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# The off-axis channel macroplate

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## Abstract

High-gain microchannel plates (MCPs) which utilize curvature of the channel to inhibit ion feedback (C-plate MCPs) have demonstrated excellent performance characteristics. However, C-plate MCPs are at present costly to fabricate, and the shearing process used to curve the channels produces a low device yield. We describe here a totally new type of high-gain MCP structure in which each channel has an axially symmetric curvature. Initial tests of proof-of-concept units of these MCPs with 75-micron-diameter channels (macroplates) suggest that their performance characteristics have the potential to be equal to those of a C-plate MCP while the fabrication process is no more complex than that of a conventional straight-channel MCP.

## Introduction

High-gain Microchannel Plates (MCPs) used to date have the configurations shown in Figure 1. "Chevron" and "Z-plate" MCP stacks, which are constructed from 2 or 3 MCPs having straight channels, are relatively easy to fabricate but do not have optimum performance characteristics. Even with bias angles of the order of 10 to 15 degrees, the trapping of positive ions at the interfaces of the plates is not completely effective, and there is a high level of residual ion feedback. In addition, spreading of charge at the interfaces degrades the spatial resolution of these MCP stacks when used with high-spatial-resolution readout systems. There is a further degradation of performance for high-resolution imaging systems caused by the broad pulse-height distributions of these MCPs at gain levels of the order of $10^6$ to $10^7$ electrons pulse$^{-1}$. The C-plate MCP, (Figure 1c), which employs curved channels to inhibit ion feedback in an identical manner to that used in a conventional channel electron multiplier (CEM), provides a high level of suppression of ion-feedback, a narrow output pulse-height distribution, and a very high spatial resolution. In particular, stable operation at gains in excess of $10^6$ electrons pulse $^{-1}$, a resolution of the output pulse-height distribution of 30% or better, and a count rate capability in excess of $10^5$ counts mm$^{-2}$ s$^{-1}$ have been realized with a single MCP with 12-micron-diameter channels on 15-micron centers.[1] Unfortunately, the shearing process required to introduce curvature into the channel is at this time difficult to control, the C-plates are at present costly to fabricate, and there is a low device yield.

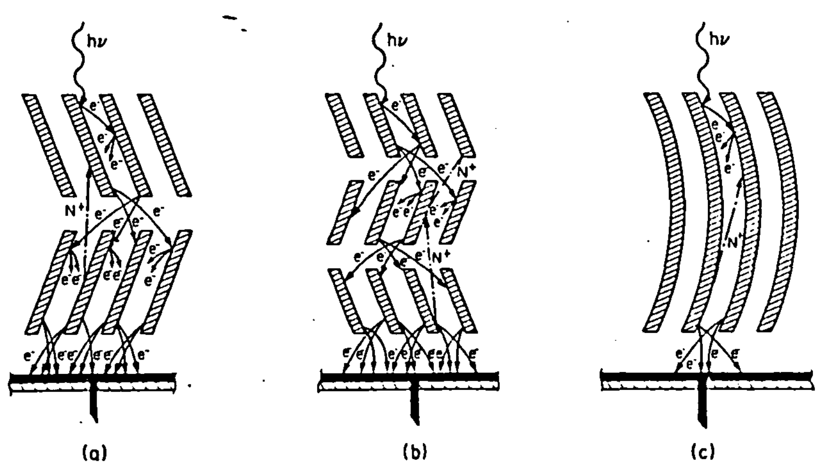


Figure 1. Configurations of high-gain MCPs.
a. "Chevron" MCP. b. "Z-plate" MCP. c. "C-plate" MCP.

In this paper we describe the performance characteristics of proof-of-concept units of an MCP structure which employs an axially symmetric twist of the channel to produce the curvature required to effectively inhibit ion feedback. Since the curvature is built into the channel at the time of the fiber draw, the "off-axis channel" MCP (patent pending) is as simple to fabricate as a conventional straight-channel MCP, yet has the potential to provide the superior performance characteristics of the sheared curved-channel MCP.

## The "off-axis channel" macroplate

The configuration of the "off-axis channel" electron multiplier is shown in Figure 2. One or more channels are fabricated off-center within a larger glass fiber. Twisting the fiber produces a helical channel with the appropriate geometrical form to inhibit the trajectories of positive ions.

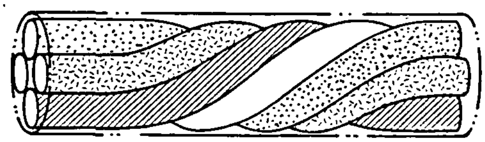

Figure 2. Configuration of the "off-axis channel" electron multiplier.

