Characterization of Gemini Near-IR Arrays

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ABSTRACT

Four ALADDIN Type II 1024x1024 InSb arrays have been tested in the NOAO Infrared Detector Lab for use in the Gemini infrared instruments; the Gemini Near-Infrared Spectrometer (GNIRS), and the Near Infrared Imager (NIRI). Santa Barbara Research Center (SBRC) has been able to successfully deliver science devices. The best of which will be selected for use at Mauna Kea and Cerro Pachon. These results are reported to show the progress in the development of these arrays.

1. INTRODUCTION

Each array has been tested using the custom low noise Barracuda / Wildfire system[2]. The test dewar is outfitted with a filter wheel and aperture wheel and has a CaF window. The data taking system uses a 16 bit analog to digital converter and data is reduced using NOAO's IRAF.

The testing procedure is performed in two stages depending on the quality of the device. Initially each array is visually inspected and any defects due to the manufacturing process are noted. These include epoxy voids, cracks, and overthinning but these features do not necessarily disqualify the array from science worthiness.

2. DETECTOR SPECIFICATIONS

The ALADDIN Type II 1024x1024 Focal Plane Specifications

Number of Pixels	1024 (H) x 1024 (V) 1,048,576 Pixels
Architecture	4 Independent 512 x 512 Quadrants
Pixel Size	27 um x 27 um
Effective Fill Factor	100%
Outputs	32 (8 per quadrant)
Frame Rate	~50 ms
Readout Type	PMOS SFD Unit Cell CMOS Shift registers and Control Logic PMOS Output Drivers
Detector	Thinned InSb Gateless Process
Wavelength Range	0.9 to 5 Microns extendable to visible with AR coating
Operating Temperature	35K
Dark Current	<0.1e/sec
Full Well	300,000 Electrons at 1.0 v Bias
Noise	<25e rms with Fowler Sampling
Quantum Efficiency	>80% 0.9 to 5 Microns
Defective Pixels	<0.5% No bad rows or columns

3. CHARACTERIZATION TESTS

The testing procedure is performed in two stages. Level one screening includes visual inspection, room temperature clocking, and then some preliminary cold tests at 35K. If it is determined that a quadrant should be deselected, the dewar is warmed and jumpers are changed inside of the dewar before proceeding with level 2 testing.

1. Level 1 Screening

During warm testing the array is activated with a small bias of 50 mv and clocked at room temperature. Short integration dark frames are taken. This test will show the functionality of the quadrants and also may show the location of defects leading to photon emitting defects (PEDs). During a dark frame the array sees a cold aluminum plug in the aperture wheel.

The array is cooled to 35K using a closed cycle helium cryocooler with a LN2 prechill. This takes about a day. Frames are taken with the reset on to quickly check readout uniformity. In addition, dark as well as exposed frames are taken to assess cosmetic quality and approximate dark current levels.

2. Level 2 Screening

Level 2 testing consists of electrical gain, mean-variance, dark current, full well capacity, and residual image tests.

The Mean-Variance test is the key test for determining read noise and photon conversion gain which is used in all other performance calculations. It also demonstrates that there are no low level linearity problems.

The array is activated with a nominal bias of 0.4 volts. Incident flux is varied from the dark level to saturation levels. At each level 10 frames of data are taken and the mean and standard deviation is calculated on a pixel by pixel basis. The variance frames are generated by squaring the sigma frames. The data is plotted with the average of the variance in the dark frames subtracted from the variance at each incident flux level. From this data the conversion gain in electrons per adu is calculated in the region around 1000 adu (8-10K electrons).

A read noise histogram in Electrons RMS vs. Number of Pixels is produced. This shows the general distribution of the read noise statistics. The data for the histogram is generated from the variance of the darks taken at the beginning and end of the test.

The gain test is run with the detector deactivated. Frames are taken with Vdduc varied from –2.5 to –4.2 volts. The data is processed to produce a gain image which is a pixel by pixel linear regression of the test data. A plot of Vdduc vs. Adus is produced. With the electrical gain from the detector node and the conversion gain from the Mean-Variance test, the detector node capacitance can be calculated.

