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**Letter to the Editor**

# Comparative tests of Russian microchannel plates

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We present measurements of the gain, resistance, dark noise and count rate capability of Russian microchannel plates and compare them with test results from comparable western MCPs.

Microchannel plate (MCP) electron multipliers for the detection of energetic photons and charged particles have until now been available from a very limited number of suppliers [1–3]. Now, however, it is becoming possible to obtain Russian MCPs in the West. In this letter we critically compare the operating characteristics, in pulse counting mode, of two types of Russian MCPs with those of Western MCPs tested previously at Leicester.

The two stage detector configurations are described in table 1. All measurements were made in turbomolecular pumped stainless steel vacuum systems at pressures of $5 \times 10^{-7}$ mbar of better. The MCPs were operated in existing demountable detector assemblies constructed from stainless steel and Macor [4], PTFE and PCTFE [5].

Fig. 1 shows, for each of three distinct MCP pairs, (detectors A–C), how the modal gain, ($G_c$), and FWHM of the output pulse height distribution (PHD) varies with common applied voltage on both front and rear MCPs. The observed behaviour is very similar to that of other manufacturer's MCPs although considerably higher bias voltages are required for the Russian plates (see table 2). Detector C exhibits higher gains than detectors A and B due to its larger channel diameter and the lower wavelength stimulating radiation. The predicted scaling of saturated gain with channel diameter is as $D$ [6]. Hence we would expect the gain of detector C to be a factor of $\frac{15}{12} \sim 1.25$ higher at constant bias voltage, than those of detectors A and B. The results of varying front and rear plate voltages independently, of varying the interplate gap voltage and the radiation incidence angle, all produced similar results to these observed with other manufacturer's MCPs [6,7].

A typical PHD from detector C is shown in fig. 2. Similar PHDs were obtained from detectors A and B.

Table 1
MCP detector parameters. Detectors A and B shared a common body and were operated in one test system. Detector C was operated in a second test system

| Detector | A/B | C |
|---|---|---|
| MCP diameter | 32 mm | 56 mm |
| Channel diameter $D$ | 12 μm | 15 μm |
| $L/D$ ratio | 50:1 | 50:1 |
| Open area fraction | 62% | 62% |
| MCP thickness | 0.6 mm | 0.78 |
| Bias angle | 8° | 8° |
| MCP resistance | 240–300 MΩ | 60–90 MΩ |
| Interplate gap | 160 μm | 300 μm |
| Active area | 2.27 cm$^2$ | 15.9 cm$^2$ |
| Stimulating radiation | 2540 Å (UV) | 44.7 Å (C-K X-rays) |
| Image readout | Graded Density [16] | Resistive anode |

The PHDs are exceptionally narrow for short channel MCPs ($L/D$ ratios of only 50:1), especially the 2540 Å PHDs from detectors A and B where there is a significant probability of UV reflection down the channels. Typically, these widths are at least as good as the widths of PHDs from 80:1 MCPs from other manufacturers. This performance may result from real differences in the MCP glass chemistry (see below) and the subsequent higher field strengths which can be safely applied to the Russian MCPs.

All the MCPs were stable over the ten day period of the tests. All showed a decrease in resistance with increasing high voltage of 0.011% $V^{-1}$ compared with an average of 0.0046% $V^{-1}$ for similar Philips MCPs [8]. The measured temperature coefficient of resistance was −0.7% $K^{-1}$ compared with −1.5% $K^{-1}$ for a

