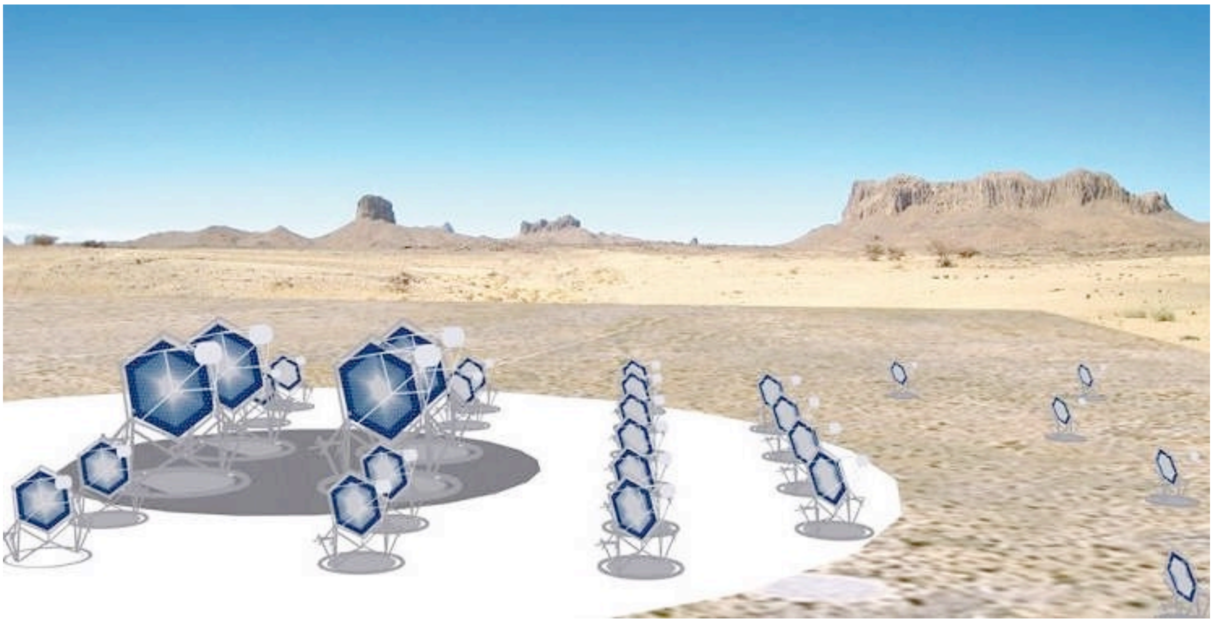
OSSERVATORIO ASTROFISICO DI CATANIA

Characterization Test of SiPM FBK

Device: NUV low AP/CSP



Osservatorio Astrofisico di Catania

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Rapporti interni e tecnici
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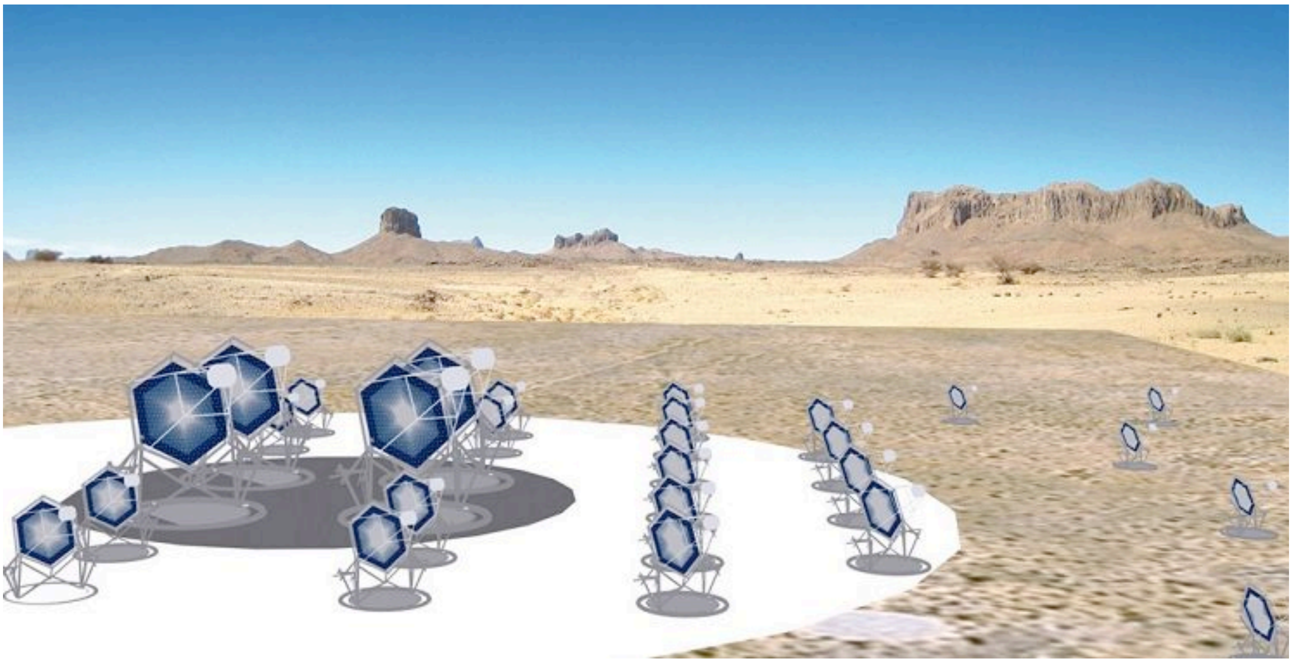
Characterization Test of SiPM FBK NUV low AP / CSP

Measures of: Dark Stairs, Dark Count Rate and Cross-Talk



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DOCUMENT HISTORY

Version	Date	Modification
1.0	Date	first version
		update

LIST OF ACRONYMS

OACT	Osservatorio Astrofisico di Catania
IFC	Istituto di Astrofisica Spaziale e Fisica Cosmica di Palermo
COLD	Catania astrophysical Observatory Laboratory for Detectors
PCB	Printed Circuit Board
SiPM	Silicon Photo-Multiplier
MPPC	Multi Pixel Photon Counter
SST-2M	Small-Size Telescope Dual-Mirror
PDM	Photon Detection Module
ASIC	Application Specific Integrated Circuit
FEE	Front-End Electronics
BEE	Back-End Electronics
FPGA	Field Programmable Gate Array
EASIROC	Extended Analogue Silicon-pm Integrated Read-Out Chip
CITIROC	Cherenkov Imaging Telescope Integrated Read-Out Chip
I/F	Interface
LCT	Low Cross Talk
PSAU	Power Supply and Amplification Unit

APPLICABLE DOCUMENTS

[AD1] AD1

REFERENCE DOCUMENTS

[RD1] G. Bonanno, et al., “Characterization Measurements Methodology and Instrumental Set-up Optimization for New SiPM Detectors - Part II: Optical Tests”, IEEE Sensors Journal, vol. 14, no. 10, pp. 3567-3578, 2014.

[RD2] G. Bonanno, et al., “Characterization Measurements Methodology and Instrumental Set-up Optimization for New SiPM Detectors - Part I: Electrical Tests”, IEEE Sensors Journal, vol. 14, no. 10, pp. 3557-3566, 2014.

1. INTRODUCTION

This document discusses on some measurement results of the SiPM most relevant characteristics: dark stairs, cross-talk (XTalk) and dark count rate (DCR), carried out at the Catania astrophysical Observatory Laboratory for Detectors (COLD) on a class of recently available detectors by FBK.

2. SCOPE

The main goals of this work is to evaluate the best features of these new devices in order to choose the best detector for new telescopes for the mini array SST-2M.