In order to produce a high-gain MCP with channels of this configuration, a number of requirements must be met. First, there must be about three or four channels per fiber in order to produce an open-area ratio equivalent to that of a conventional MCP. Second, for imaging applications, there must be an integral number of twists across the thickness of the plate in order to preserve the spatial relationship of the channel inputs and outputs. Third, in order to get at least one complete twist in a channel with a final diameter in the range from 10 to 25 microns, there must be a very high twist density in the original fiber.

As the first step in evaluating the "off-axis channel" concept, we have fabricated a number of 18-mm-format macroplates with active areas 15 mm in diameter and channel diameters of 75 microns. For ease of fabrication these proof-of-concept units employ only one channel per fiber, yielding a low open-area ratio of about 15%. Fibers of the type used to fabricate the macroplates are shown in Figure 3. Two macroplates have so far been tested, the first with a channel length-to-diameter ratio of 60:1, and the second with a channel length-to diameter ratio of 80:1.

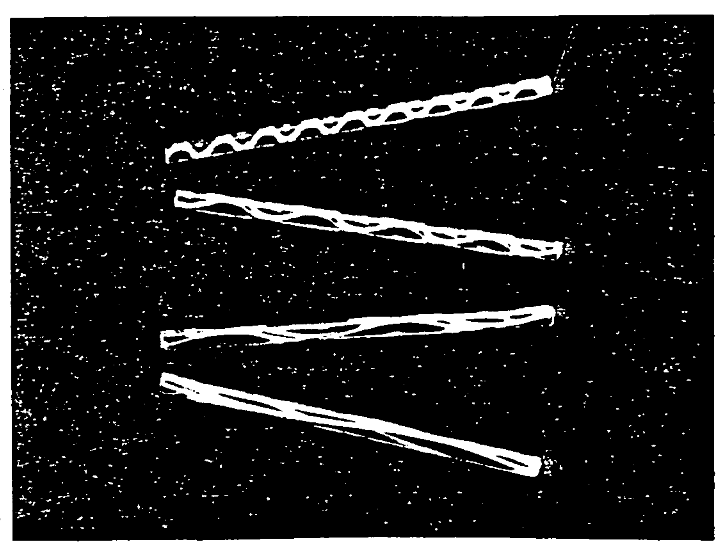

Figure 3. "Off-axis channel" fibers with different twist densities.

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## Performance Characteristics

Before evaluation both macroplates were subjected to bake and "scrub" procedures similar to those that we have developed for the C-plate MCPs.[1] However, because these macroplates employ channels of a totally new type, the evaluation program is being carried out in stages. For the initial tests, the first macroplate was baked in a hydrocarbon-free high-vacuum environment at a temperature of 120°C for a period of 24 hours and the second at 110°C for a period of 5 hours. Ultimately, the macroplates will be baked at 300° C until a pressure asymptote is attained. Each plate was "scrubbed" by operating it in a demountable MAMA detector tube[1] with the input face illuminated with ultraviolet photons from a mercury "penray" lamp. A total signal of 4 x $10^{10}$ counts, equivalent to a charge throughput of 0.01 C was accumulated before the initial evaluation. The resistances of the two macroplates were 25 MΩ and 31 MΩ respectively. In operation at an applied potential of 2400 V the strip current increased by about 12%, indicating that the temperature of the plate had increased by about 25 degrees C because of ohmic heating. However, no operating instabilities were observed.

The performance characteristics of both macroplates were very similar, with the exception that the resolution of the output pulse-height distribution (defined as $R = \Delta G/\bar{G}$ where $\Delta G$ = full width at half-height of the distribution and $\bar{G}$ = gain value at the peak of the saturated distribution) was somewhat superior for the plate with a channel length-to-diameter ratio of 80:1. Both macroplates demonstrated gain saturation at applied potentials in excess of 2000 V. The variations of the modal gain and the resolution of the output pulse-height distribution as functions of the applied potential are shown in Figure 4.