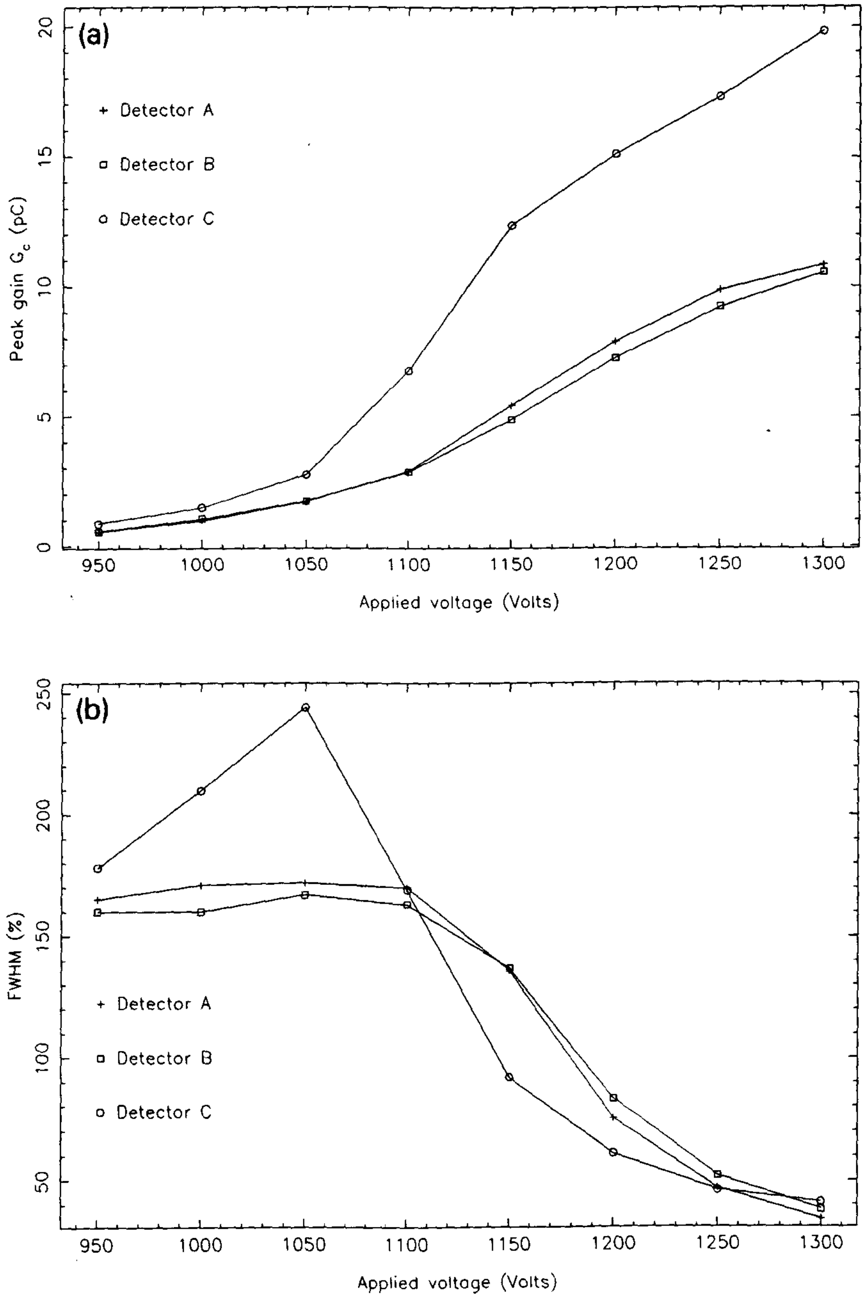


Fig. 1. Variation of output PHD with applied bias voltage ($V_f = V_r$) for detectors A, B and C. (a) Peak gain $G_c$ (b) FWHM. $V_b$ = 100 V (Detectors A and B), $V_b$ = 300 V (detector C).

