Test set up description and performances for HAWAII-2RG detector characterization at ESTEC

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ABSTRACT

In the frame work of the European Space Agency's Cosmic Vision program, the Euclid mission has the objective to map the geometry of the Dark Universe. Galaxies and clusters of galaxies will be observed in the visible and near-infrared wavelengths by an imaging and spectroscopic channel.
For the Near Infrared Spectrometer instrument (NISP), the state-of-the-art HAWAII-2RG detectors will be used, associated with the SIDECAR ASIC readout electronic which will perform the image frame acquisitions.
To characterize and validate the performance of these detectors, a test bench has been designed, tested and validated.
This publication describes the pre-tests performed to build the set up dedicated to dark current measurements and tests requiring reasonably uniform light levels (such as for conversion gain measurements). Successful cryogenic and vacuum tests on commercial LEDs and photodiodes are shown. An optimized feed through in stainless steel with a V–groove to pot the flex cable connecting the SIDECAR ASIC to the room temperature board (JADE2) has been designed and tested.
The test set up for quantum efficiency measurements consisting of a lamp, a monochromator, an integrating sphere and set of cold filters, and which is currently under construction will ensure a uniform illumination across the detector with variations lower than 2%.
A dedicated spot projector for intra-pixel measurements has been designed and built to reach a spot diameter of 5 µm at 920nm with 2nm of bandwidth [1].

Keywords: Euclid mission, HAWAII-2RG, SIDECAR ASIC, characterization, ESA

1. INTRODUCTION

The infrared channel in the payload the Euclid satellite [2] will carry a focal plane consisting of a 4×4 array of HAWAII-2RG detectors with a cut-off wavelength of 2.5µm.
The design of the satellite and final performances of the scientific mission will depend on fundamental detector performances such as dark current, readout noise and power consumption. To characterize and validate performances of these detectors, a test bench has been designed, tested and validated.
This publication describes first the performances of the set up dedicated to dark current and readout noise tests and measurements requiring a roughly uniform illumination (as required for conversion gain, linearity, persistence effects). The next section will explain the foreseen test bench for quantum efficiency and inter- and intra-pixel variations measurements.
The performance of the test set up for the SIDECAR characterization at room temperature and at cryogenic temperature will be presented in the last section.

2. CRYOGENIC TEST SET UP

2.1 Dark and low illumination uniformity test set up

The set-up consists of the HAWAII-2RG (S/N 224) detector from Teledyne Scientific and Imaging [3] with a cut-off wavelength of 2.5 microns and the SIDECAR ASIC inside a cryostat and connected to the JADE2 card located outside the cryostat, at room temperature. The flex cable between the JADE2 card and the SIDECAR ASIC has been potted in a cryostat feedthrough.

The HAWAII-2RG detector is a state-of-the-art Near-Infrared (NIR) sensor consisting of an anti-reflection (AR) coated HgCdTe active layer, bump-bonded to a readout integrated circuit. A low noise source-follower circuit underneath each pixel and connected to multiplexers allows for a non-destructive readout scheme. Reference pixels, not sensitive to incoming light are present on all sides of the detector and allow to correct for any bias drift from the active region. The

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detector's 2048×2048 pixels can be read out through 1, 4 or 32 analog outputs. A window mode, where a reduced number of pixels can be selected, is also available to achieve faster readout rates.
The SIDECAR ASIC is designed to manage all aspects of imaging array operation and output digitization. It is composed of 36 analog to digital processing channels, 32 programmable digital I/O signals and 20 programmable bias voltages/currents. The preamplifier gain covers the range from -3dB to +27dB in 3dB steps in front of a slow 16 bit or fast 12 bit ADC. The data transmission between the SIDECAR and JADE2 card can be either LVDS or CMOS. The JADE2 card serves as interface between a data acquisition computer and the SIDECAR chip.

Pictures of the detector on its molybdenum plate and the associated SIDECAR ASIC are shown Figure **1**.

