A ULTRA LOW PHOTON BACKGROUND 1 TO 5 MICRON DETECTOR MOSAIC TEST FACILITY

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Abstract:

This paper presents the design of a new ultra low background detector mosaic test facility for IR detectors with cutoff wavelengths up to 5.3 μm and operating temperatures down to 20 Kelvin. In instruments with high spectral resolution such as the ESO CRIRES instrument, dark current and readout noise of the detector system is often the limiting performance factor. This test facility allows us to develop, optimize, test and assess the functionality and performance of IR detector mosaics prior to integration in the instrument for low flux applications. Therefore detector tests have to be carried out under extremely low photon backgrounds of << 0.1 photons/sec/pixels. No cryostat window is used and the blackbody is contained inside the hermetically sealed radiation tight cold structure.

Key words: IR Detectors, FPA, mosaics, detector testing, low background

1. INTRODUCTION

Many present and upcoming infrared instruments at ESO use large IR mosaics in their focal planes. Usually these detectors cannot be properly tested in the instrument due to tight schedule and testing of other instrument components. To be able to test large detector mosaics for future ESO IR instruments the IR detector group developed a new ultra low background mosaic test facility. Almost all performance parameters and calibration measurements as well as optimization procedures can be carried out with fast cooldown capability and easy handling of the detectors. Key issues are:

- *Functionality and cryogenic performance of the detector system*
- *Optimization of feedtroughs and radiation shielding*
- *Darkcurrent and readnoise for very low flux applications*
- *Development of new readout modes*
- *Optimization of readout parameters to get maximum signal to noise ratio*
- *Cosmetic quality, uniformity and electroluminescence*
- *Quantum efficiency in J, H, K, L and M*
- *Analog bandwidth of the video output*
- *Photon transfer curve and calibration*

2. CRYOGENICS REQUIREMENTS

In order to keep the instrument simple, no image quality tests are performed and therefore no optics is installed. However it is possible to put a pinhole grid mask in front of the detector mosaic to illuminate selected areas on the detector for crosstalk tests. Extremely low background radiation was the major goal of the facility and instead of a window, a cryogenic blackbody has been implemented. To determine the cryogenic requirements, the thermal flux seen by the detector from 2π steradian was calculated as a function of instrument temperature for detectors with a cutoff wavelength of 5.3 microns. To obtain a photon flux < 0.1 electrons/sec/pixel assuming a pixel size of 27 micron, the warmest part of the testfacility needed to be colder than 77 Kelvin. The following plot shows this curve in the case of the CRIRES Aladdin mosaic (Dorn et al, 2004).

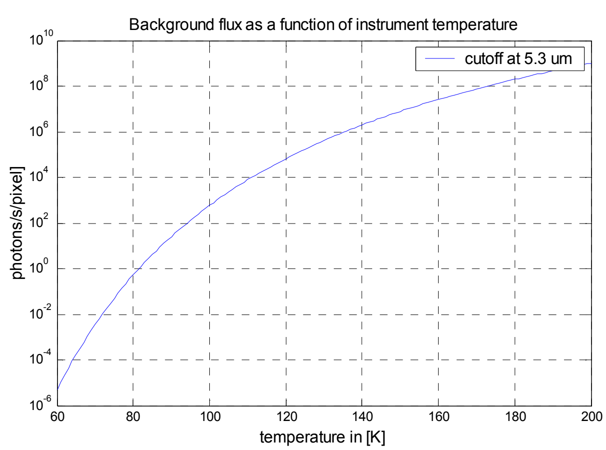

Figure 1. Background flux from 2π steradian as a function of instrument temperature