In addition to the gain, the shorted input noise is measured by taking data at the nominal operating point with Vdduc set to -3.5 volts and computing the standard deviation of a temporal data set of ten frames on a pixel by pixel basis. This is done to insure that the system or chip noise does not dominate the read noise determined in the Mean-Variance test.

The dark current test measures dark current by taking frames with integration times of 0.8 to 512 seconds. Ten frames are taken at each integration time and averaged to eliminate short term variations in operating temperature. The data is used to produce a rate and intercept image. The rate image is multiplied by the conversion gain to produce a dark current image in electrons/pixel/second. A histogram of the rate image is made to show the distribution of the dark current.

A plot of dark current vs. integration time is also made from the raw data.

The Full Well Capacity Test measures the full well capacity of the device at three different bias levels of 300, 600, and 800 millivolts. The integration time is increased until the output signal saturates. A plot of Output Adus vs. Integration time is made at each bias level.

The Residual Image Test uses the H filter and a pin hole aperture, the array is exposed to a near saturation flux level and a frame taken. A dark plug is immediately selected and a series of dark frames are taken at an integration time sufficient to show any residual image.

4. TEST RESULTS

Gemini Device #1 SCA 44308

This array has four working quadrants. The warm screen image indicates that there are some open pixels in the corner of quadrant 1, along the left side and bottom of quadrant 3, and scattered pixels in the lower right corner of quadrant 4. The cold screen test shows no gross nonuniformity. There is a bright as well as a dark feature in quadrant 1. Quadrant 2 has a small annular feature. The normalized dark image shows the hot spot along the edge of quadrant 1 and the defect area in quadrant 2. There appears to be a lot of scattered individual hot pixels in a ring shaped band in quadrant 3 and 4. There is a small epoxy void problem in quadrant 2.

The dark current at 400 mv bias is 0.3 electrons/sec and the response is down in a large area of quadrant 4. The noise varies from a low of 30 e in quadrant 2 to a high of 37 in quadrant 3 using Fowler 1 sampling. The average noise over the array is 35 e rms. The average dark current over the array is 0.33 e/sec. A quick residual image test shows very little image retention.
The bright spots at the center of the array in Figure 3 are the projection of 3 spot test target with a black body. There is some masking in the chip holder and vignetting in the optics of the test system

Figure 1. 44308 Normalized Cold Dark Image
Figure 2. 44308 Histogram of the Normalized Dark Image
Figure 3. 44308 Normalized Response Image from the Mean-Variance Data at an Average Illumination of 2000 Adus

Gemini Device #2 SCA 44309

This array has four working quadrants and three PEDs. A PED appears as a saturated bright spot which may be on the order of 100 pixels in diameter. The saturated center of the PED appears black in the difference of two frames. Prior to array delivery, SBRC tests the devices warm and may determine if there are any PEDs in the array. PEDs were not found in the original ALADDIN arrays.   Quadrant 1 had two PEDs and quadrant 2 also had a PED near the edge of the chip. Quadrants 1 and 2 were initially disabled to test quadrants 3 and 4. There may be an off chip PED causing the glow in the lower right corner of quadrant 4. There is a large area of open circuit dead pixels on the right side of quadrant 2 extending into quadrant 4.

SBRC has developed a process to mask and remove the PEDs without affecting adjacent pixels. This device was sent back to SBRC for PED removal in quadrants 1 and 2. The affected repaired PED areas are 6x10 pixels, 7x7 pixels, and 6x7 pixels. Average dark current at 400 mv bias is about 180 electrons per second for integrations of 512 seconds for quadrants 1 and 3 with quadrants 2 and 4 disconnected. Read noise is about 53 electrons using Fowler 1 sampling.

Following the pedectomy, quadrants 1 and 2 were enabled revealing a small bright defect at the corner of quadrant 2 above the large open circuit defect area of quadrants 2 and 4. There also appears to be a small epoxy problem at the top edge of quadrant 2 extending into quadrant 1.

After additional testing the array was returned to SBRC for additonal InSb removal at the far right side of the detector. The higher than expected dark current is felt to be due to a PED off the corner of quadrant 4 which was not initially removed.