3. MEASUREMENT SYSTEM

A Xenon lamp is used as a radiation source; a wavelength selection system constituted by a set of band-pass filters and mirrors, and a Czerny-Turner monochromator are exploited to achieve the desired wavelength in the 130-1100nm spectral range, with a FWHM smaller than 1nm. A beam splitter is employed to direct the monochromatic radiation through an optical lens towards an integrating sphere, which hosts, in one port, a 1-cm^2 NIST-traced reference photodiode and, in a second port, the SiPM sensor to be characterized. The photon flux intensity coming into the integrating sphere can be regulated by means of neutral density filters or changing the aperture of the entrance or exit slits of the monochromator. Due to the small dimensions of the detectors to be characterized with respect to the optical beam, the integrating sphere is used to spatially integrate the radiant flux. Furthermore, appropriate mechanical structures are realized, in terms of both aperture and distance from the centre of the sphere, to illuminate the SiPM detector and the NIST-traced photodiode with the same radiant flux. The reference photodiode allows to evaluate the number of photons per unit area, and then, after a proper rescaling, the number of photons impinging on the detectors under test.

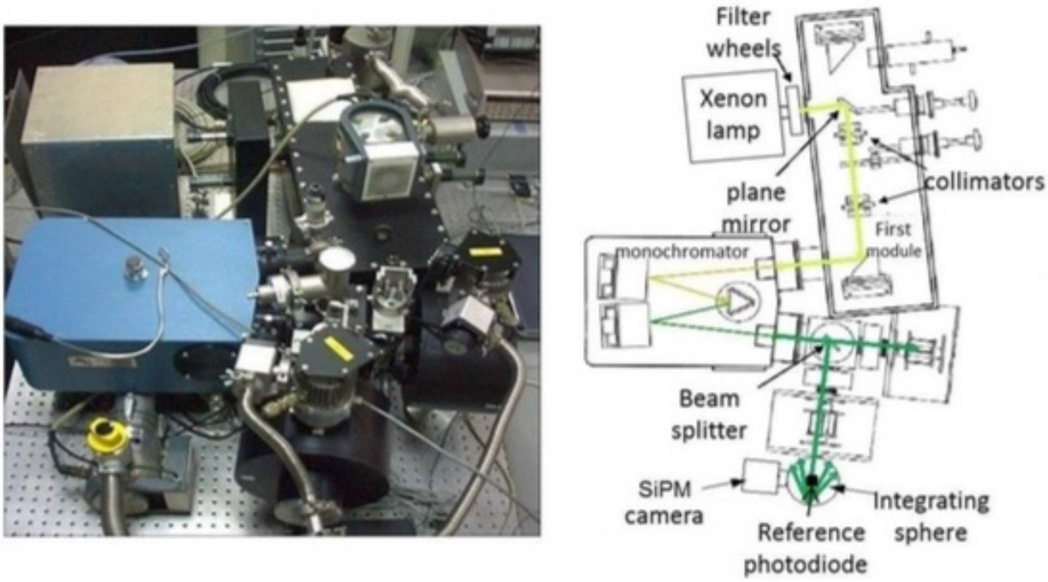

Figure 1. Simplified schematization of the COLD optical apparatus. On the left side: photograph of the characterization equipment. On the right side: scheme of the implemented mechanical and optical parts of the apparatus, where the green line indicates the light path.

The SiPM front-end electronics is the Integrated Read-Out Chip (CITIROC) produced by Omega. CITIROC is a 32-channel fully-analog front-end ASIC specifically designed to directly interface SiPM detectors. The Figure 2 shows a photograph of the CITIROC evaluation board with the black light-tight box that prevents accidental light exposure of the SiPM detectors and allows a thermic regulation by means of a cooling system adopting a Peltier thermoelectric cooler device.

Figure 2. Citiroc evaluation board and the black light-tight box with cooling system based on Peltier TEC.

To obtain a comparison between the measurements we used another front-end electronics. a power supply and amplification unit (PSAU), produced by CAEN Electronics, and a two-channel digitizer (Figure 3 and Figure 4). The PSAU is an electronic system embedding a power supply and a tunable amplification unit. It provides the cathode voltage for the SiPM detector in a range of 0–120 V with a 16 bit resolution, and features a variable amplification factor up to 50 dB. It integrates a feedback circuit to stabilize the operating voltage (and, in turn, the sensor gain) against thermal variations and a leading edge discriminator feeding an internal counter. In addition, the system can provide a digital output with a tunable width from 20 ns to 320 ns. All parameters can be programmed and monitored via a standard USB interface. An additional holder interface has been implemented for the SiPM electrical board to be connected to the PSAU, and a mechanical cooling adapter has also been realized, allowing to operate the SiPM from room temperatures down to 10°C.

