The Development and the Study of R5900-00-M64 for Scintillating / Optical Fiber Read Out

Y. Yoshizawa, H. Ohtsu, N. Ota, T. Watanabe, J. Takeuchi
Hamamatsu Photonics K.K., Electron Tube Center
314-5, Shimokanzo, Toyooka Village, Iwata-gun, Shizuoka Pref., JAPAN

Abstract

In High Energy Physics (HEP) experiments, scintillating or optical fibers are used for tracking detectors and sampling calorimeters. As recent trend, the size of detectors are getting large in accordance with increase of particle energy. It leads to enlargement of read out channels. In addition, count rate of signals is also increased. In some cases, gas detectors can't be used with high count rate signal. A multi channel photodetectors with low channel cost are getting necessary in those conditions.

Hamamatsu has developed R5900-00-M64 [1] as one of such photodetectors to satisfy the above requirement. R5900-00-M64 is a 64 channel multi anode PMT. It uses metal channel dynodes and 28 x 28 mm metal package. Its basic performance are studied and reported in this paper.

I. INTRODUCTION

R5900-00-M64 is one of the R5900 series [2] and is 64 channels multi anode PMT that incorporates an 12-stage electron multiplier constructed with stacked thin electrodes, it's called Metal Channel Dynode [3], into a metal can package of 28 x 28 mm square and 20 mm in height. The size and the pitch of its anode pixel are 2 x 2 mm square and 2.3 mm, respectively. It has bialkali photocathode and its typical gain is 3 x 10^5 at 800V. The dimensional outline of R5900-00-M64 is shown in Figure 1. Its anode pattern is shown in Figure 2.

As the metal channel dynode is a sort of an array of small linear focused dynodes, secondary electrons hardly go to adjacent dynode channel in a process of multiplication. It makes possible to have a multi anode PMT with low cross-talk. Hamamatsu have already developed R5900-00-M4 [4] (4 channels with 2 x 2 matrix) and R5900-00-M16 [5] (16 channels with 4 x 4 matrix) utilizing the same dynode and the metal package, but R5900-00-M64 fits the demand of multi channel photodetectors with low channel cost. Its basic performance were studied and are shown in this paper.

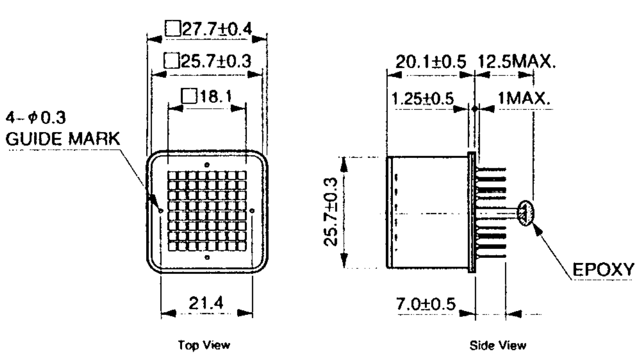

Figure 1: The dimensional outline of R5900-00-M64

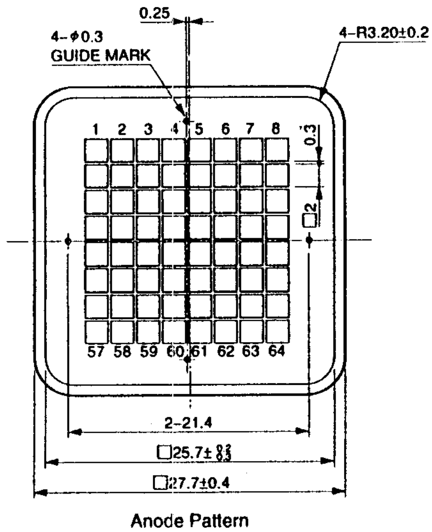

Figure 2: The anode pattern of R5900-00-M64

II. TEST RESULTS

A. Cross-talk

For the scintillating fiber read out, a cross-talk is one of the most important characteristics of multi anode PMTs. As R5900-00-M64 doesn't use FOP (Fiber Optic Plate) for its face plate, and its pixel size is small as 2 x 2 mm, the cross-talk should be well studied.