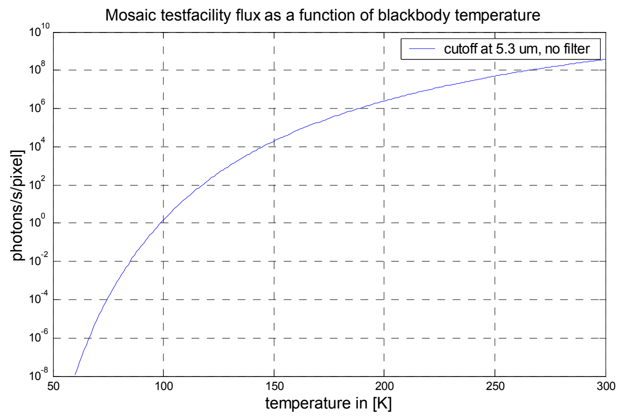

Figure 2. Flux seen by the detectors as a function of blackbody temperature

The thermal flux seen by the detector from the cryogenic blackbody can also be calculated with Planks law of photon emittance by including the geometric properties and the detector mosaic to be tested. Figure 2 shows the flux in electrons/sec/pixels in the case of the CRIRES mosaic. To calculate flux for QE measurements the filtercuves need to be included.

3. DESIGN OF THE TEST FACILITY

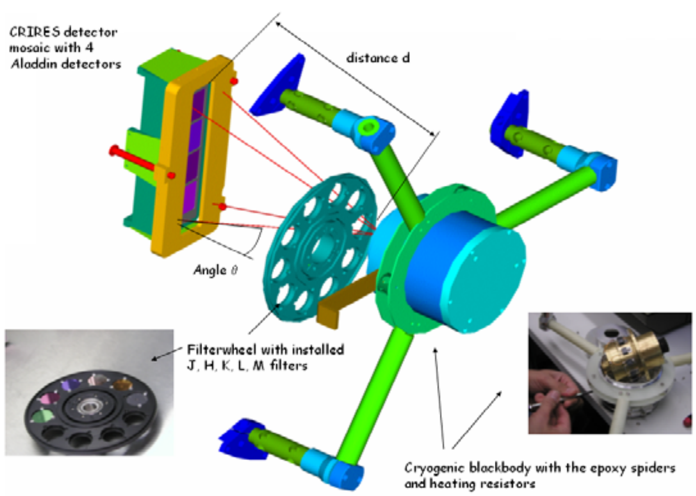

Figure 3. 3D drawing of the design of the testfacility

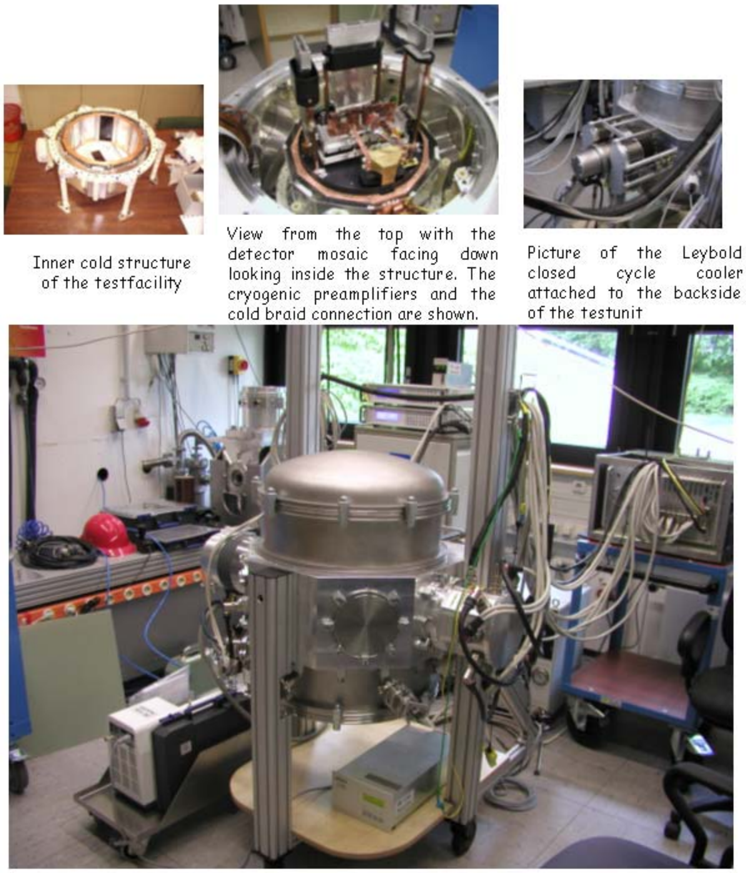

Figure 4. Moasic testfacillity in the ESO infrared laboratory. The blackbody and the detectors are temperature controlled by two Lakeshore 340 controllers. The closed cycle cooler is mounted on the backside. On the right the cable connectors and the 128 video channel IRACE controller can be seen. On the left side the pre-vacuum and the turbo vacuum pump are shown (turbomolecular pump directly attached to the vessel).

