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HIGH-RESOLUTION DETECTORS FOR IMAGING AND SPECTROSCOPY AT ULTRAVIOLET AND SOFT X-RAY WAVELENGTHS

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Abstract.- The Multi-Anode Microchannel Arrays (MAMAs) are a family of pulse-counting imaging array detectors designed specifically for astrophysical investigations in space. The MAMAs have a number of unique performance characteristics which make them particularly suitable for imaging and spectroscopy at ultraviolet and soft x-ray wavelengths. First, they employ "solar blind" photocathodes eliminating the "red leak" problem associated with solid state arrays such as the CCDs. Second, they operate with zero readout noise, yielding photon-statistics limited signals. Third, they utilize a random readout technique and can determine both the location of a detected photon and also its arrival time to an accuracy of the order of 100 ns. This paper will give an overview of the construction, mode-of-operation and performance characteristics of the MAMA detectors and will describe the current status of the development program.

MAMA Detector Systems.

The Multi-Anode Microchannel Array (MAMA) detector tube employs proximity-focused electron optics in order to obtain the best possible spatial resolution and geometric fidelity and stability [1]. The structure of an imaging MAMA detector tube is shown in the schematic in Figure 1. An appropriate photocathode material is deposited on, or mounted in proximity focus with, the front face of a high-gain curved-channel microchannel plate (MCP). At near ultraviolet wavelengths a semi-transparent Cs₂Te photocathode is deposited on a window, as shown in Figure 2a. The photocathode is protected from damage, caused by the impact of positive ions produced within the channels of the MCP, by a thin SiO₂ or Al₂O₃ membrane on the front face of the MCP. At extreme ultraviolet (EUV) and soft x-ray wavelengths, when the detector is operated in a windowless configuration, an opaque photocathode such as CsI is deposited directly on the front face of the MCP, as shown in Figure 2b. The focus electrode is used to ensure that photoelectrons produced on the web area between the channels are directed into the channels and are detected.

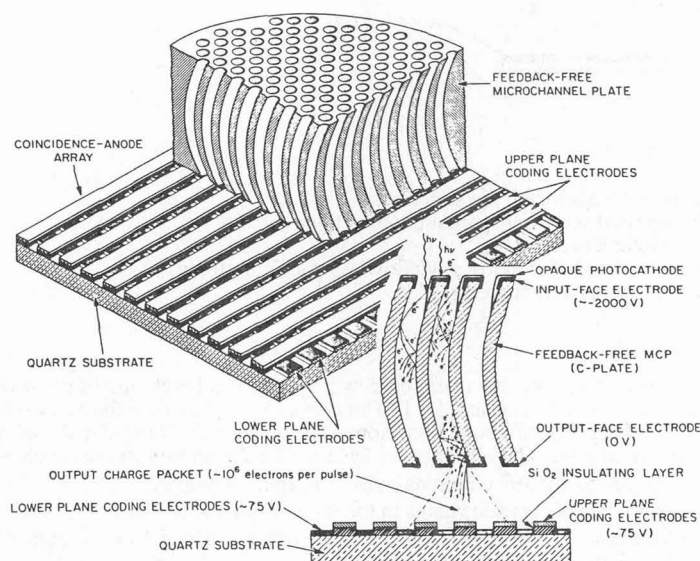


Figure 1. Schematic of imaging MAMA detector tube.