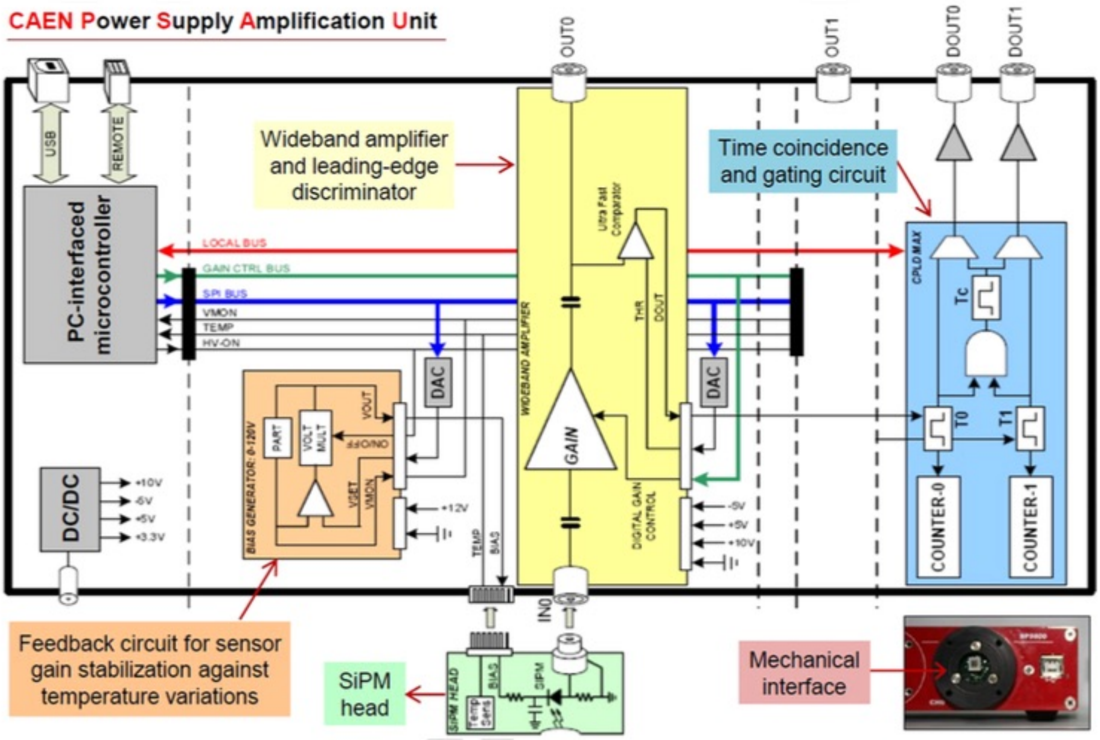

Figure 3. Simplified electric schematization of the power supply and amplification unit.