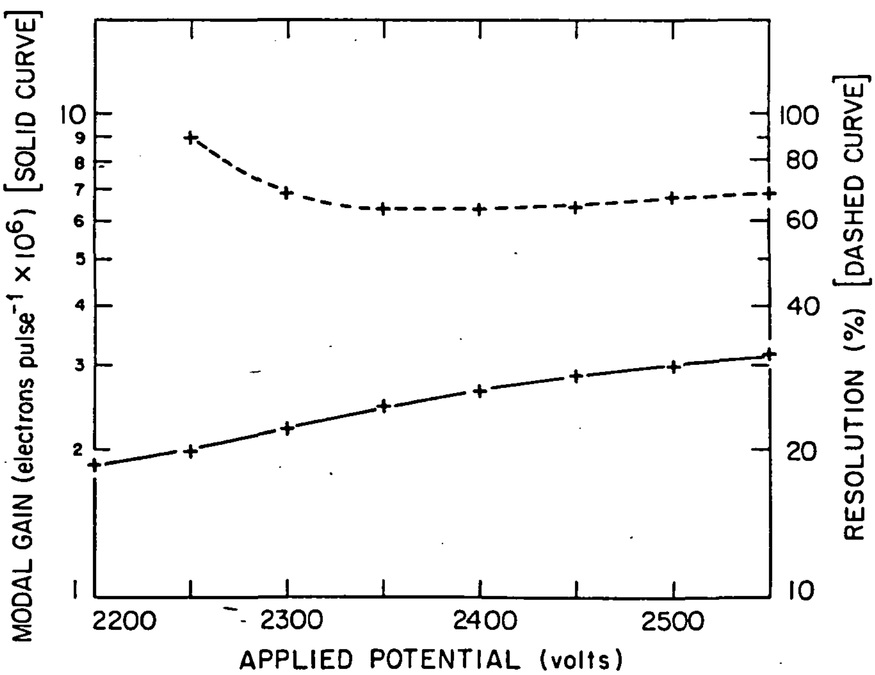


Figure 4. Variations of the modal gain and the resolution of the output pulse-height distribution as functions of the applied potential for the macroplate with an 80:1 channel length-to-diameter ratio. Macroplate was stimulated by 2537 A photons.

The saturated form of the output pulse-height distribution (see Figure 5) clearly demonstrates that the helical form of the channel is effective in suppressing ion feedback at high gain levels. The best resolution of the pulse-height distribution for the macroplate with a channel length-to-diameter ratio of 80:1 (~64%) is superior to the values that we have obtained in the past with "Chevron" and "Z-plate" MCP stacks.[2] The macroplate with a 60:1 channel length-to-diameter ratio yielded essentially identical gain values but the best resolution was about 71%. A further indication of the high level of suppression of ion feedback is the very low dark count rate (~0.3 counts $s^{-1}$ for the total active area).

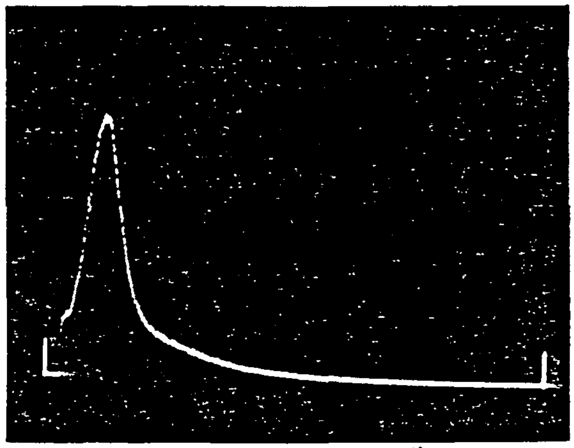

Figure 5. Output pulse-height distribution for macroplate with 80:1 channel length-to-diameter ratio at an applied potential of 2400 V. Modal gain 2.6 x $10^6$ electrons $pulse^{-1}$, resolution 63.5%.

One immediate difference between the performance of the macroplate and that of a conventional MCP is the very strong dependence of the macroplate detection efficiency on the electrostatic field strength at the input to the channels which is caused by the low open-area ratio. The macroplate was operated with the input face at a high negative potential and the output face at ground. By applying a higher negative potential on a focusing electrode mounted in front of the macroplate, photoelectrons liberated on the front-face electrode could be directed into the channels. As shown in Figure 6, the collection efficiency was a very sensitive function of the applied potential. Further, the focusing electrode potential for maximum detection efficiency varied with the distance from the center of the macroplate.

