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Group
Red
Imaging
Detector

Summary of Detector Stage 2 Testing - Second Cool Down

(13th November - 25th November 1999.)

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1. POST COOL DOWN 1 MODIFICATIONS MADE

1.1 Detector heating resisters rewired to provide 25 Ohm load and 4 times increase in power. Maximum current of heater limited to 80% of full power to protect SDSU series pass transistor.
1.2 Wiring error in polarity of detector temp sensor corrected.
1.3 Shield temperature sensor mounted on ccc cold finger to monitor performance.
1.4 SDSU temperature sensor calculation implementation modified to provide required dynamic range and readout in milliKelvin. In addition a sliding 16 point averaging algorithm was implemented in the raw telemetry value read routine to reduce high frequency noise on telemetry data.
1.5 Cold finger to casting connection braid augmented by 3 copper straps each 12mm x 1.6mm x 220mm.
1.6 The engineering array was fitted to the science detector fanout board and assembled into the cryostat.
1.7 The SDSU controller motherboard was modified to allow slot 5 to be occupied by the Utility board. This liberates slot 6 (last slot) so that it may be used for accessing any other board for debug purposes via the SDSU chassis side panel.

2. PRE-COOL DOWN

1.1 Galvanic isolation was proved between the SDSU controller and the cryostat. A direct short to cryostat ground is provided for through the temperature cable (SK8) and this is intact. With only the detector cables (PL6, PL7) plugged in, an open circuit is seen between SDSU ground and the cryostat. HOWEVER, THERE REMAINS A GROUND PATH THROUGH THE HELIUM LINES CONNECTED TO THE CCC. THIS GROUND PATH MUST BE ISOLATED BEFORE REVIEW OF THE SCIENCE DEVICE AS IT DRAMATICALLY AFFECTS NOISE PERFORMANCE.

1.2. The engineering device (ENG) was functional and consistent at room temperatures before cool down. However, Image data was not comprehensible due to dark current generation causing a massive gradient on the device. The detector only became coherent after the temperature dropped below 140 Kelvin during cool down.

1.3. Terminal pressure after 2 day pump down on the cryostat was 8.1E-4 mbar on 110 litre / sec pump.

2. COOL DOWN

2.1 Cool down began at 16:08 15th November. Temperatures and pressures were logged each ten minutes. A dedicated LN2 fill tube needs to be constructed to prevent excess LN2 from freezing neck ‘O’ ring and endangering vacuum integrity.

2.2 The attached graphs show the temperature and pressure profiles during cool down. The vacuum pump was switched off two hours after starting cool down with a final pressure of 1.6E-5. Pressure then started to rise slowly. The ccc was switched on 4 hours after cool down start and reached a terminal temperature of 27 Kelvin after 2.5 hours. Terminal temperatures for the casting and detector were reached in 13.5 hours. The calculated values where 84 K and 76 K respectively. During the later phase of cool down (as temperatures where nearing their limits), the ccc was shut down to allow the LN2 terminal temperatures to be logged. With the ccc running, terminal temperatures were cold finger 29.7 K, casting 75.3 K, detector 82.8 K. Final cold pressure was 1.1E-5 millibar.

2.3 The pressure increase observed during this phase was very low, consistent with cryopumping action from the ccc cold finger. The pressure increase rate dropped with temperature as expected. Final pressure reached cold and after two ‘top ups’ from the pump was 1.1E-5 mbar. The pressure remained essentially static for the duration of the cold cycle.

2.4 Approximately 100 litres of LN2 was used to affect cool down. The total LN2 consumption for the thermal cycle was approx. 150 litres.

2.5 The detector image bias was logged during cool down and showed only weak correspondence to the MUX temperature curve. The detector ‘Came alive' at a temperature of 140 Kelvin where the characteristics of the bias shift to temperature changed, adopting a lower coefficient of change to temperature. The mean slope in this regime is calculated to be 108 ADU / Kelvin. THIS RE-ENFORCES EVIDENCE FROM THE PREVIOUS COOL DOWN INDICATING THAT TEMPERATURE CONTROL TO A MUCH MORE CONSTRAINED DEGREE IS REQUIRED TO AVOID TEMPERATURE INDUCED BIAS ERRORS IN THE IMAGE DATA.

2.6 Noise figures for the ENG detector were recorded at 10 minute intervals. The noise signature increased generally with decrease in temperature (or increase in time). In addition the spread of the noise value increased consistent to the increase of noise value. This result is consistent with the MUX detector result. At 77 Kelvin raw readout rms. noise (i.e. pixel to pixel variation in a 10x10 average box) is between 260 and 550 ADU. There is still no explanation for this phenomenon. As a first order guess, it may be that the type of external FET current sinks used may cause this. Alternatively the noise increase may be a function of intrinsic reset anomaly to the HAWAII detector. Investigation must continue.

3. COLD TESTING

3.1 Temperature servo performance was evaluated and tuned. Best servo operation was obtained with the following co-efficient values; Proportional 0.65, Integration 0.01, Derivative 0.03, servo time constant 4 seconds. Under these conditions peak to peak temp variation was 1.6 Kelvin (i.e. 3 LSB's of temperature sensor resolution) at a set point of 87 Kelvin. Period of the oscillations was 25 minutes.

3.2 The closed cycle cooler was run continuously during the thermal cycle with no apparent problems. However, the link between the ccc cold finger and the casting was still of too high an impedance to allow the ccc to take the full thermal load of INGRID. However, LN2 use was reduced to about 5 litres / day indicating that the ccc was absorbing the major part of the thermal load.

