADU. Full well measurements need to be done, however, it is suspected that this value has reduced to approximately 90,000 e- (was 120,000 e-).

6. **Readout speeds and Timing**.

Version 3.2 Beta software allows the selection of two readout speeds - Fast and Slow. This is a first step towards providing optimised readout for NAOMI frame grab operations. The following table indicates the current timing values

Speed	Read Time	Flush Time	Min Integ	Gain	Noise
Fast	400ms	130ms	530ms	5.3 e- / adu	8.5
Slow	750ms	130ms	880ms	5.3 e- / adu	9.5

Default speed is slow which provides for less artefacts in the image.

7. **Other work**.

In addition, the following work was carried out and incorporated into version 3.2 Beta software.

a. Removed dead first row from each quadrant image readout. The first row now contains valid data.

b. Removed first two dead columns from each quadrant readout. These columns now show signal but are somewhat more noisey than normal.
c. Re-ordered pixel output. The first pixel output now is a real pixel. In previous versions there was a dummy first pixel output because of the conversion pipeline delay in the SDSU controller.
d. Test data now provides pixel position information to verify correct operation of the comms link + host software re-ordering algorithms.
e. Tested timing accuracy and verify that integration timing within the SDSU is accurate to 1 millisecond.