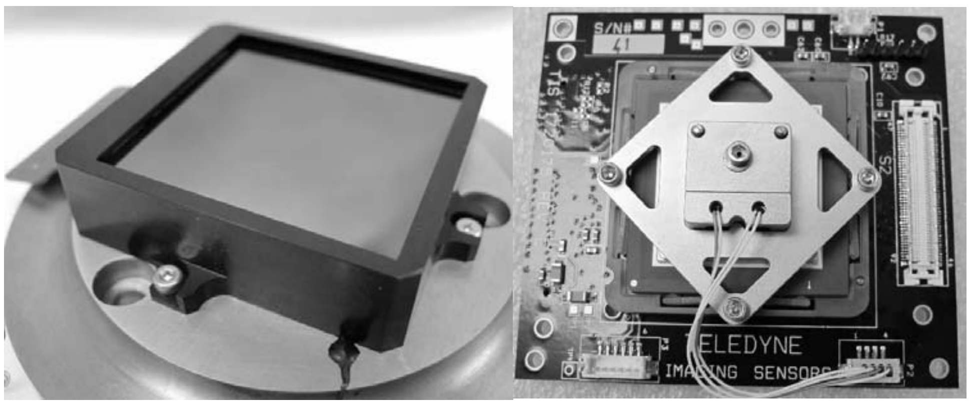

Figure 1 Left: Picture of the HAWAII-2RG detector on its molybdenum plate. Right: Picture of the SIDECAR ASIC

The cooling of the detector and SIDECAR is achieved through an interface to a 12 liters liquid nitrogen tank residing in the Dewar.
For the detector, this interface consists of a PEEK ring, which thermally isolates the rest of the detector assembly from the 77K cold plate and is dimensioned to allow for a safe passive cooling (lower than 1K/min), a bloc of copper on which two Kapton heaters and one temperature sensor diode DT470 are respectively clamped and glued and finally a molybdenum plate. The detector legs are screwed on this molybdenum plate to allow for a thermal match with the detector and good thermal conductivity .
The heaters and temperature sensor are linked to a Lakeshore 340 temperature controller for which the P, I and D coefficients have been optimized. A mK temperature stability is reached with this set up, allowing for stable and accurate low dark current measurements.

The SIDECAR is mounted on a separate bloc similarly consisting of a ring of PEEK, a copper bloc with two Kapton heaters and temperature sensor DT470. The SIDECAR is mounted on PEEK supports screwed on the copper bloc. A copper strap attached from the top of the SIDECAR ensures the heat transfer between the copper block and the SIDECAR (see Figure 2).
The temperature control is done with a Lakeshore 325 and offers also a mK temperature stability.

A series of additional temperature PT100 sensors are mounted on the base plate and on each bloc. Their wires are anchored to the LN2 base plate and at several intermediate temperature stages between the ambient temperature Dewar outer shell and the sensor. All sensors are equipped with a 4 wire connection to compensate the high lead resistances.

The ramping function of the Lakeshore allows a smooth transition between two desired temperatures for the SIDECAR or for the detector.
A gold coated cap covering the detector, LED and photodiode is used to create a reasonably flat illumination level over the detector (see Figure 2).