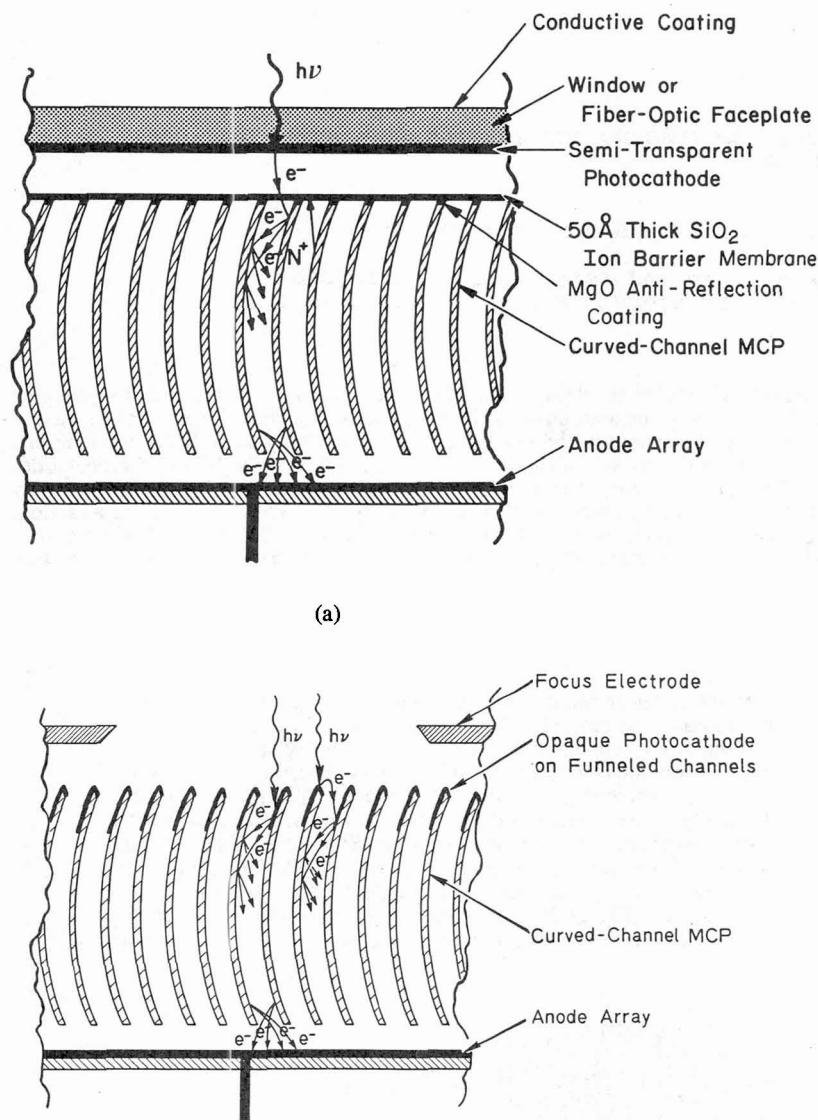


Figure 2. MAMA detector tube photocathode structures.

- a. Proximity-focused semi-transparent photocathode for use at ultraviolet wavelengths.
- b. Opaque photocathode for use in a windowless configuration at EUV and soft x-ray wavelengths.

The curved-channel MCP produces a high-gain and a very narrow output pulse-height distribution which is ideal for a high-resolution electronic imaging system [2]. The curve in the channel effectively inhibits the feedback of positive ions, preventing the initiation of spurious after pulses. The curved-channel MCP accordingly has a very low dark count rate. Curved-channel MCPs with 25-micron-diameter channels produce gains in the range from 1×10^6 to 3×10^6 electrons pulse⁻¹ at applied potentials of 2.0 to 2.5 kV, and MCPs with 12-micron-diameter channels produce gains in the range from 5×10^5 to 1×10^6 electrons pulse⁻¹ with the same applied potentials. Typical dark count rates are of the order of 1 to 5 counts s⁻¹ for a properly conditioned MCP with a 25-mm-diameter active area.

Because of the high gain and the narrow output pulse-height distribution, the curved-channel MCP displays excellent photometric stability when used in the pulse-counting mode.

The MAMA readout system employs a multi-layer array of precision metallic electrodes mounted in proximity focus with the output face of the MCP. The electrodes are arranged in a $2\sqrt{N}$ encoding scheme to provide the very large numbers of pixels required for imaging or high-resolution spectroscopy, without requiring a prohibitively large number of amplifier and discriminator circuits. Thus a (1×1024) -pixel linear array only requires 64 amplifier and discriminator circuits, and a (1024×1024) -pixel imaging array only requires 128 amplifier and discriminator circuits. Details of the encoding electrode structures and the decoding algorithms used in the digital electronics can be found elsewhere in the literature [3][4].

