THE DEVELOPMENT AND TEST OF MULTI-ANODE MICROCHANNEL ARRAY DETECTOR SYSTEMS

II. SOFT X-RAY DETECTORS

Final report for NASA grant NAG5-211

For the Period through 30 November 1983

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I. INTRODUCTION

The objectives of the development program supported by this grant are, first, to define the techniques and procedures for producing very-large-format pulse-counting array detector systems for use in forthcoming high-energy astrophysics facilities and, second to determine the structures and performance characteristics of high-sensitivity photocathodes for use at soft x-ray wavelengths between 100 and 1 A. This final report describes the progress made to date in each of these areas and summarizes the tasks that will be undertaken when the program is continued at Stanford University.

II. CURVED-CHANNEL MICROCHANNEL PLATES

The key component of the Multi-anode Microchannel Array (MAMA) detector system is the high-gain curved-channel Microchannel Plate (MCP). Accordingly during the first period of this grant, a significant amount of effort was expended at Galileo Electro-Optics Corp. in developing the engineering procedures required for the fabrication of curved-channel MCPs with active areas 75 mm in diameter and larger. On the basis of the results of the initial fabrications of the first-generation curved-channel MCPs with active areas 27 mm in diameter, there was considerable concern that there would be a problem in maintaining the uniformity of curvature of the channels across the active area of a large diameter MCP. During the period of this grant these efforts have paid off and the first units of the curved-channel MCPs have been fabricated with active areas 40 mm in diameter as shown in Fig. 1. The initial test data for these MCPs indicate that the curvature of the channels across the active area is extremely uniform.

A second area of concern is the flatness of the MCP since the distance between the output face of the MCP and the multi-anode array must be less than 50 microns if a spatial resolution of 25 microns or better is to be obtained.

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The output faces of the first two 40 mm MCPs are flat to better than 15 microns meeting this requirement.

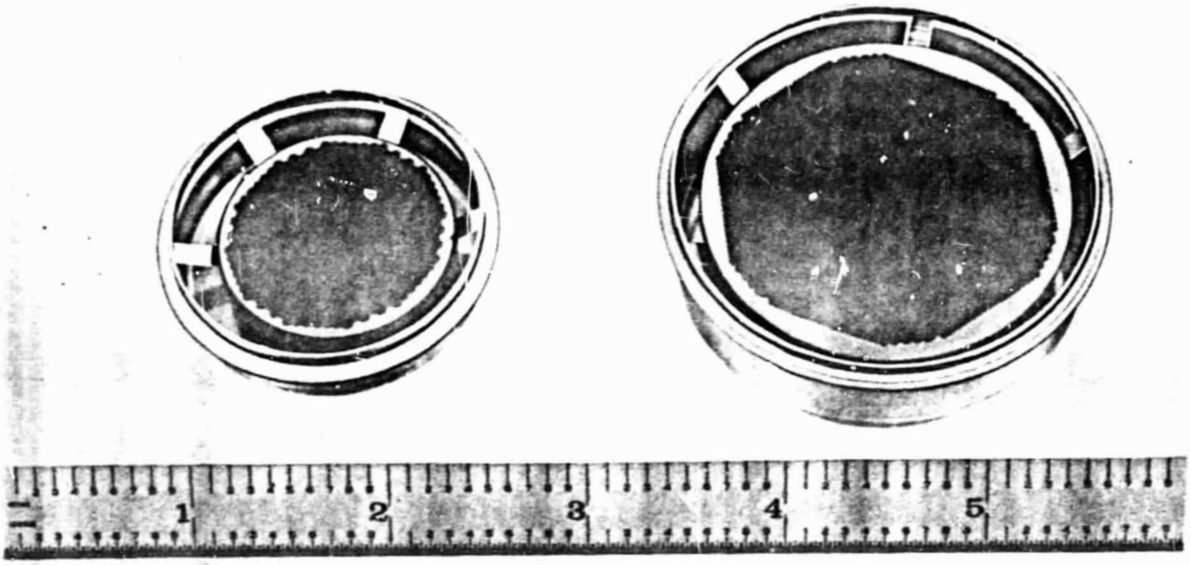

Figure 1. 27 mm and 40 mm curved-channel MCPs.

The internal surface area of a curved-channel MCP is extremely large, of the order of 1400 cm^2 for a 27-mm diameter MCP with 12-micron-diameter channels. In order to facilitate the outgassing of the channels prior to operation of the MCP and to reduce the overall dark count rate it is highly desirable to reduce the active area of the channels to match that of the readout array. Under a separate grant from the NASA Astrophysics office we have procured 27-mm-diameter curved-channel MCPs with rectangular active areas of 7 x 27 mm^2 to match the (256 x 1024)-pixel MAMA anode array (see Fig. 2). As the next step in this fabrication program we have just received the first 40-mm curved-channel MCP with a square active area of 27 x 27 mm^2. This format will be used for the (1024 x 1024)-pixel x-ray detector to be fabricated during the next phase of this development program.