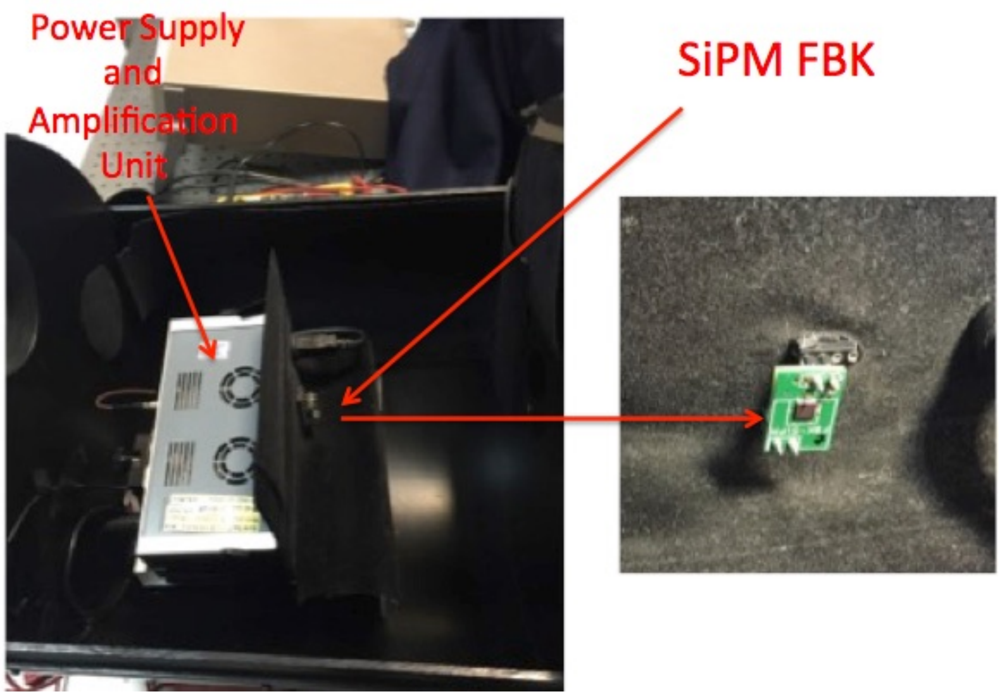

Figure 4. Connection with the CAEN PSAU amplifier

4. Electrical Characteristics and Physical from Data Sheet.

The characterized SiPM detector presented in this report is the latest device series manufactured by SensL. The following table reports the main physical features of the characterized detector.

Device Series	*NUV low AP*
serial number	CSP and n°7
cell pitch	40 µm
device size	3×3 mm^2
micro-pixels	5520
fill factor	-
Breakdown voltage	26V

5. Measurements Results

Staircase and Cross-Talk Measurements

Dark current and optical cross-talk are the main crucial parameters affecting the performance of SiPM detectors. The Dark Count Rate (DCR) is defined as the number of avalanche current pulses produced by thermally generated carriers simulating the detection of single photons at a certain bias voltage. Since the dark noise is comprised of a series of time pulses, its magnitude is often quoted as a pulse rate, typically expressed in kHz or MHz.

It is extremely important that the SiPM operating conditions are maintained stable versus the working temperature during the measurements. The dark signal is amplified and discriminated , generating a logic output pulse each time a dark pulse crosses a predefined voltage level, allowing to select the appropriate threshold.

Optical cross-talk occurs when optical photons that are emitted by accelerated charge carriers undergoing an avalanche propagate towards neighboring diode pixels where, depending on their energy and location, they have a certain probability to generate an additional Geiger avalanche discharge; as a consequence, since the original and neighbor avalanches may occur almost simultaneously (on the same scale of few nanoseconds), single absorbed photons may generate output signals equivalent to more than 1-pe (photoelectron) avalanche events. The experimental approach used for assessing the SiPM cross-talk probability relies on the analysis of DCR measurement results. The SiPM optical cross-talk is evaluated from the DCR data as the ratio between the first and the second event count rate.

In Figure 5 is shown the staircase at 20°C and at different overvoltage with the use of the system CAEN.