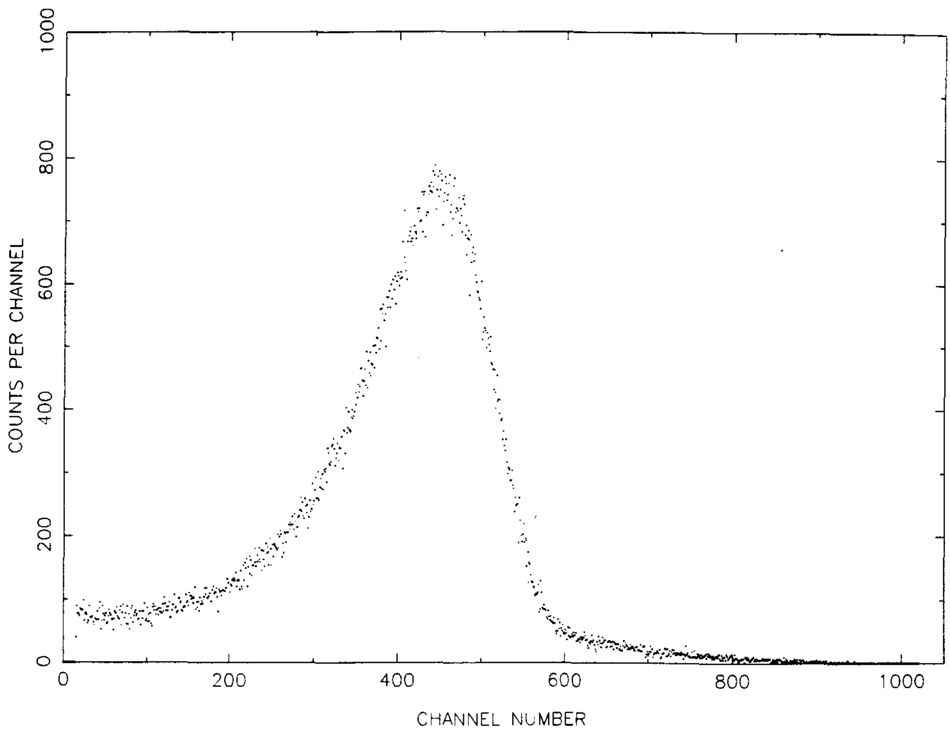


Fig. 2. Typical output PHD from detector C. $V_f = 1250$ V, $V_r = 1250$ V, $V_g = 200$ V, $V_b = 300$ V, C-K X-rays. $G_c = 17.8$ pC, FWHM = 41%.

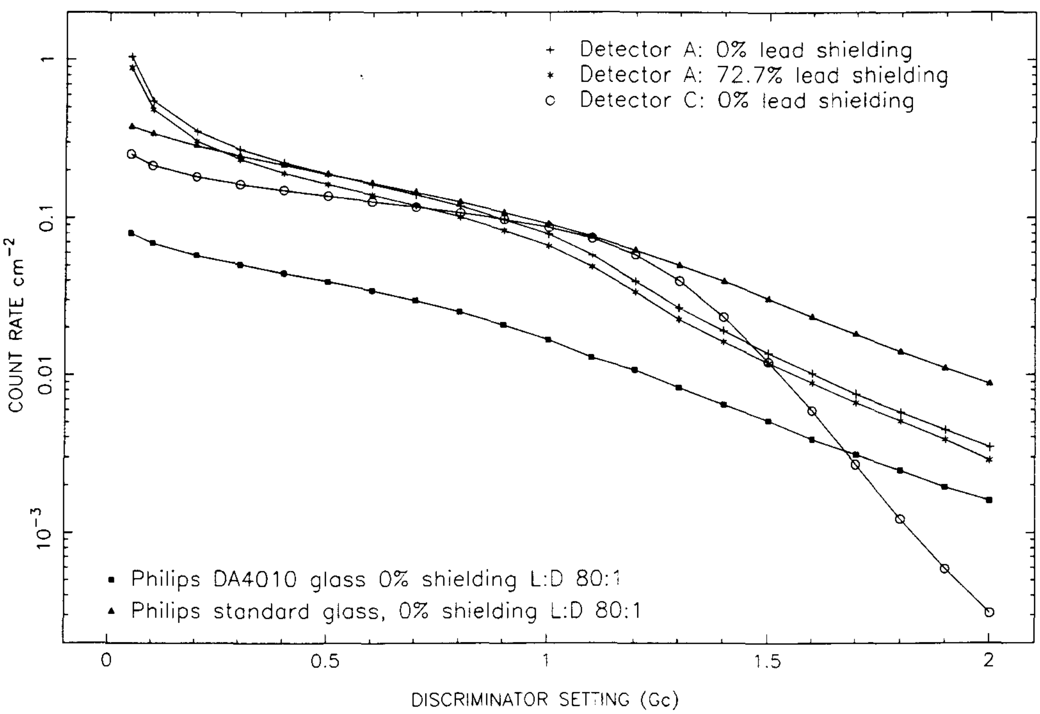


Fig. 3. Background noise count rate as a function of normalised discriminator threshold. Philips DA4010 glass is a low noise composition. Quoted shielding is the fraction of the sphere that is covered with 5 cm thick lead blocks.

typical Philips MCP. A 5% increase in resistance was observed after 407 h at 317 K for the front plate of detector B. The resistance of Philips and Galileo MCPs tends to decrease with time.