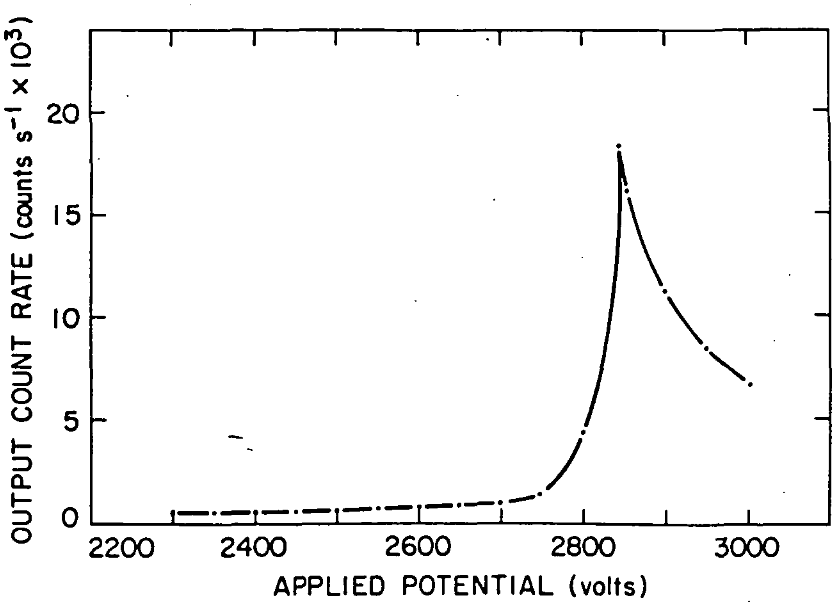


Figure 6. Variation of the macroplate output count rate as a function of the focusing electrode potential. Macroplate input face potential 2400 V. Both electrodes operated at negative potentials with respect to ground. Center of macroplate illuminated with 2537 A photons.

Since the increase in the detection efficiency is significantly greater than the closed-to-open area ratio, it is clear that there is a low detection efficiency within the channels which is almost certainly caused by the combination of the zero bias angle of the channels and the collimated input beam. No significant gain changes were observed as a function of the field electrode potential. When the collection efficiency was optimized by applying a suitable focusing electrode bias potential (typically in the range from 280 to 350 V negative of the macroplate input face potential), the variation of the output count rate as a function of the macroplate potential had the form shown in Figure 7.

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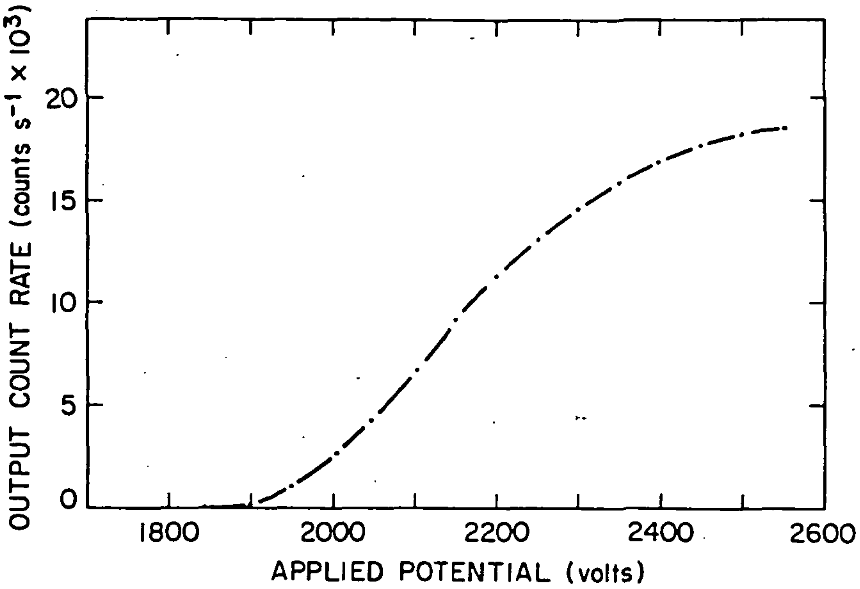


Figure 7. Variation of the output count rate as a function of the macroplate potential. Focusing electrode potential set for maximum detection efficiency. Center of macroplate illuminated with 2537 A photons.

The shape of this curve shows the characteristic plateau obtained with a high-gain channel multiplier providing a saturated output pulse-height distribution.

In summary, the data from the initial evaluations show clearly that the "off-axis channel" is effective in suppressing ion-feedback and that this structure can be used to construct a high-gain MCP.

## Future Developments

With the "off-axis channel" concept validated, the need now is to demonstrate that this technology can produce a high-gain MCP with a channel diameter in the range from 10 to 25 microns and an open-area ratio of greater than 50%. The next step in the development program will be to produce sample MCPs with 25-micron channel diameters. The first units will again employ a single channel per fiber. Following this, the first MCPs with multiple channels per fiber will be fabricated, starting with large channel diameters and working down to diameters in the range from 10 to 25 microns. As soon as the first MCPs are available, imaging tests will be initiated to verify that the spatial relationship of the channel inputs and outputs can be maintained.

## Acknowledgments

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