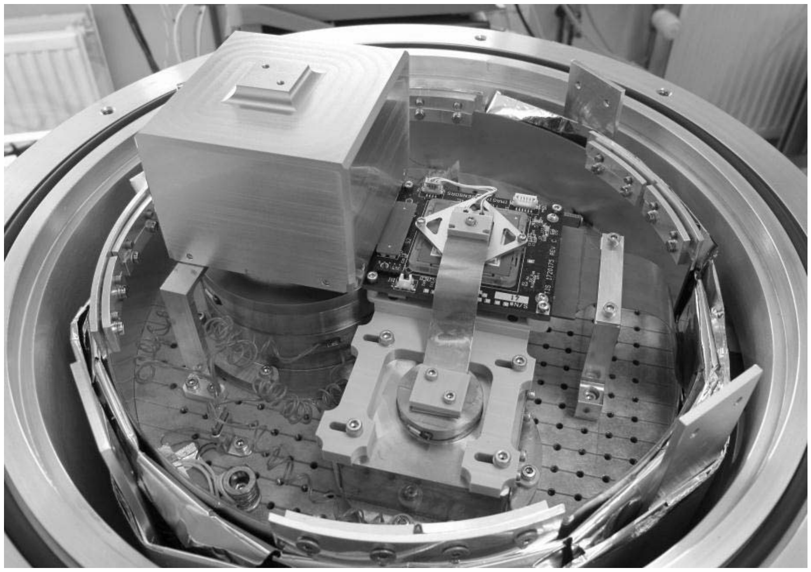

Figure 2 Gold cap covering the detector, two LEDs and photodiode

A separate (black) cap, covering only the detector, is used for dark current measurements (see Figure 3).

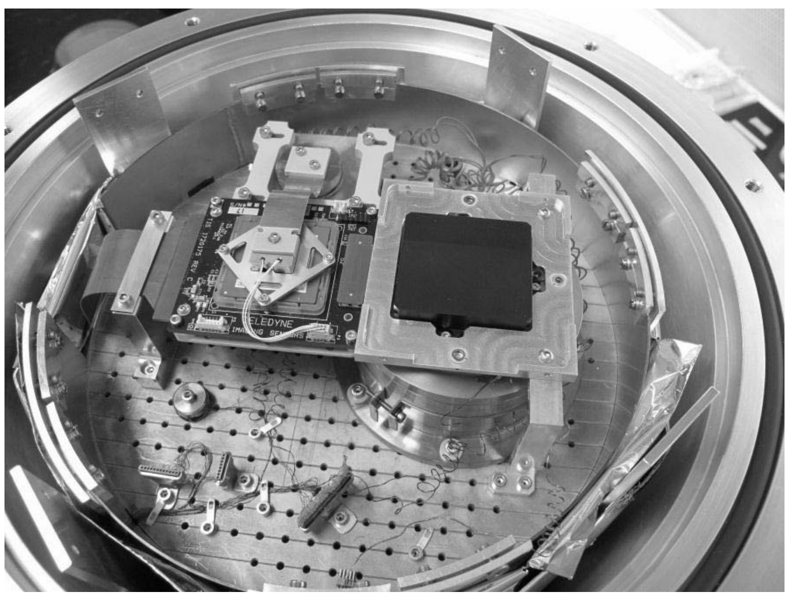

Figure 3 Dark current test configuration with a cap over the detector. One can also see the thermalization of the wires on the 77K base plate

The flex cable connecting the SIDECAR to the JADE2 card located at room temperature, needed to be potted through the wall of the cryostat. Leakage tests on different feed-through shapes have been performed to ensure the most reliable vacuum-tight potting. The best results have been obtained using a stainless steel flange with a V–groove and a rim about half height of the groove and a cover-plate on the top (see Figure 4). A 3M Scotch-Weld 2216A/B glue and a Torr-Seal epoxy at the cover-plate have been used for potting.