3.3 With the blank filter in filter wheel 2 in place, very low light leakage was seen. A comparison of 0.8 sec and 10 sec 'dark' integration frames showed the leakage to be below the system noise level of 5 ADU rms.

3.4 On raw dark data frames taken with mndr's of between 1 and 8, very many hot pixels were observed with amplitudes increasing with increasing mndr value. These pixels are spatially stable but do not effectively cancel with reset subtraction. Their effect can be moderated by reduction of Vbias but since this affects the conversion gain of the system, the apparent decrease in amplitude is probably an illusion.

3.5 A simple reduction technique was constructed in IRAF to facilitate basic detector performance. This procedure simply subtracted the post integration frame from the post reset frame and assessed statistics for a predetermined area of quadrant 2. Testing was restricted because of a problem with the acquisition software that only allowed a maximum of 10 second integration for any exposure.

3.6 An attempt to assess dark current failed as the 10 second limit did not allow enough time for dark current signal to overcome system noise of 5 ADU.

3.7 A series of tests were performed with bias frames (minimum integration time of 0.8 seconds) to assess noise source contribution. Apparent in the image frames are white and interference (banding) noise contributions. Interference sources were identified from the mechanism controller and the ccc compressor safety ground. By isolating these two interference sources a minimum of 3 ADU rms. white noise was achieved. These figures agree well with test data taken at RGO on this device. THE MECHANISM CONTROLLER WIRING MUST BE INVESTIGATED AND THE CCC HELIUM LINES MUST BE ISOLATED FROM THE CRYOSTAT.

3.8 A series of integrations were done with the Z band filter to assess linearity and gain. Generally, preliminary reduction of this data yielded very poor linearity. With Vrst = 0.55v data is linear to the 10% level between 12.5 K ADU to 27K ADU with conversion gain estimated to be approximately 3.7 e-/ADU. End to end linearity is of order 30% ! Reduced data from two other cases with Vrst equal to 0.75v and 0.95v produced the same characteristic curves. However, the span of the 10% linearity band increased to 22K ADU with a corresponding increase of start and end points. I believe conversion gain must be influenced also by Vrst as at 0.95v on Vrst, saturation occurs at 44K ADU which implies a full well of 163K e-, 63% higher than specified by Rockwell. POST ACQUISITION DATA LINEARIZATION ALGORITHMS MUST BE IMPLIMENTED TO EXTEND THE USABLE RANGE OF THESE DETECTORS.

3.9 No remanance testing was performed.

4. WARM UP

4.1 Warm up began at 01:00 24th November and took approximately 20 hours for the casting to reach ambient. The detector temperature servo protection loop was activated and maintained the detector at least 3 Kelvin warmer than the casting throughout the warm up. The ccc was shut down and a rapid pressure increase to 5E-4 during the first hour was observed. No detector measurements were performed during warm up.

5. POST WARM UP

5.1 Normal behaviour of the ENG detector was observed, albeit that the detector is not very functional at ambient temperature.

6. SUMMARY OF ANALYSIS.

1. “From plot 1, is the bias / temperature relationship the same as for the mux device?” “Is there similarity in the profile suggesting that all bias offset comes from the mux?”

ANS. The bias / temperature profiles are sufficiently different to make any assumptions inaccurate given the steep bias / temperature gradient found.

2. From plot 2, does the profile and time to reach equilibrium match the mux tests? Did the engineering detector mount with the same thermal characteristics? Do we need to refine the detector mounting procedure?

ANS. Thermal behaviour appears to be predictable. No modification of procedures is required.

3. From plots generated in step 3 above, assess dark current generation profile across 20 degrees K. Are we out past the knee? What is the slope (i.e. sensitivity) of dark current to temperature? Is bias level stable over time and temperature excursions? Optimise operating temperature. If step 20 was done, what is the max shield temperature before radiation leaks were seen? At what temperature is the knee?

ANS. Further testing required, however, at an operating temperature of 87 Kelvin the dark current generation appears to be suppressed to at least first order.

4. From plots generated in step 3 & 4 above, calculate electronic gain, deviation from linearity, read noise component. Is the gain that expected? Is gain the same in both bands? Did we hit limits of linearity? What is the read noise component? Do these values reflect the initial work done at RGO? Is amplifier glow a factor?

ANS. Conversion gain agrees with that measured at RGO. Linearity is of order worse than expected and would seem to be intrinsic and therefor not correctable by electronic means. Noise is reasonable but more work is required to eliminate the induced (pattern) component. If conversion gain is indeed close to 4 e-/ADU then best noise figure will be approximately 12 e- rms.

5. From plot 5, is there evidence of remenance? Is this reflected in the linearity data from above?

ANS. No data taken. Will need to be ascertained on science device.

6. From plot 6, Is there evidence of bias level dependence on cryostat skin temperature? What is the derivative of primary shield temperature to cryostat skin temperature?

ANS. There is a very strong relationship to bias level with temperature of the detector array / fanout board. The casting temperature is the first defence for radiation load on this sub assembly and did not deviate when ambient temperature changed by 11 Kelvin during normal diurnal cycles.

7. From test 16, derive a bad pixel map for the engineering array. Is this array suitable for science?

ANS. Given the large number of ‘Hot Pixels’ and the one quadrant that is essentially dead, the engineering array cannot be classed as a science grade detector.