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EVALUATION OF AN INNOVATIVE COLOR SENSOR FOR SPACE APPLICATION

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ABSTRACT

We present in this paper an evaluation of an innovative image sensor that provides color information without the need of organic filters. The sensor is a CMOS array with more than 4 millions pixels which filters the incident photons into R, G, and B channels, delivering the full resolution in color. Such a sensor, combining high performance with low power consumption, is of high interest for future space missions.
The paper presents the characteristics of the detector as well as the first results of environmental testing.

1 OVERVIEW

1.1 Detector characteristics

The silicon image sensor is fabricated using standard 0.18µm CMOS process and has three stacked photodiodes per pixel location to provide full-color imaging without external color filters.
With a fill factor exceeding 50%, the image sensor achieves approximately 45% peak quantum efficiency in the mid range visible and provides usable response extending from the near-ultraviolet to the near-infrared. This device produces images free from color artifacts common in images made with sensors incorporating color filter arrays.

1.2 Test facilities

The planetary environment simulator of Micro-Cameras & Space Exploration SA (MCSE) allows reproducing the conditions of temperature and pressure of several planetary surfaces in the solar system like the Moon, Mars or celestial bodies like comet surfaces. It is composed of a cryostat (with two observation ports), a pumping system (composed of a primary pump and a turbo-molecular pump), a thermal control and measurement system, and tanks of liquid nitrogen.

Table 1: Characteristics of MCSE's Cryostat

Working diameter	60 cm
Working height	60 cm
Number of thermal regulation sensors	4
Working temperature range	–180°C to +150°C
Stability of controlled temperature (constant temperature and temperature ramp)	± 0.1°C
Working pressure range	10^{-6} mbar to 1 bar

Fig. 1: View of MCSE's Planetary Simulator

2 THERMAL TESTS DESCRIPTION

2.1 Test objective

The objective of the test is to check the functional behaviour of the detector at low temperature. The calibration of the detector color response is not intended for this test.

2.2 Test set-up

The test set-up overview is given in Fig. 2 and Fig. 3. The detector test board equipped with a wide angle lens is placed inside the cryostat chamber, facing a colour optical chart. The camera is isolated from the planetary simulator baseplate thanks to a mechanical support with Teflon feet. A dedicated thermal interface has been designed and manufactured in order to cool efficiently the detector while minimising detector test board cooling since the later has not been developed for low temperature operations. Several thermal sensors are used to monitor the test temperatures.

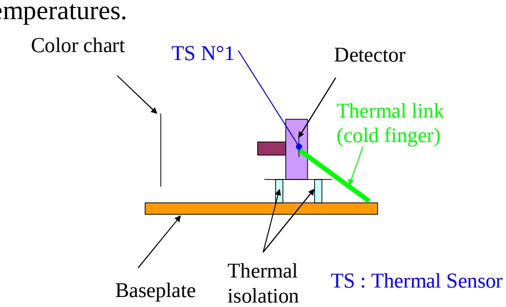

Fig. 2: Test set-up (side view)

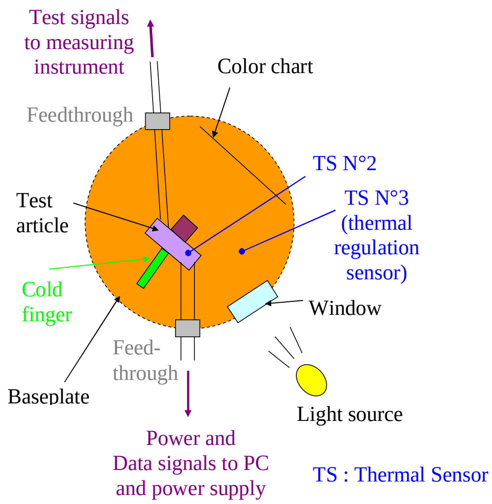

Fig. 3: Test set-up (top view)

The color chart used for the test is the GretagMacbeth color checker which is a “test pattern” of 24 scientifically prepared colour squares. The chart is lightened by a light source located outside the planetary simulator in front of the window.

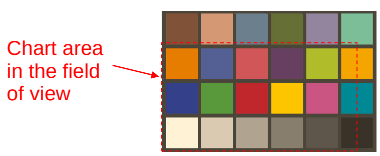

Fig. 4: View of GretagMacbeth Color Checker

2.3 Test description

The main test consists in taking images of the color chart and controlling the power consumption. Several images are taken at various temperatures and with various integration times. For each temperature step several measurements are carried out.

3 MAIN TESTS RESULTS

3.1 Thermal conditions

The first test sequence is performed at ambient temperature. From this temperature, the test chamber temperature is dropped to 0°C and then decreased by step of 10°C or 20°C. At every step, a stabilisation plateau is held in order to stabilise the detector to the desired temperature during around 20-30 minutes. The temperature change rate is 4°C/min. Tests are performed at every end of plateau when the temperature of the detector is stabilised in steady state.

3.2 Results summary

The detector is performing well from ambient temperature to -50°C. Fig. 5 shows a raw test image of the color chart obtained at -50°C. Due to the limited space available inside the chamber to set up the test, it was not possible to have a uniform illumination on the optical chart. The white square is slightly saturated and a reflection from the light is visible on the left side.

Fig. 5: Test image @ -50°C

Fig. 6 shows the R, G, B content of the red square area for 400ms, 600ms, 800ms, 1000ms exposure time @ -50°C. It shows that the R, G, B content increase linearly with the exposure.

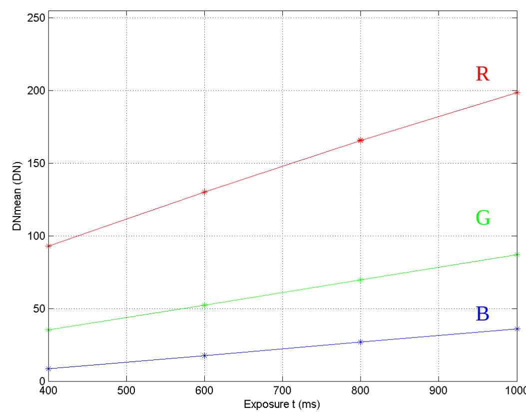

Fig. 6: Detector linearity @ -50°C
for the red square of the chart

The power consumption remains stable along the temperature range.

4 CONCLUSION & NEXT ACTIVITIES

The results of the thermal tests performed on the color detector are very positive. The detector is performing well until a temperature of around -50°C.Two thermal descents have been performed. Both tests results are consistent and the detector behavior showed a good reproducibility. The detector test shows a good potential for a operating at low temperatures. The development of a specific board to be developed for low temperatures will allow further characterization of the detector.