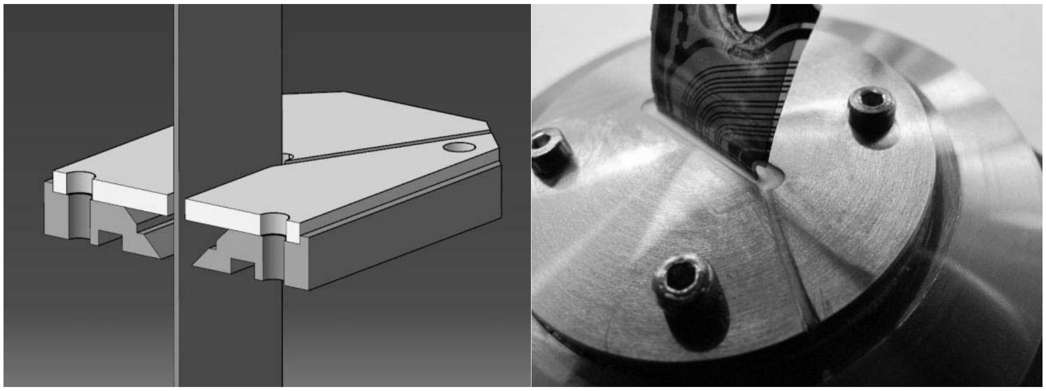

Figure 4 Left: Mechanical cross section of the V–groove with a rim about half height of the groove and a cover-plate on the top. The flex cable is going up to down. Right: Zoom in of the flange developed with a standard cable potted

For tests requiring light, the detector can be illuminated via two LEDs (L10822 from Hamamatsu) with a peak emission wavelength at 1.3 micron. From the received batch of components, LEDs have been matched in pairs according to their relative flux levels. The two LEDs with the closest flux have been chosen to be integrated in the set up.
A photodiode (InGaAs, G8370 from Hamamatsu) placed in the vicinity of the detector is used to control the relative illumination flux stability.
These LEDs and photodiode have been qualified by the manufacturer to work only down to -30C. To test them at cryogenic temperature, a set up consisting of a photodiode with in front an LED and a PT100 temperature sensor has been built. This set up allows, under vacuum, to sink progressively into liquid nitrogen, the photodiode and LED while monitoring the current, voltage on the LED, the photocurrent in the photodiode and the temperature (see Figure 5).