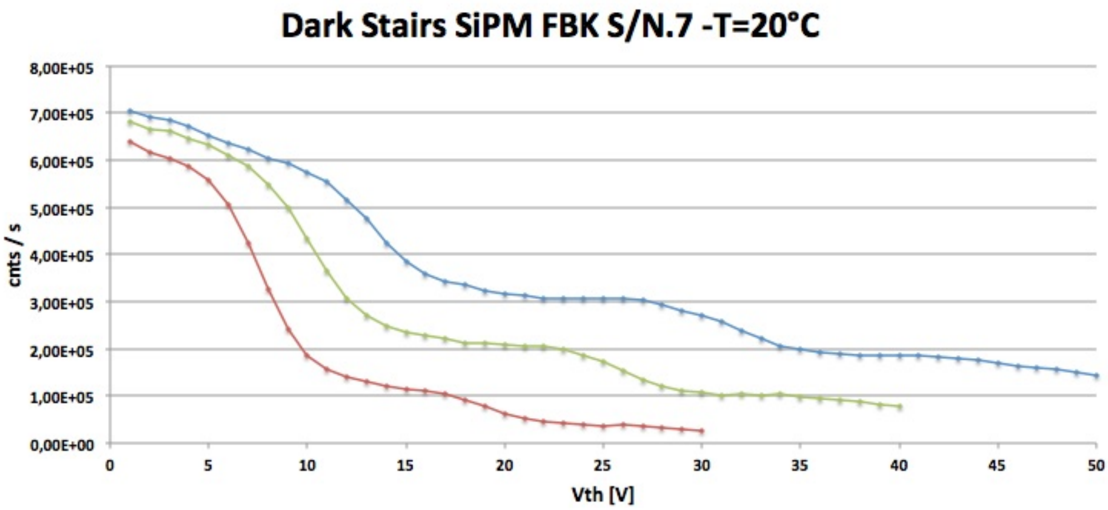

Figure 5. FBK NUV n°7 Staircase at 20°C and at different overvoltages with the use of the system CAEN

In Figure 6 is shown the connection between FBK device and the electronics CITIROC through the use of light-tight box.

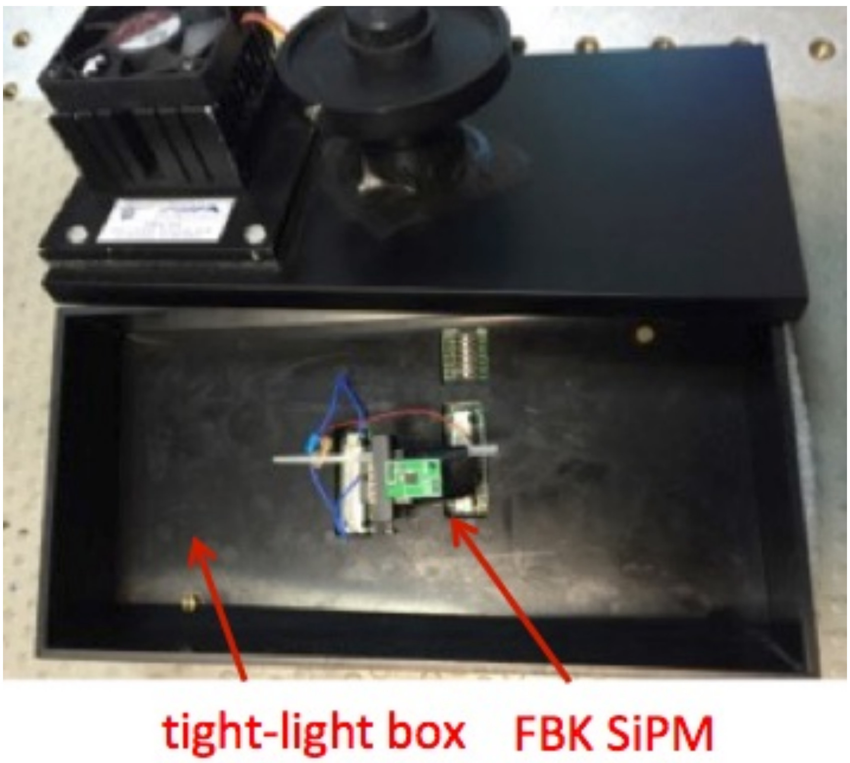

Figure 6. Connection with the CITIROC amplifier

In Figure 7 and Figure 8 are shown the staircase and cross-talk at 19.5°C and at different overvoltage with the use of the CITIROC.

