Wide dynamic range UV photon counting detectors based on MCPs readout with custom-developed ASIC

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We present the development of a novel UV, solar blind, photon counting detector with unprecedented dynamic range, for astronomical applications in the FUV/EUV range (55-200 nm). The detector is based on MCPs read out with a 2D anode array integrated in a custom designed Read Out Integrated Circuit (MIRA - Microchannel plate Readout ASIC), able to detect and count photon events on-chip up to very high flux (up to 100Kcounts/s·pixel), with spatial resolution close to 30 μm and working. The low noise of the electronics allows working at low MCP gains, enabling an increase in the average lifetime and maximum flux limit of the detector.

This work started in the framework of the PLUS project [1], supported by the Italian Space Agency under the contract ASI-INAF 2018-16-HH.O, "Attività di studio per la comunità scientifica per Sistema Solare ed Eso-Pianeti", aimed at developing high-performance extreme and far ultraviolet spectrographs, and it is currently on-going, in collaboration with Politecnico di Milano, CNR-IFN Padova, Università di Padova.

1. INTRODUCTION

Microchannel plate (MCP) based detectors have long been the preferred choice for astronomical applications in the FUV/EUV range, owing to their:

- ✓ Photon counting capability
- ✓ High spatial resolution
- ✓ Potential for solar blindness

However, these detectors also have well-known limitations:

- × Restricted dynamic range
- × Limited lifetime

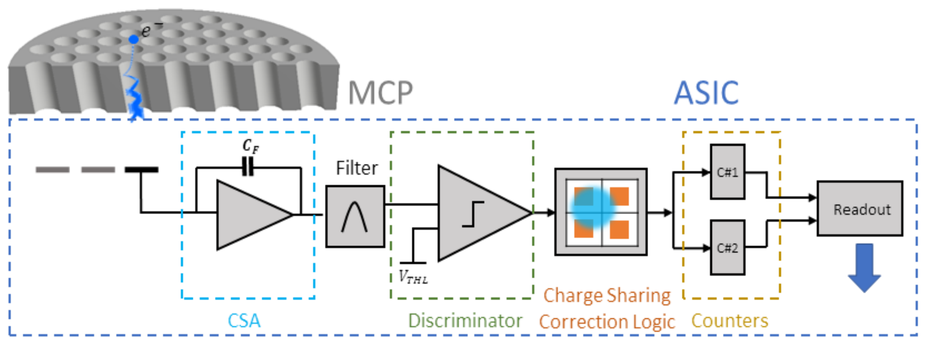

Fig.1 Schematic representation of the PLUS MCP detector with MIRA ASIC readout

Both parameters can be enhanced by operating MCPs at low gains. By combining novel production techniques with borosilicate glasses and Atomic Layer Deposition (ALD) [2], significant improvements (2-3 orders of magnitude [3]) have been achieved in the maximum extractable charge. This has led to clear performance enhancements in terms of dynamic range and operational lifespan.To fully exploit the potential of these new MCPs, developing a new readout system capable of operating at low gains and high count rates is crucial. We have therefore developed a custom ASIC readout system: MIRA - Microchannel plate Readout ASIC (Fig.1). A demonstrator with a 32x32 pixel array, 35×35 μm² (Fig.2), has been realized, tested, and integrated into a standard demountable MCP [4,5].

A new MIRA version is under design, with improved performance in terms of power consumption and with a scalable architecture, as an intermediate step to realize larger arrays.

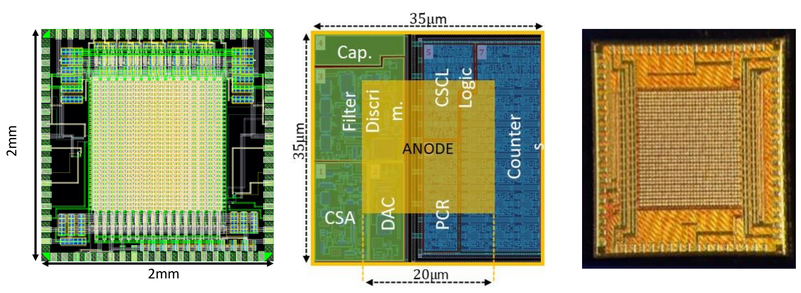

Fig. 2 Architecture of the MIRA device (left), pixel structure (center) and microscope picture of the 32x32 pixels MIRA first release (right)

MIRA prototype
- 32 x 32 pixels
- High spatial resolution → 35μm x 35 μm pixel
- Low noise → ENC = 27 e^-
- High count rate capabilities → 36 kcps/pixel
- Zero dead time

2. MIRA

The MIRA pixel readout chain is composed of the collecting anode, the low-noise charge sensitive amplifier (CSA) with a selectable analog processing time, a filtering stage, a discriminator with a 5-bit selectable threshold, a charge-sharing compensation logic (CSCL) granting a pixel-limited spatial resolution. Finally, two 17-bit counters alternating in parallel and, thus, granting zero dead time in the serial digital readout. The frame rate of the demonstrator is 0.3 Hz and the maximum count rate per pixel is 30 kcps.