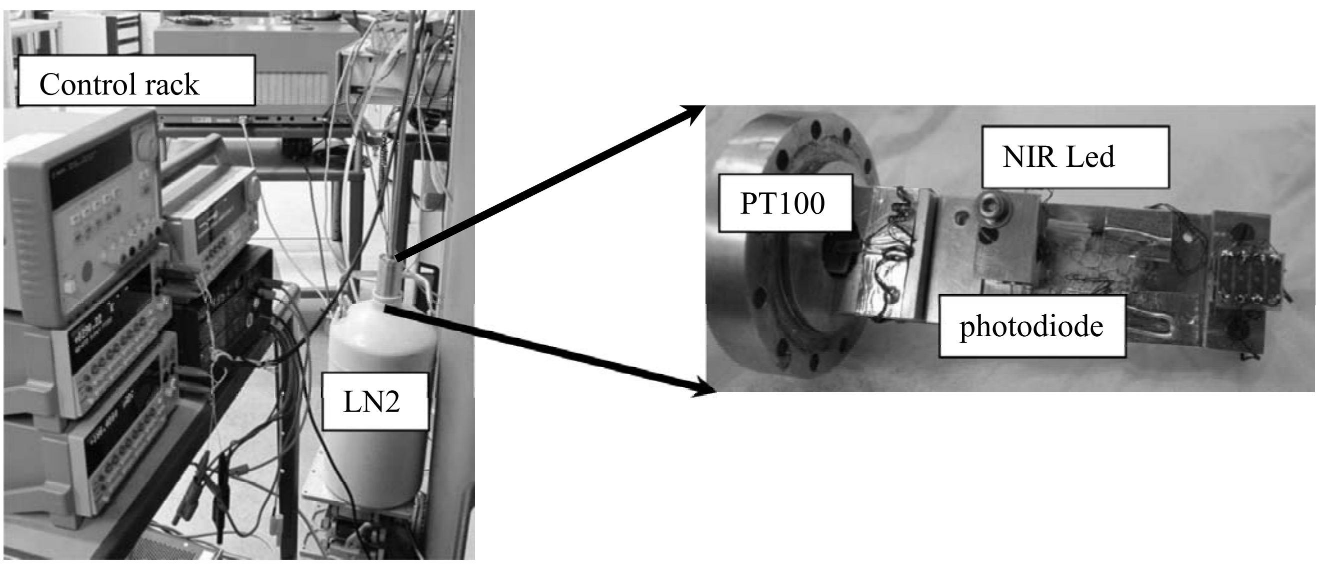

Figure 5 Test set up for the LED and photodiode at cryogenic temperatures

The results at 77K, on Figure 6, show LED and photodiode are still operational under vacuum and cryogenic temperature. Several thermal cycles between room and LN2 temperature have been performed, followed by an inspection at room temperature. No damage has been reported after these cyclings.

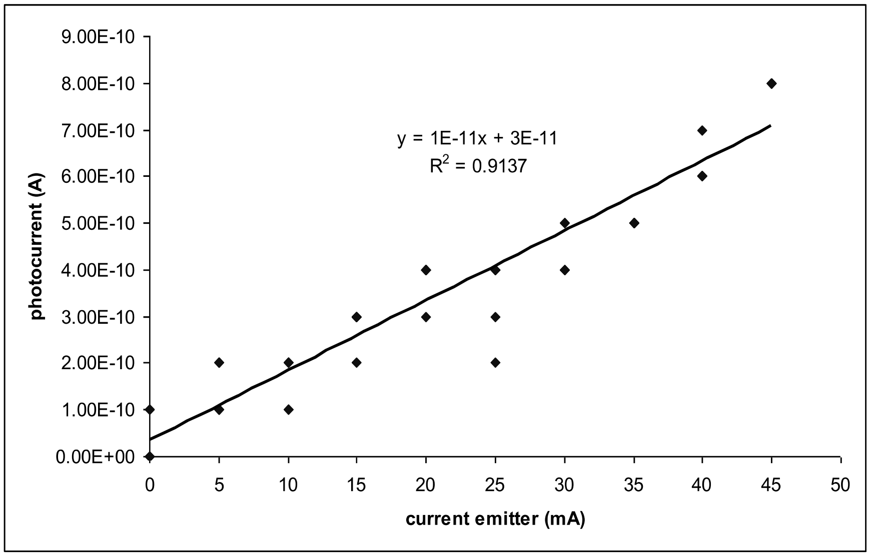

Figure 6 Photocurrent received by the LED at 77K with different LED current

For the power consumption measurements, a PCBoard (see Figure 7) has been designed and placed between the JADE2 card and the flex cable to the SIDECAR. This PCBoard allows to extract simultaneously, current and voltage of the main SIDECAR supplies e.g. V_{dda},V_{ddd},V_{dd3p3} and $V_{ddI/O}$. They are recorded with a series of multimeters.

Figure 7 PCB board allowing power consumption measurement situated between the JADE2 card and the flex cable to the SIDECAR

The set up allows measurements of dark current, readout noise, linearity, persistence effect, power consumption of the detector and the SIDECAR between 82K and room temperature. Results obtained with this set up are shown in the publication [4]

2.2 Quantum efficiency test set up

Quantum efficiency tests require a uniform illumination at the percent level. In the previous set up, the incoming light is monochromatic, it can't be controlled and it is not uniform enough over the full detector area. A dedicated set up for quantum efficiency measurements needs to be designed.

Different solutions are possible depending on the position of the light source (room temperature or cryogenic), the system used to create a uniform illumination and the position (cryogenic or room temperature) of the reference detector.

To control the incoming light we decided to generate and monitor the light at room temperature and illuminate via an integrating sphere and a window the detector situated in the cryostat.

A smooth lamp spectrum (as compare to arc lamp) is obtain by using a QTH lamp and easily spans the wavelength range from 400nm up to 2.7µm. A monochromator (Oriel Cornestone 130) creates the desired monochromatic flux. An integrating sphere from Gigahertz-Optik with $BaSO_4$ coating creates the uniform flux onto the detector. Given the diameter of the integrating sphere's output port and the dimension of the detector, the distance between them will need to be larger than 31cm to create an illumination non-uniformity of less than 2% across the detector.