The gain of detector C was measured at five positions (see table 3). The majority of measurements on this detector were taken at the (0, 0) position. By comparing initial and final PHDs an approximate measurement of gain decay can be made. By considering the average gain of the detector during the tests, and the total number of counts accumulated at the (0, 0) position we estimate that the charge density abstracted was 0.01 C $cm^{-2}$. The consequent gain decrease of 31% is very similar to that observed with Philips and Galileo MCPs [7]. From table 3 it can be seen that spatial gain variations of the order of ±15% occur on

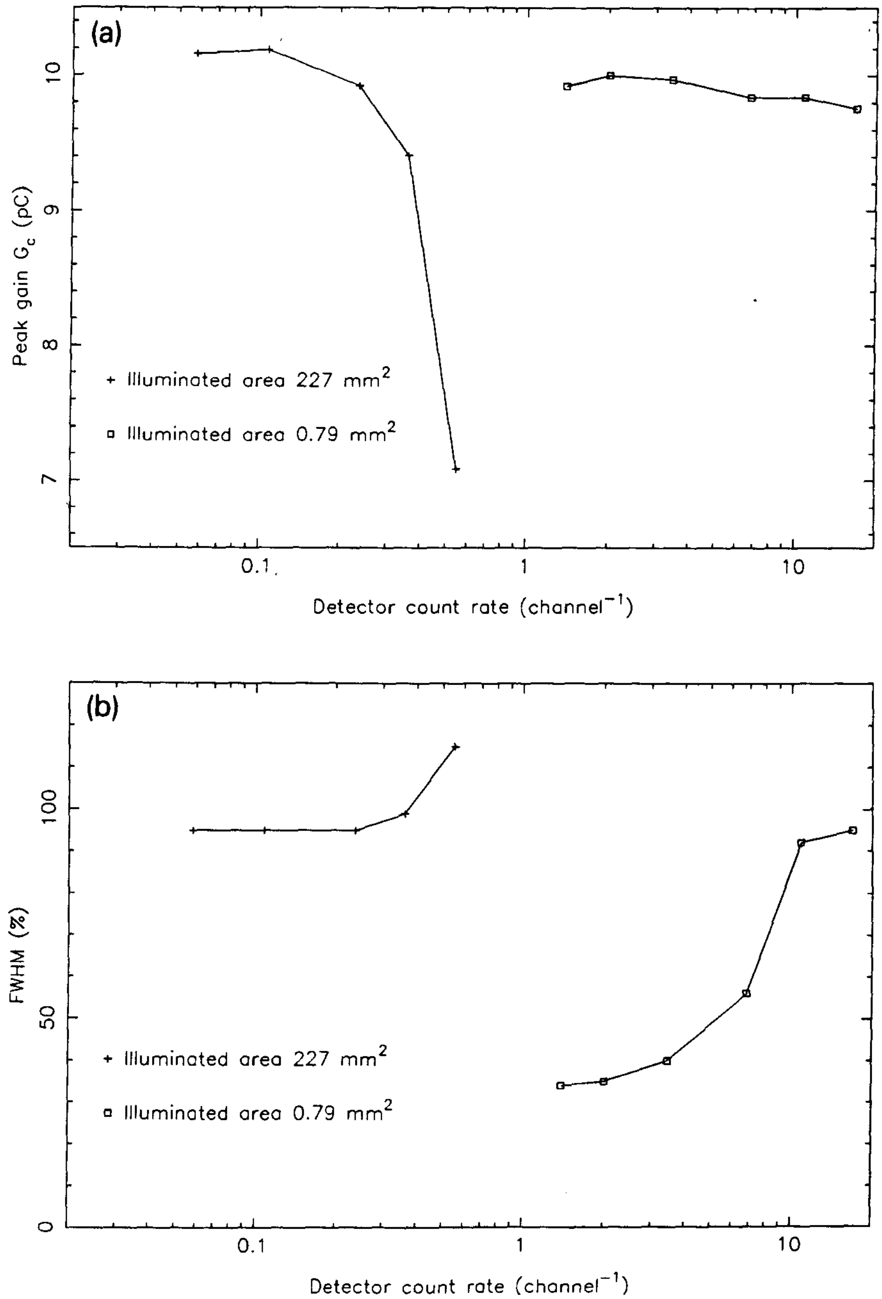


Fig. 4. Variation of output PHD with detector count rate per channel for two different illuminated areas, detector A. (a) peak gain $G_c$ (b) FWHM. $V_f = 1250$ V, $V_r = 1250$ V, $V_g = 200$ V, $V_b = 100$ V, 2540 Å PHD.