Figure 4. 44309 Dark Image Berfore PED Removal
Figure 5. 44309 Normalized Dark Image After PED Removal
Figure 6. 44309 Dark Counts vs. Integration Time for Quadrant 1

Gemini Device #3 SCA 45581

This array has 3 good working quadrants and no PEDs. There were some thinning problems at the bottom edges of quadrant 3 and 4. There also appears to be a slight epoxy problem in quadrant 2. Prior to disconnecting quadrant 1, dark current was high across the whole array, around 162 to 191 adu per second for a 30 second integration. Quadrant 1 was disconnected by removing clocks, biases, and outputs to and from this quadrant because all pixels read out in this quadrant were saturated. After disconnecting quadrant 1, the remainder of the array is well behaved. Dark current is about 0.2 electrons per second at 400 mv bias at an integration time of 512 seconds. Read noise is about 36 electrons rms using Fowler 1 sampling. Full well at 300 mv bias is about 75k electrons, at 600 mv bias 171k electrons, and at 800 mv bias 237k electrons.

Figure 7. 45581 Normalized Dark Image with All Quadrants Connected
Figure 8. 45581 Normalized Dark Image with Quadrant 1 Disconnected
Figure 9. 45581 Electrical Gain Test
Figure 10. 45581 Full Well Capacity Test

Gemini Device #4 SCA 46899

This array has four good quadrants and does not have PEDs. The upper left corner appears to have some thinning problem and there is a very small defect in the lower right of quadrant 4. This appears to be a good science grade array. The array has just begun the testing process.

Figure 11. 46899 Normalized Dark Image

5. SUMMARY

In this paper we have shown the early test results for Gemini's first three in a series of 1024x1024 InSb arrays. The fourth array, which we have just received, appears to be the best detector yet. SBRC's PED repair process proved to be successful in not degrading adjacent areas and restoring operability to the affected quadrant. Of the five arrays, which have been tested, only one had a quadrant that was not operational. Only one of the five devices has had PEDs.

6. ACKNOWLEDGEMENTS

We gratefully acknowledge the contributions of Alan Hoffman, Joe Rosbeck, and Arnold Estrada of SBRC , Michael Merrill and Larry Daggert of NOAO and Doug Simons and Fred Gillett of Gemini in this work.

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7. REFERENCES

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2. G.B.Heim, N.C. Buchholz, and A.M. Fowler, "Controlling an ALADDIN 1Kx1K array with Wildfire," *SPIE Proceedings on Infrared Detectors and Instrumentation for Astronomy* **2475**(April 1995).

3. A.M. Fowler, J.B.Heynssens, I. Gatley, F.J. Vrba, H.D. Ables, A. Hoffman, J.Woolaway, "ALADDIN, the 1024x1024 InSb Array: Test Results," *NOAO Preprint*