A pyroelectric detector (model 70362 from Newport) fixed on the lateral port of the integrating sphere coupled with a chopper (placed between the lamp and the monochromator) and a Merlin Digital Lock-in Radiometry system ensures the monitoring of the incoming flux.

A set of cold filters inside the cryostat is mounted on a filter wheel and block most of the 300K black body radiation to a level sufficiently low to ensure a confortable signal to noise ratio level on the detector. A mechanical cross section view is given in Figure 8.

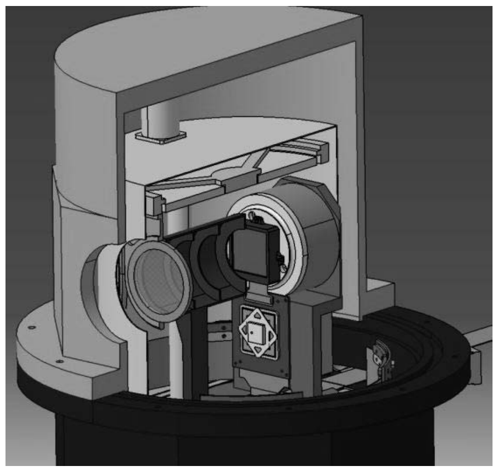

Figure 8 A mechanical cross section of the cryostat with the filter wheel, baffling, detector and sidecar

2.3 Intra-pixel test set up

In the frame work of Euclid mission, the PSF of the NISP instrument is under sampled so the sensitivity map inside the pixel needs to be known.

This test requires a dedicated set up to create a spot smaller than the pixel size.

A spot projector system (see Figure 9) has been designed at ESTEC and fabricated by JENOPTIK to ensure a diameter of the central maximum of the PSF function of 5µm at 920nm for a 2nm of spectral bandwidth. An extended description of this spot projector for the Euclid CCD characterization is given in the publication [1].

The PSF will be characterized using the knife edge method.

The system consists of a lamp followed by a monochromator and a pinhole. The image of the pinhole through the spot projector will create the final spot on the detector placed in the cryostat.

The spot projector, mounted on translation stages, will scan pixels with high spatial resolution and reveal the sensitivity map for each pixel as well as the cross-talk between pixels.

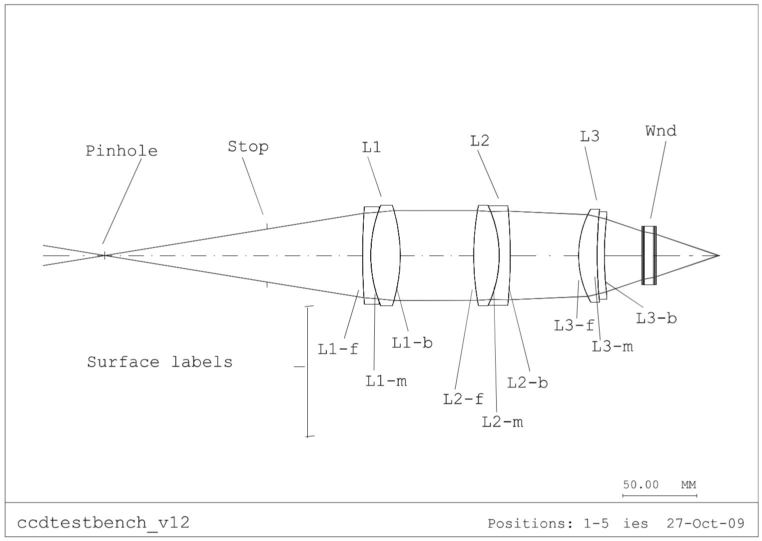

Figure 9 Spot projector optical design

3. ROOM TEMPERATURE TEST SET UP

For the characterization of the electrical parameters of the SIDECAR itself (without detector), a separate test set up was also developed. At first this set up consisted of the Teledyne room temperature kit (SIDECAR development board and JADE2 card). In a later step, it will be transferred to the cryogenic SIDECAR. For the tests, a dedicated PCB was designed to get access to important signals of the SIDECAR. It is plugged instead of the detector. This board allows to measure the biases generated by the SIDECAR as well as to feed the SIDECAR with very stable external biases.