The Charge Sharing Correction Logic (CSCL) assigns the count to the pixel with the highest amount of collected charge by comparing the discriminator outputs of different pixels. MIRA features three modalities of operation:

- ➢ Mode 1, the charge sharing correction logic is disabled
- ➢ Mode 2, the charge sharing correction logic performs horizontal and vertical comparisons among adjacent pixels to find the pixel with the highest charge
- ➢ Mode 3, a two-step algorithm is enabled: the cluster with the highest amount of charge is selected and the pixel, inside the cluster, with the highest amount of charge is identified

The first version, 32 x 32 pixels, of MIRA (MIcrochannel plate Readout Asic) ASIC, has been realized (Fig. 2) using a scaled 65nm CMOS technology in order to achieve the compact pixel size requirement with a 32% Fill Factor [6]. The device has been tested before integration [7]

3. DETECTOR PROTOTYPE

MIRA was integrated with a Chevron stack of Microchannel plate, to validate the readout system [4].

The assembly of the detector prototype is shown in Fig.3, with the mechanical housing integral with the feedthrough connectors flange. The carrier board is allocated on a macor support.

The detector electronics consists of three boards to be hosted in vacuum, close to the MCP, and an external board which generate all the required supplies and signals to operate MIRA and readout their output signals.

The boards placed in vacuum include:

- ➢ the MIRA carrier board
- ➢ the Digital Board, which provides digital supplies and digital control signals to the MIRA ASIC
- ➢ the Analog Board , which provides analog supplies and references, and test stages are also present to be able to monitor the correct functioning of MIRA.

Fig.4 shows the integrated assembly.

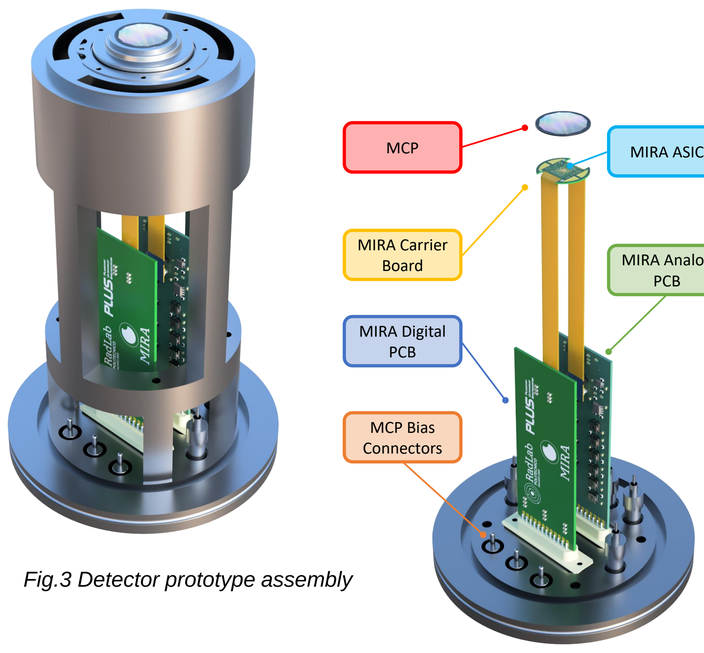

Fig.3 Detector prototype assembly

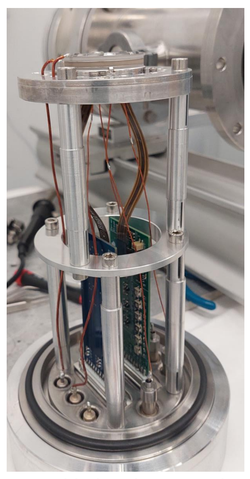

Fig.4 Prototype assembled and mounted on the vacuum chamber

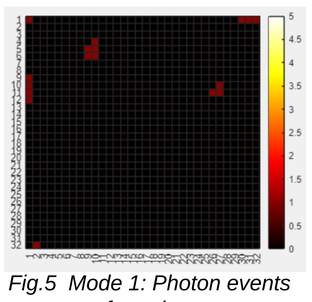

Fig.5 Mode 1: Photon events footprints

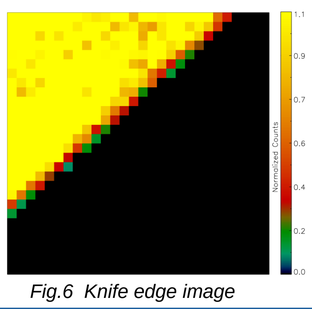

Fig.6 Knife edge image

3. TEST RESULTS

The prototype has been tested in a vacuum chamber, with a pressure of 1.e^-[6] mbar (Fig.4). The assembly was illuminated with a LED with emission peak at 245nm, exploiting the residual efficiency of the bare MCP at these wavelengths.

The photon event footprints (Fig.5) have been characterized using MIRA readout mode 1 (in this mode all the pixel over threshold are counted) and lowering the input photon flux in order to have photon footprints without overlapping.

To evaluate the spatial response, a knife-edge target was positioned close to the input surface of the MCP and the LED was placed in the focus of a convex lens in order to produce an incoming plane wavefront (Fig.6).

References

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