When the development of R5900-00-M64 was started, the thickness of the face plate was 1.3 mm, but now it was reduced to 0.8 mm accordingly to minimize the optical cross-talk inside the face plate.

As the first step, we studied light spreads of a scintillating fiber and optical fibers. SCSF78, which is a scintillating fiber and its peak wavelength of the emission is around 440 nm, with 1 mm in diameter and optical fibers with 1 mm and 1.7 mm in diameters were used. They are courtesy from Kuraray and all of them were double cladding fibers. Figure 3 shows the test set up.

In this test, UV (Ultra Violet) DC (Direct Current) light source was used to irradiate fibers from side direction. The lights from the fibers were traced on a thin paper. The light spreads were monitored by imaging camera, which consists of an image intensifier and a C.C.D camera, while distance (d) between the fibers and the tracing paper were changed. The light spreads at

0-7803-4258-5/98/$10.00

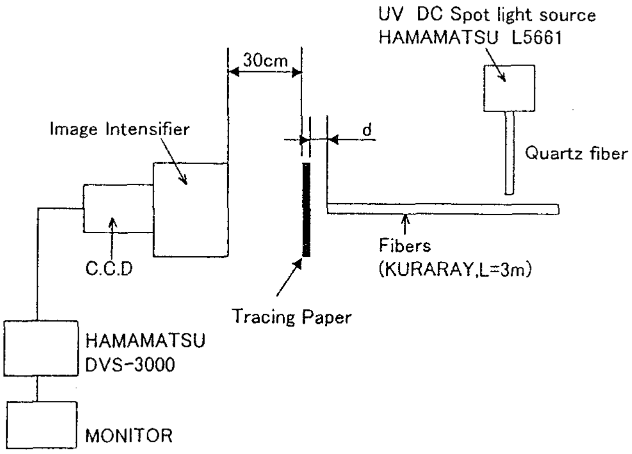

Figure 3: Test set up for light spreads of fibers

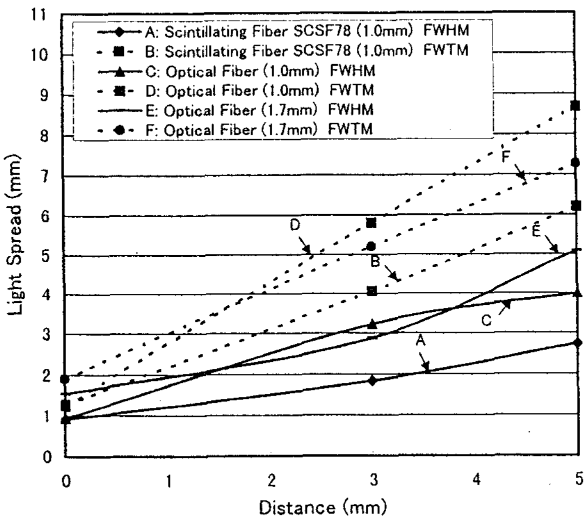

Figure 4: Test result of light spread of fibers

FWHM (full width at half maximum) and FWTM (full width at tenth maximum) are shown in Figure 4. In the actual use, distance between a fiber and a face plate of a multi anode PMT could be within 0.5 mm. It was confirmed that the spot size on the face plate is less than 1.5 mm in diameter at its FWHM, if a fiber with 1 mm in diameter is used.

As next step, the cross-talk of R5900-00-M64 was measured while changing position of the SCSF78 in X and Y axis with keeping the distance of 0 mm between the fiber and the face plate. The scintillating fiber was set on the face plate where corresponds to a center of a pixel, and was irradiated by UV DC light source from side direction. The anode signal of the pixel as well as its adjacent 8 pixels were measured at each position.