A 3 D drawing of the main parts of the facility in the case of CRIRES is shown in Figure 3. The blackbody is supported by epoxy spiders at a distance of 20 cm from the focal plane with an aperture of 20 mm. A filter wheel hosting 1 inch filters which are heat sinked to 60 Kelvin is mounted in front of the blackbody. The blackbody temperature can be be changed from 80 to 380 Kelvin without changing the temperature of the focal plane by more than 10 mK. A background level of < 0.2 electrons/sec/pixel was obtained with the Aladdin mosaic. A picture of the testfacility is shown in Figure 4.

3.1 Illumination distribution

As there is no optics inside the cryostat, the angle θ (maximum 18 degrees in the case of CRIRES) defines the intensity of illumination across the detector array. The illumination for off axis points on the detector mosaic falls off. For Ω as the solid angle on axis, the solid angle off the axis at an angle of θ will be $\Omega \cos^3 \theta$. Since the illumination falls obliquely at an angle of θ, there is a further factor of cos θ. Therefore the off axis illumination falls of as $\cos^4 \theta$. A map for correction is shown below for the CRIRES mosaic together with an image of the four detectors masked by the pinhole grid mask. Hence it is possible to calculate the exact flux on the detectors to obtain the quantum efficiency.

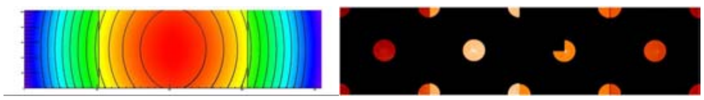

Figure 5. Illumination distribution and map of efficiency for the CRIRES mosaic

4. THE CRIRES AND HAWK-I MOSAICS

The first application for the testfacility was the CRIRES 512 x 4096 pixels Aladdin InSb focal plane array mosaic mounted on the newly developed 3-side buttable package shown in figure 6 left. The second application is the Hawk-I detector mosaic (Pirard et al, 2004) with four 2kx2k Rockwell HgCdTe MBE buttable arrays with 2.5µm cut-off. GL Scientific was providing the packaging and mount as seen in the right picture below

Figure 6. The CRIRES and HAWK-I detector mosaics

5. EXAMPLES OF RESULTS

Some results obtained with the CRIRES detectors are shown next as an example. The left chart is a photon transfer curve and the right the relative efficiency of the four Aladdin detectors tested. See more in a paper by Finger et al, 2005.

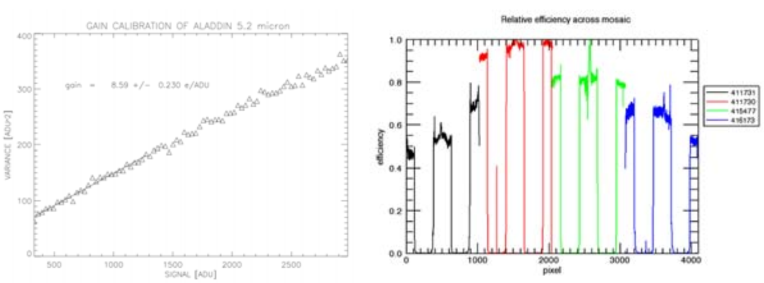

Figure 7. Gain calibration curve for an Aladdin array and comparison of efficiency corrected for $\cos^4$ dependence of illumination

6. CONCLUSIONS

The new ESO IR detector mosaic testfacillity allows us to develop, optimize, test and assess the functionality and performance in a very efficient way. It also shows that many detector parameters can be evaluated without cryostat window, which helps to achieve ultralow background flux levels.

7. REFERENCES

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