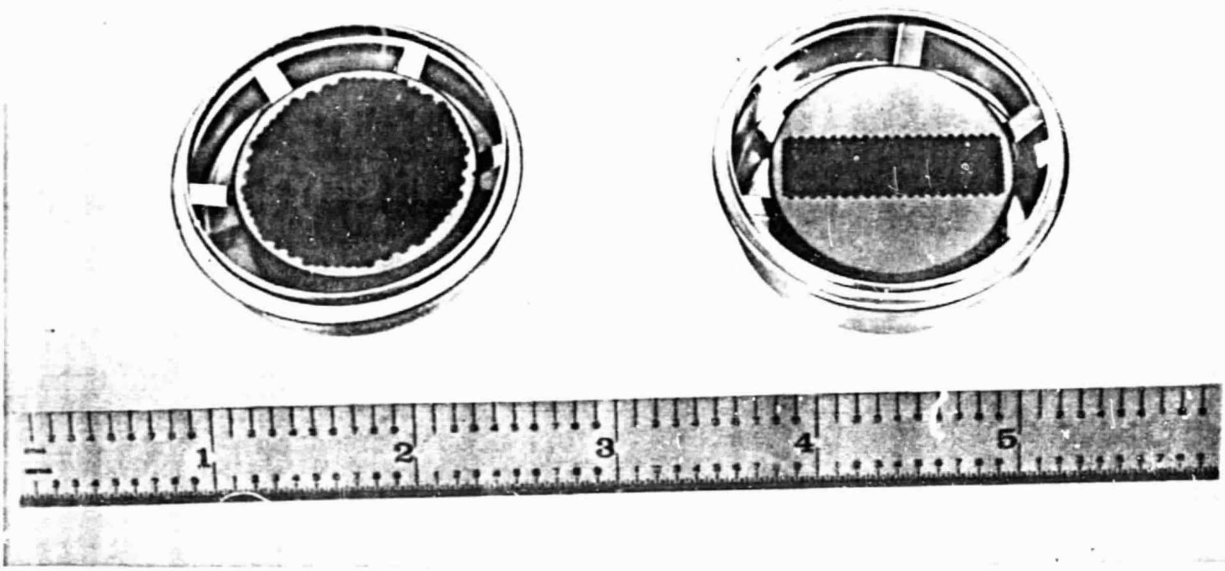

Figure 2. 27-mm-diameter curved-channel MCPs with circular and rectangular active areas.

In order to facilitate the fabrication of high-gain MCPs with very large active areas it is important to increase the length-to-diameter ratios of the channels above the current value of 100:1. Several units of the recently delivered MCPs have channel length-to-diameter ratios of 140:1 and the fabrication of an MCP with channel length-to diameter ratios of 200:1 has just been completed succesfully. These thicker MCPs will be significantly more rugged and mechanically stable. In addition it will be possible to fabricate a curved-channel MCP with a curved input surface to match the focal surface of a Wolter grazing-incidence telescope system and a planar output surface which can be mounted in proximity focus with a high-resolution multi-anode readout array. A

27-mm-diameter curved-channel MCP with the input face ground to a radius-of-curvature of 0.25 m has just been delivered and will be tested during the next phase of this program. An alternative technique for curving the MCP, namely "slumping" the MCP, will be investigated at a future date.

As the result of these development efforts we now have the high gain MCPs required for high-resolution x-ray detectors with formats of (1024 x 1024) pixels. Further, the fabrication procedures developed at Galileo Electro-Optics will permit the fabrication of curved-channel MCPs with diameters of 75 mm and larger. These large diameter MCPs will enable us to fabricate the very-large-format (4096 x 4096 pixels and larger) high-resolution detectors required for the high energy astrophysics missions of the next decade.

III. HIGH-SENSITIVITY X-RAY PHOTOCATHODES

We have determined from earlier tests that CsI has potentially very high quantum efficiencies at Extreme Ultraviolet (EUV) and soft x-ray wavelengths. It is also clear from preliminary data obtained by other investigators that the high quantum efficiencies extend to x-ray wavelengths as short as 1 A. However, it is also clear that a severe degradation of the quantum efficiency will result if the cathode is exposed to the ambient atmosphere. Accordingly, in order to process and evaluate CsI photocathodes under high vacuum, we have assembled a discrete-anode MAMA detector tube with a high-vacuum gate valve and a MgF_2 window as shown in Fig. 3.

Two different types of CsI photocathodes need to be studied namely, opaque CsI deposited directly on the front face of the MCP and illuminated at grazing incidence, and low-density "fluffy" CsI mounted in proximity focus with the front face of the MCP.The first evaluations will be of opaque CsI photocathodes. With the gate valve open and the tube sealed by the MgF_2 window assembly , it will be possible to process the CsI photocathode using established visual and photoelectric monitoring procedures to determine the optimum thickness for a high quantum yield at EUV and soft x-ray wavelengths.