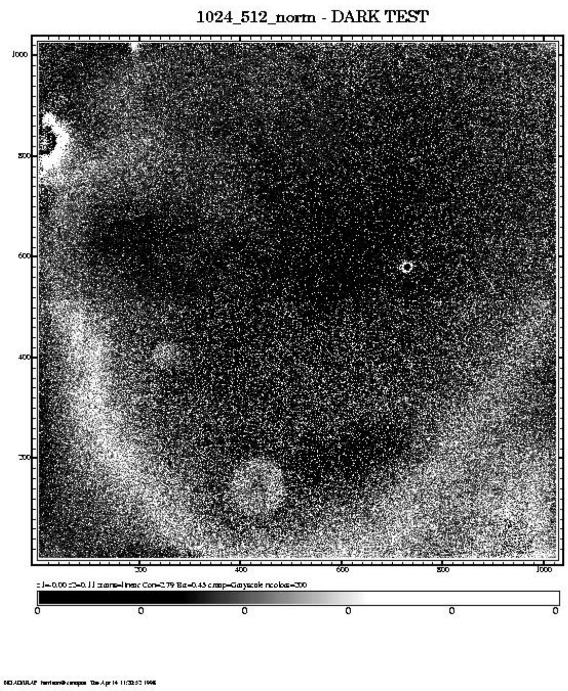

Figure 1. 44308 Normalized Cold Dark Image

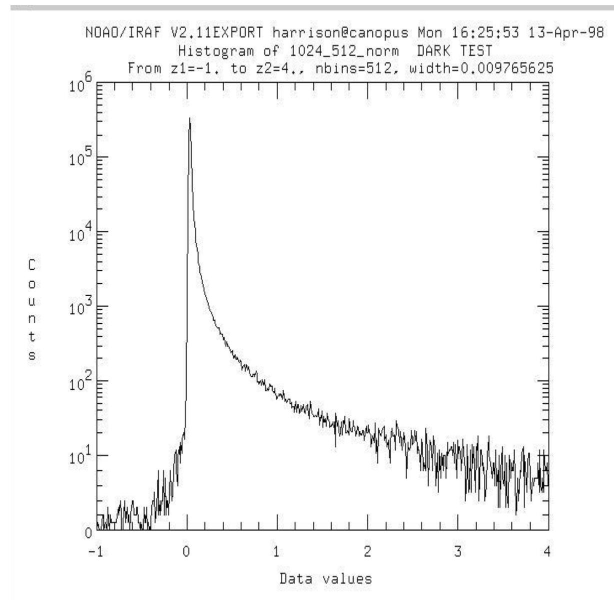

Figure 2. 44308 Histogram of Normalized Dark Image

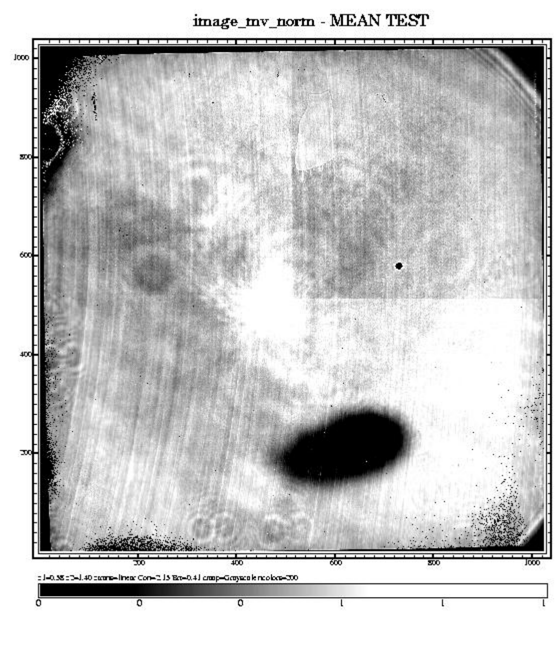

Figure 3. 44308 Normalized Response Image from the Mean –Variance at an Average Illumination of 2000 ADUs