Table 2
Typical optimum operating voltages for different types of MCP. Voltages quoted are bias potential differences across: front MCP $V_f$, rear MCP $V_r$, interplate gap $V_g$. Note that the above variations in $V_g$ will have only a small impact on the PHD shape

| Voltage | $V_f$ | $V_g$ | $V_r$ |
|---|---|---|---|
| Detector A/B | 1300 | 200 | 1250 |
| Detector C | 1300 | 200 | 1250 |
| Philips 40:1 | 950 | 200 | 1000 |
| Philips 80:1 | 1200 | 400 | 1200 |
| Galileo 40:1 | 950 | 600 | 1000 |
| Galileo 80:1 | 1250 | 400 | 1250 |

Table 3
Variation of PHD with position $(X, Y)$ in mm from the MCP centre. Detector C, $V_f = 1250$, $V_r = 1250$, $V_g = 200$, C-K X-rays. The first set of measurements were made on areas where no gain decay had taken place. The second (0, 0) measurement was made after 0.01 C $cm^{-2}$ charge had been extracted from the illuminated area

| $X$ | $Y$ | $G_c$ [pC] | FWHM [%] |
|---|---|---|---|
| 0 | 0 | 17.30 | 46 |
| 11 | 0 | 16.18 | 25 |
| −11 | 0 | 15.74 | 28 |
| 0 | 11 | 15.58 | 31 |
| 0 | −11 | 13.68 | 41 |
| 0 | 0 | 11.96 | 49 |

scales of 5–10 mm. Image analysis shows variation in gain of at most $\pm 3\%$ within the 5 mm diameter of the X-ray illuminated spots and no isolated high gain multifibres.

The intrinsic background noise of the MCPs was measured with respect to the detector peak gain as described previously [9,10] (see fig. 3). Plotted here for comparison are results from Philips standard and low noise (radioisotope free) MCPs. The differences in curve shapes above $1 \times G_c$ are due to variation in the shape of the respective normalising X-ray or UV PHDs. The difference in noise count rate for detector A with and without lead shielding is in line with previous observations on the elimination of laboratory gamma rays [11,12]. The intrinsic noise per unit volume of glass of the Russian MCPs is very similar to that of Philips standard MCPs, implying a similar $^{40}K$ content. The glass composition of the Russian MCPs is unknown in detail.