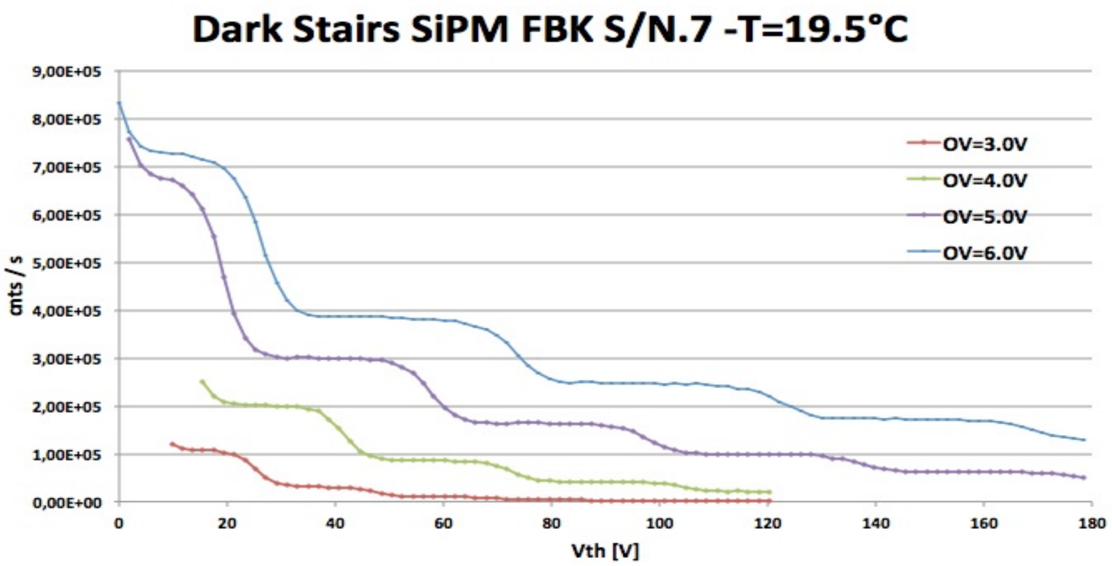

Figure 7. FBK NUV n°7 Staircase at 19.5°C and at different overvoltages with the use of the CITIROC.

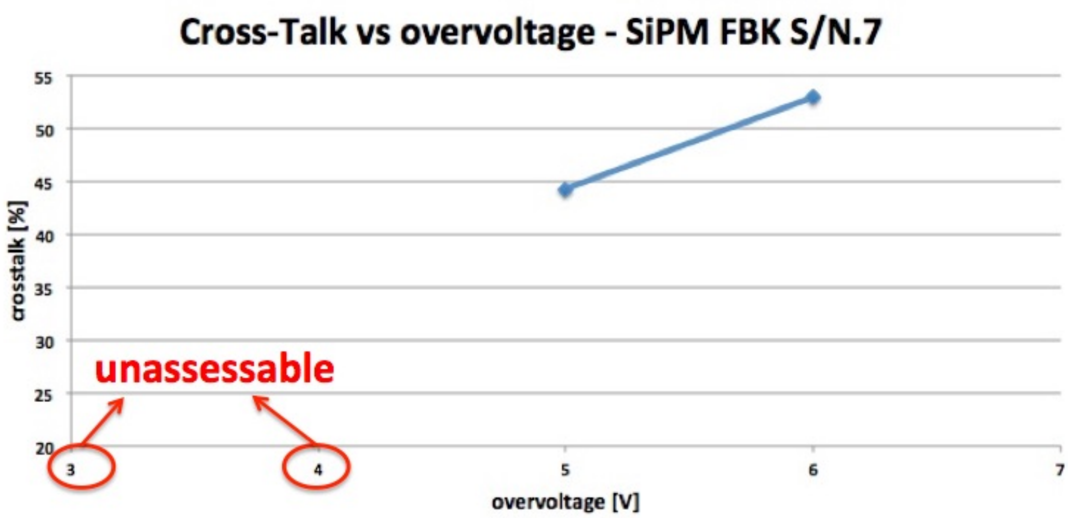

Figure 8. FBK NUV n°7 Cross-Talk at different overvoltages with the use of the CITIROC.

From Figure 7 It is clearly evident that for low values of overvoltage, the high noise does not allow a correct discrimination of the detector signal. In fact you can see from the staircase that the first plateaux is not visible.

Increasing the gain (from 5 volts up) the detector signal can be processed properly.

The same results were obtained on the device NUV CSP.

As shown in Figures 9 and 10.