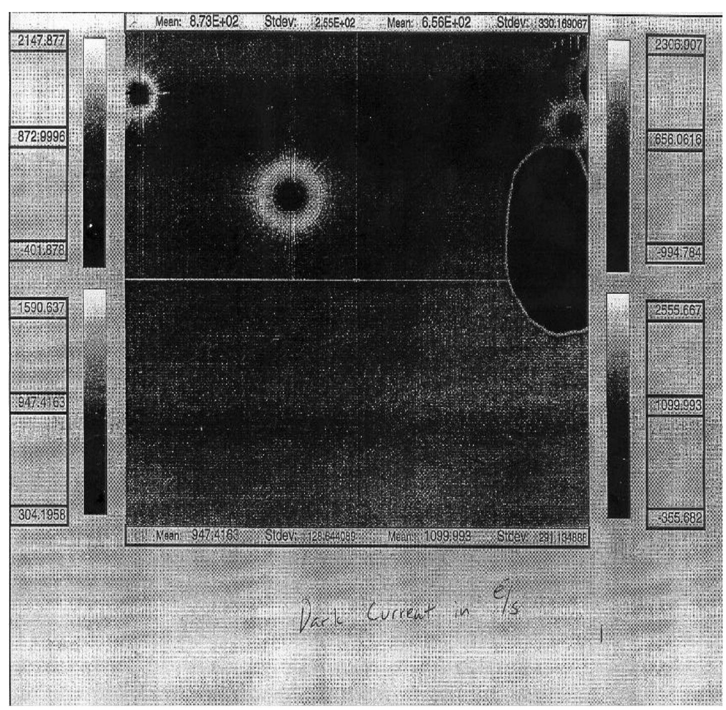

Figure 4. 44309 Dark Image Before PED Removal

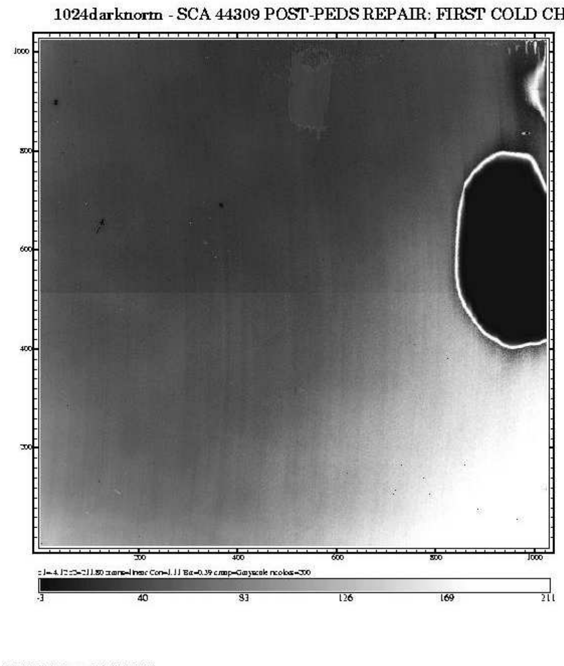

Figure 5. 44309 Normalized Dark Image After PED Removal

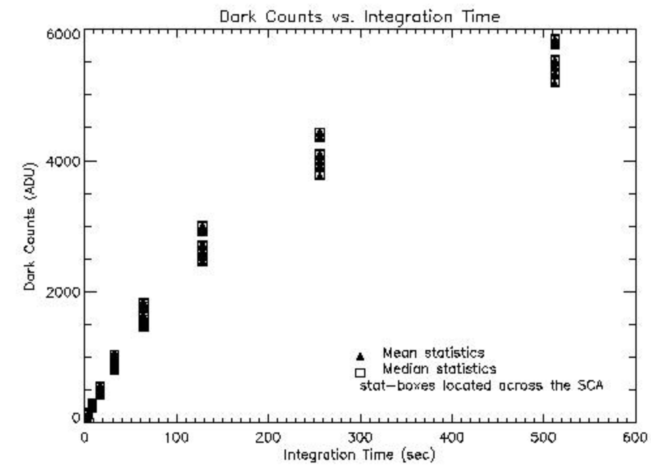

Figure 6. 44309 Dark Counts vs. Integration Time for Quadrant 1

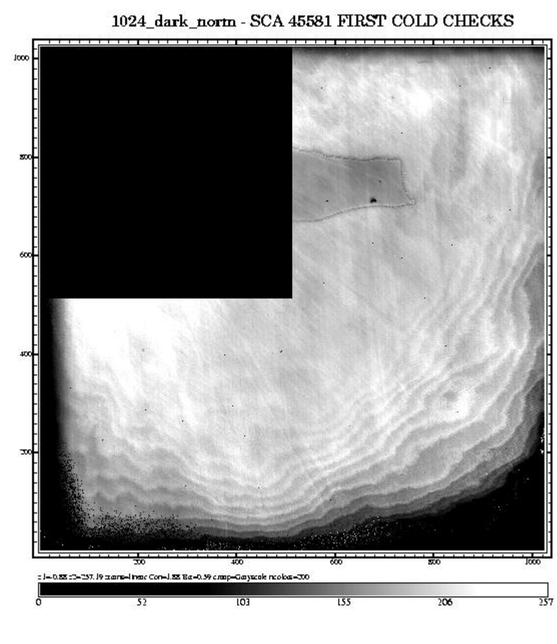

Figure 7. 45581 Normalized Dark Image with All Quadrants Connected