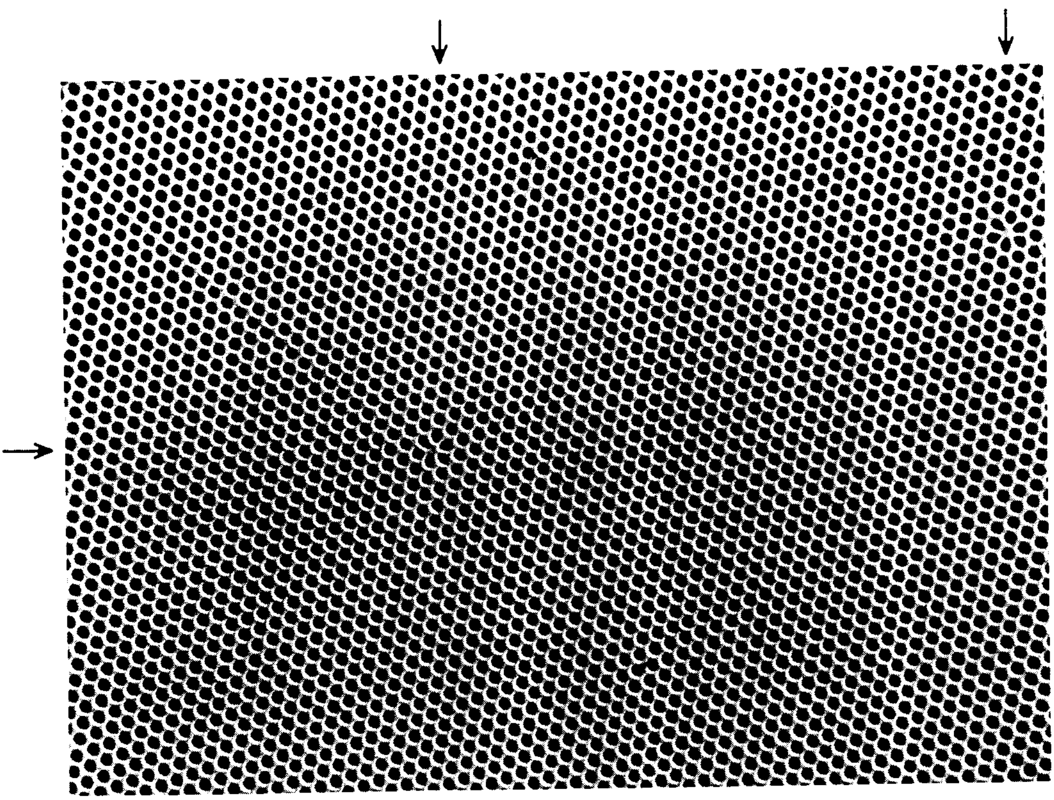

Fig. 5. SEM photographs of a 56 mm MCP showing two rosette type defects (arrowed). Small distortions along the multifibre boundaries are visible on other images.

The variation in response of detector A with input count rate for two different illuminated areas is shown in fig. 4. The observed behaviour is in agreement with what has been observed previously [13] in that higher count rates per unit area are achievable with smaller illuminated areas.

The mechanical regularity of both sizes of Russian MCP was examined using a scanning electron microscope (SEM). Fig. 5 shows a typical image from a 56 mm diameter MCP. The observed circularity of channels and regularity of array is similar to that of western MCPs that we have examined previously. A number of "rosette" defects are visible at the corner points of the multifibre boundaries and some distortion also occurs along the edges of the multifibres. None of the observed distortions caused any operational problems in these tests although we have previously observed rosette defects to produce localised low gain areas. No "chicken wire" [14] patterns were observed in any of the deep images ($1 \times 10^6$ counts $mm^{-2}$) that were accumulated during our tests.

The open area fraction of the two MCP types was calculated from the SEM photographs and found to be approximately 62%, similar to that quoted by other manufacturers (55% to 68%) in their catalogues.

Some information on the underlying properties of the secondary emissive glass surfaces can be obtained from the bias voltage at which the detector "starts';' to multiply. The threshold at which an MCP acts as a multiplier of gain unity, $(V_0)_T$, is given by [6]:

$$(V_0)_T = (4VV_1)^{1/2}(L/D),$$

where $V$ is the most probable energy of an emitted secondary electron from the channel wall and $V_1$ is the first crossover potential. An upper limit for $(V_0)_T$ can be obtained from the point at which noise counts are first observed as bias voltages are increased. For all three detectors we obtain $(V_0)_T \approx 850$ V which implies $VV_1 < 72$ [$V^2$].

A similar analysis for Philips 120:1 MCPs gives $(V_0)_T \approx 1300$ V which implies $VV_1 < 29$ $V^2$. From direct measurements on Philips glass surfaces [15] $V_1 = 20$ V, with $V = 1$ eV. By using $VV_1 = 20$ $V^2$ we estimate the true threshold value to be 1075 V. If we assume that the ratio of measured threshold to true threshold is the same for both Philips plates and the Russian plates we estimate a true threshold value of 705 V for the Russian plates. Using this calculated true threshold value for the Russian plates we get $VV_1 = 50$ $V^2$, indicitive of a rather different secondary electron yield versus energy curve.

In summary, the performance of both sizes of Russian MCP compare favourably with that of MCPs from both Galileo and Philips that we have previously tested. The quality of the PHDs, especially those obtained with UV radiation, is exceptional for plates with an $L/D$ ratio of only 50:1.

Further tests are required to fully qualify the Russian MCPs for scientific use. The main tests would be 1) to check the variation of MCP performance with production batch, 2) detailed life testing of representative samples.

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