MAMA detector systems with formats of 256×1024 pixels and pixel dimensions of 25×25 microns² are currently being optimized in the laboratory, and are being operated at visible, ultraviolet and soft x-ray wavelengths. A prototype EUV MAMA detector system has been flown successfully on sounding rockets [Snow *et al.*, to be published in *Astrophysical Journal*, February 1988], and a sealed ultraviolet MAMA detector has been qualified for flight on high-altitude balloons. The MAMA detector systems with second-generation electronic circuits have pulse-pair resolutions of 100 ns and can operate at total array count rates of 10^6 counts s^{-1} (random) with a 10% loss of detective quantum efficiency (DQE) caused by coincident pulses. The present generation of curved-channel MCPs can deliver count rates in excess of 10^5 counts $s^{-1}mm^{-2}$ (random) with a 10% loss of DQE caused by the reduction of gain at high count rates. In addition, laboratory tests have shown that, with a moderate signal-to-noise ratio, the MAMAs can determine the centroid of a spatial or spectral feature to an accuracy of better than 1 micron [1]. Because the MAMAs employ a random readout system, they can determine the arrival time of a detected photon to an accuracy of the order of 100 ns. A time-tag module with a temporal resolution of 10 μs has been constructed and is currently being used for speckle imaging and astrometric measurements [5]. Very-large-format (1024×1024) - and (2048×2048) -pixel MAMA detectors, with pixel dimensions of 25×25 microns², are currently under development for use on the NASA Goddard Space Flight Center's *Hubble* Space Telescope Imaging Spectrograph (STIS) [6]. This is a second-generation instrument scheduled to be installed in orbit by astronauts in 1994. In order to provide redundancy for a multi-year space mission and to increase the dynamic range, the (2048×2048) -pixel detector is constructed from four independent (1024×1024) -pixels arrays separated by a single-pixel dead space, as shown in Figure 3.

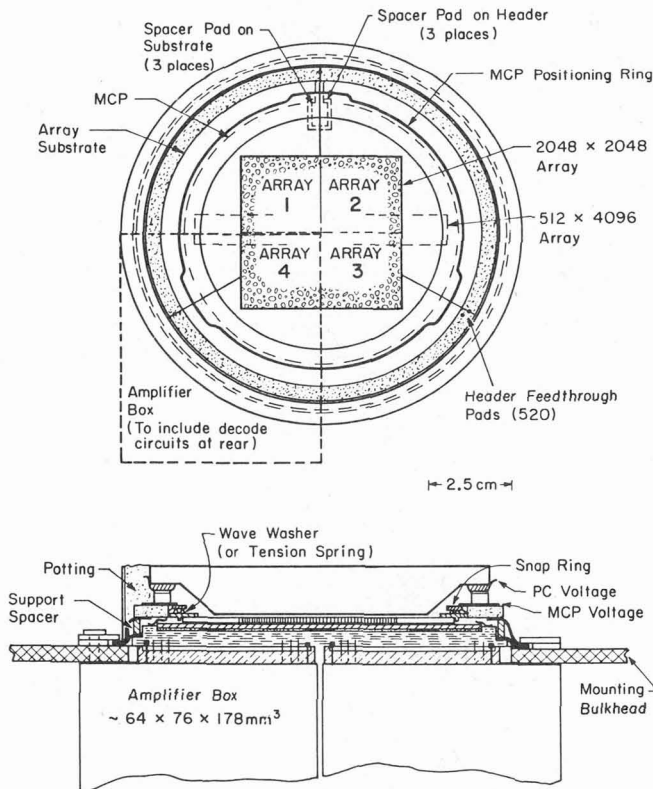


Figure 3. Configuration of the (2048×2048) -pixel MAMA detector for the *Hubble* Space Telescope Imaging Spectrograph (STIS)

The first (1024 x 1024)-pixel detector system will be in operation in January 1988, and the first (2048 x 2048)-pixel detector system is scheduled to be in operation in the first quarter of 1989. MAMA detectors with pixel dimensions of 15 x 15 microns² will also be fabricated early in 1988 for potential use on the ESA/NASA *Lyman* far ultraviolet spectroscopic Explorer mission and on the ESA/NASA Solar and Heliospheric Observatory (SOHO) mission. These MAMA detectors will employ MCPs with either 8- or 6-micron channel diameters.

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