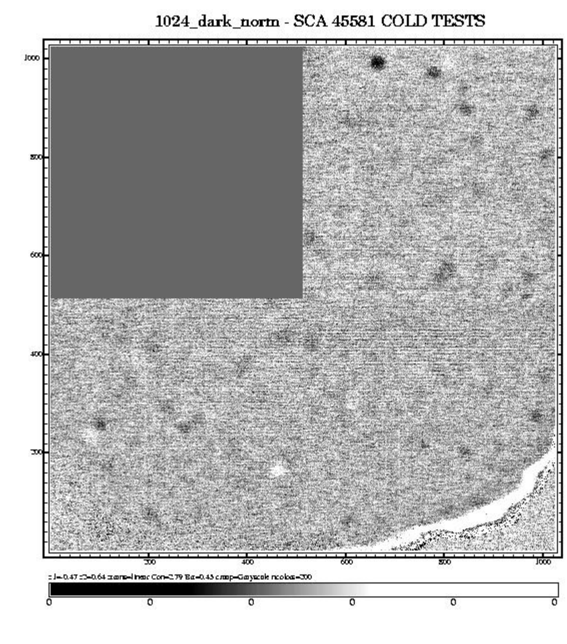

Figure 8. 45581 Normalized Dark Image with Quadrant1 Disconnected

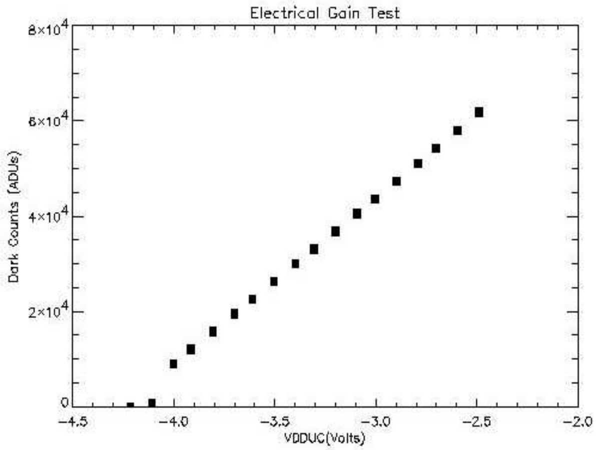

Figure 9. 45587 Electrical Gain Test

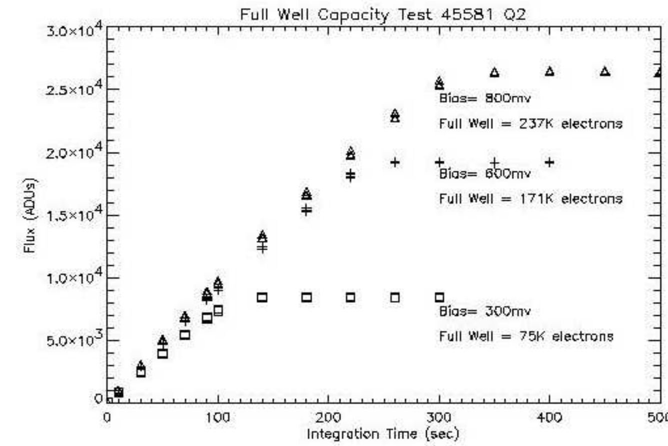

Figure 10. 45581 Full Well Capacity Test

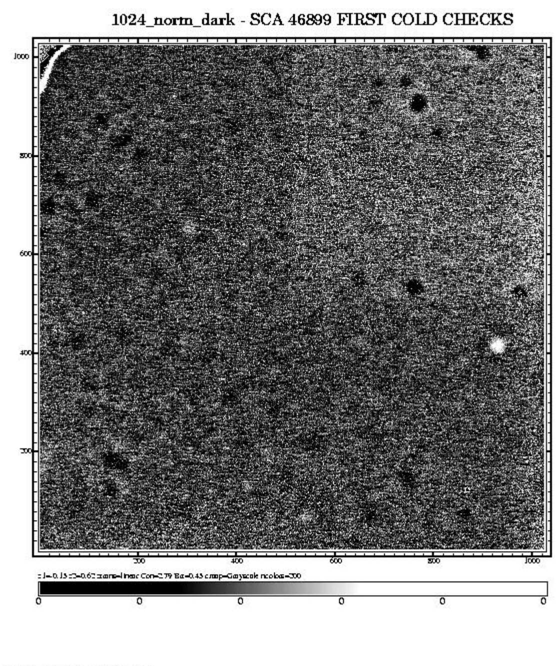

Figure 11. 46899 Normalized Dark Image