The bias voltages generated by the SIDECAR DACs are measured by a Fluke 8508A 8.5 digit reference multimeter. The SIDECAR ADCs can be biased with a very stable voltage calibrator Fluke 5440B.

3.1 SIDECAR room temperature test bench

The SIDECAR test bench is composed of the room temperature SIDECAR ASIC board connected to the JADE2 card and linked to a computer by a USB interface. An Agilent power supply provides the operating voltage of 5.5V to the JADE2 card. A small PCB with a 92 pin connector is mounted on the SIDECAR board instead of the detector flex cable. This board offers access to the SIDECAR DAC output channels 0 and 3. In the Teledyne development kits these channels are used for V_{reset} (detector reset voltage) and $V_{biaspower}$ (used to drive the pixel source follower).The reason for choosing these two biases was that V_{reset} is one of the biases which is not connected to decoupling capacitors on the board and $V_{biaspower}$ is filtered for noise reduction with a combination of 47µF+1µF+1µF decoupling capacitors. This choice allows evaluating the impact of the decoupling capacitors on the noise. It is anticipated that these two biases are representative for the other ones. On the board there is also an SMA female connector which is wired to the ADC channel 15 input for ADC characterization. References for all measurements is analogue ground (AGND). The photo Figure 10 shows the mounted PCB.

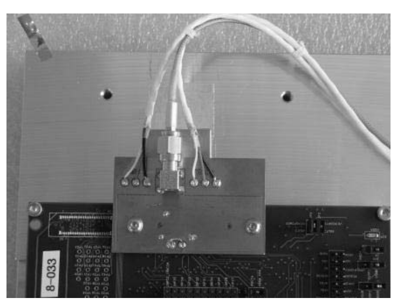

Figure 10 Measurement connection board connected on SIDECAR instead of HAWAII-2RG detector

In this study, optimal values for $V_{refMain}$ and $V_{preAmpRef1}$ (two reference voltages generated and internally used in the SIDECAR), have been determined and can be adjusted to give the maximum linearity and cover the desired input voltage range [4]. The measurements will be repeated on the cryogenic set-up to verify the system also at low operating temperatures.

4. CONCLUSION

We have designed and tested a new test bench for HAWAII-2RG and SIDECAR characterization in the frame work of the Euclid mission.

A first set up, dedicated to dark current tests, readout noise, linearity, total electrical consumption and conversion gain has been designed and tested. LEDs have been tested successfully at cryogenic temperature and are placed around the detector to create sufficient and homogeneous light. A cap over the detector allows for the measurement of extremely low dark current levels. Heaters coupled with temperature sensors to Lakeshore controllers allow the independent adjustment of the cryogenic temperature for both the detector and SIDECAR.

The test set up for quantum efficiency measurements consists of a lamp, a monochromator and an integrating sphere to create, via a window, a uniform (better than 2%) flat field over the detector. A set of cold filters will block the black body radiation of the environment to ensure enough signal to noise ratio on the detector.

For the intra-pixel test set up, a spot projector has been designed and built to create a spot smaller than the pixel size. The spot projector will scan several pixels thanks to a two-axes translation stage. The PSF will be characterized using the knife edge method.

On the room temperature set up, two dedicated PCBs have been designed and built. One is used for electrical power consumption measurements and the other for electrical characterization of the SIDECAR ADCs and DACs without detector.

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