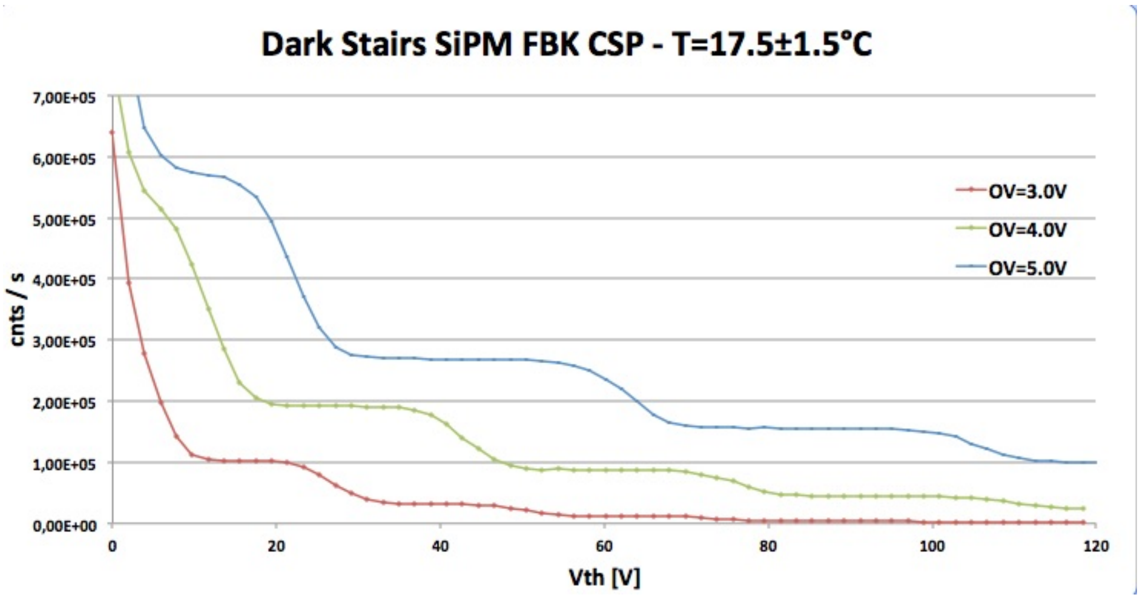

Figure 9. FBK NUV CSP Staircase at 17.5°C and at different overvoltages with the use of the CITIROC.

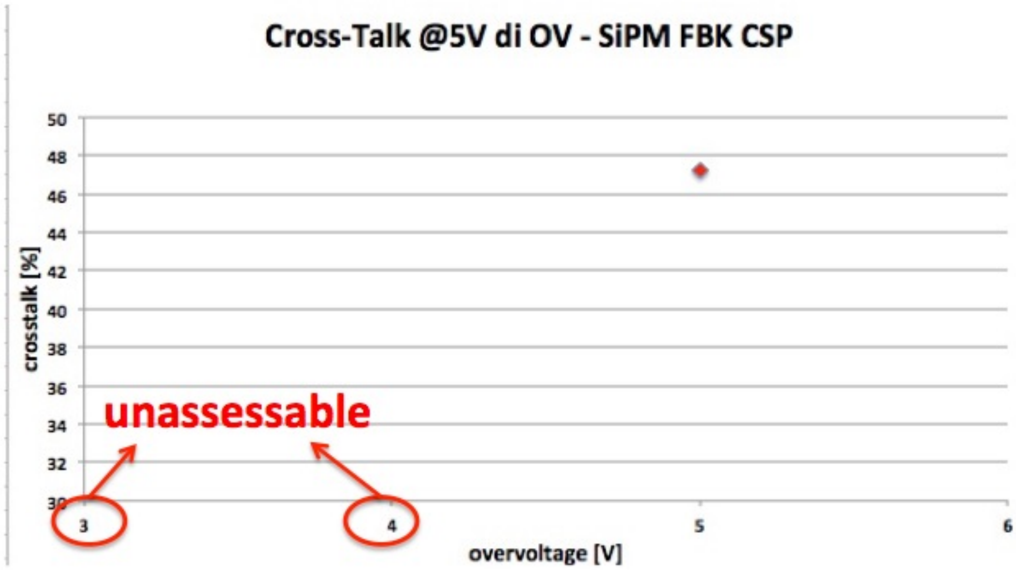

Figure 10. FBK NUV CSP Cross-Talk at different overvoltages with the use of the CITIROC.

All files related to the experimental measurements presented in this report, are located in the database on the PC-LAB (COLD) site Astrophysical Observatory of Catania, path C:\Users\CCDLab1\Desktop\Romeo\Misure

6. CONTACTS

The team working on the electronic design of the ASTRI camera is composed by people from INAF's Catania Astrophysical Observatory and Palermo IFC. It is also referred to as the Electronics Camera Team.

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