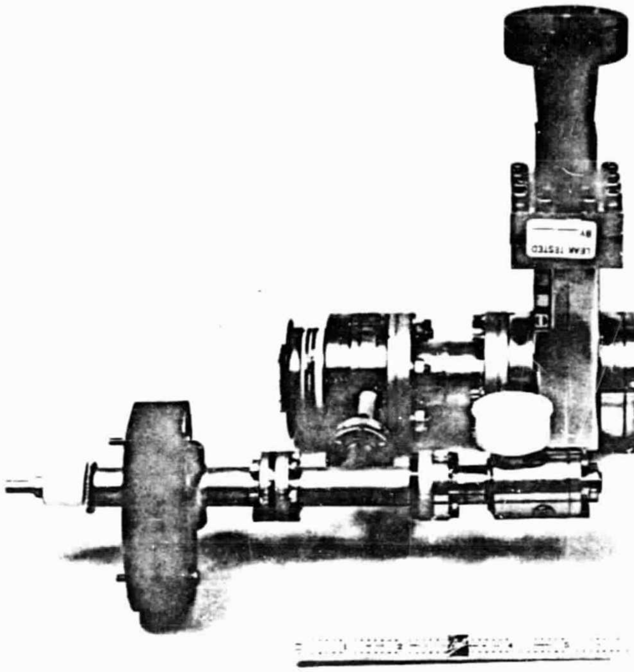

Figure 3. Demountable MAMA detector tube with a high-vacuum gate-valve assembly.

The quantum efficiency of the photocathode will be measured through the MgF_2 window down to wavelengths as short as 1160 A. The gate valve will then be closed, the MgF_2 window removed, and the detector tube attached to a high-vacuum x-ray calibration facility for quantum efficiency measurements in the open-structure mode at wavelengths down to 1 A.

Progress with this aspect of the development program has been much slower than expected because of the inordinate delay in the delvery of the high-vacuum gate-valve. However the assembly of the gate-valve tube was finally completed late last summer. Prior to assembly, the curved-channel MCP was baked out at a temperature in excess of 350°C and "burned-in" with ultraviolet light until gain stability was achieved. The accumulated signal required to fully clean up the MCP was in excess of 4×10^{10} counts mm^{-2} with a total charge throughput of the order of 0.5 C cm^{-2}. These count levels are a factor of 100 higher than the maximum count rate capabilities reported for the high gain MCPs used in the Einstein High-Resolution Imager (HRI). The fact that signal levels of this magnitude are required to clean up a curved-channel MCP and reach a plateau of gain stability should dispel any concerns regarding the lifetimes of the current generation of high gain MCPs.

During bakeout and "burn-in", residual gas analyses were recorded to provide quantitative measurements of the constituent gases present inside the vacuum system. As a further test, prior to assembly of the gate-valve detector tube, the MCP was briefly exposed to dry nitrogen at atmospheric pressure and then re-evacuated for further operation without an additional bakeout. This was carried out in order to determine the effects of exposure to ambient atmosphere as might happen, for example, in an open-structure flight detector system during environmental testing and spacecraft integration. It was found that the nominal gain value was obtained at an applied potential about 50 V lower than that required prior to exposure to dry nitrogen, i.e. a slight gain recovery was observed. This behavior is identical to that observed with open-structure channel electron multipliers used in earlier space missions. Subsequent operation has eliminated this slight gain recovery and the MCP has returned to a stable operating plateau. However, it does appear desirable for maximum photometric stability to maintain the MCP in a high vacuum environment at all times prior to operation in orbit. This fact, together with the need to protect the CsI photocathode, underlines the need for a high-vacuum gate-valve assembly as an essential part of a high-sensitivity x-ray detector. At this time, we are completing the final characterisation of the MCP in preparation for CsI photocathode deposition.

IV. SUMMARY OF FUTURE PROGRAM TASKS

Following the transfer of the program to Stanford University the following tasks will be undertaken:

1) Determine in detail the performance characteristics of the 40-mm-diameter curved-channel MCPs.

2) Determine the performance characteristics of the 27-mm-diameter curved-channel MCP with the curved input face.

3) Complete the initial program of measurements of the quantum efficiencies of opaque CsI photocathodes at soft x-ray wavelengths down to 1 A.

4) Attempt a quantitative comparative evaluation between an opaque and a "fluffy" CsI photocathode.

5) Define the procedures required for the fabrication of 75-mm-diameter curved-channel MCPs.

6) Determine the performance characteristics of a high-resolution (1024 x 1024)-pixel detector at x-ray wavelengths.

V. REFERENCE

"Multi-Anode Microchannel Arrays: New detectors for imaging and spectroscopy in space" by J. G. Timothy and R. L. Bybee (attached).