Figure 5 shows an alignment of 8 pixels, their symbols from A through H and directions of X and Y axis. The blank at the center of the matrix corresponds to the pixel where the fiber was set at its center as standard position. The fiber was moved from the standard position in a range of +/- 0.5 mm with 0.1 mm step in both axes. Figure 6 and Figure 7 show the test result in X and Y axis, respectively. It was confirmed that a tolerance of

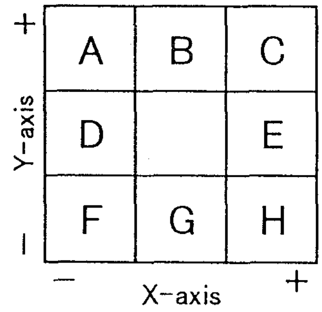

Figure 5: The alignment of pixels and symbols

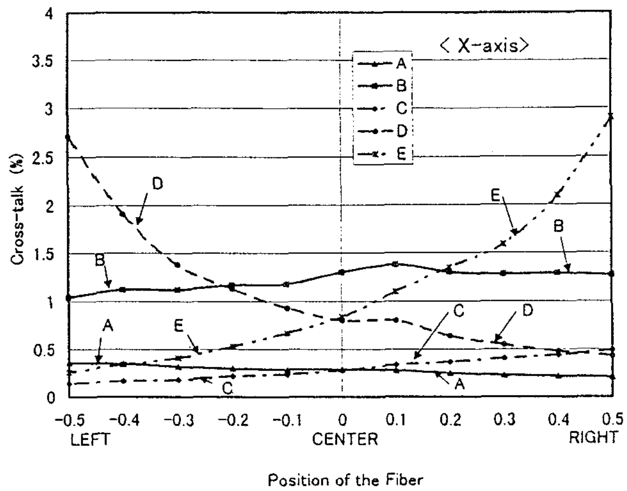

Figure 6: The cross-talk in accordance with position of the fiber (X-axis)

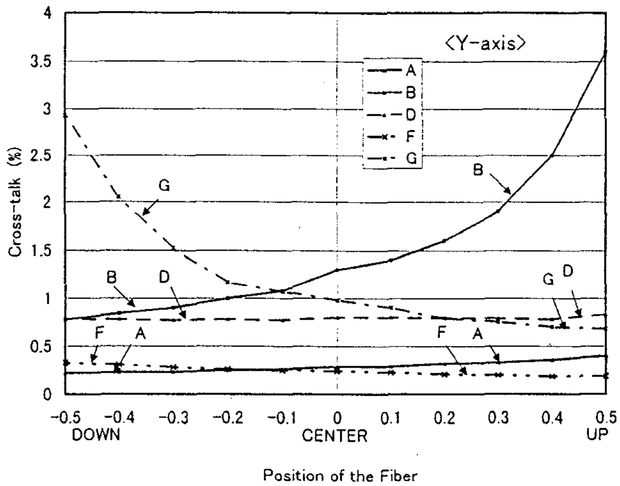

Figure 7: The cross-talk in accordance with position of the fiber (Y-axis)

positioning of a fiber is around +/- 0.2 mm if the cross-talk should be kept within 2 %.

Next, the cross-talk was measured while changing a height (h) of the SCSF78 from the face plate. The height was changed in a range from 0 mm to 2.0 mm with 0.5 mm step with keeping the position of the fiber at the center of the pixel. Figure 8 shows h=0mm

0.3	1.4	0.4
0.8	100	1.2
0.2	1.1	0.3

Light Source: SCSF78(1.0mm)
Applied Voltage: 800(V)

h=0.5mm

0.4	2.6	0.6
1.5	100	1.9
0.3	1.8	0.4

Light Source: SCSF78(1.0mm)
Applied Voltage: 800(V)

Figure 8: The cross-talk in accordance with the height of the fiber (h=0 mm and h=0.5 mm)

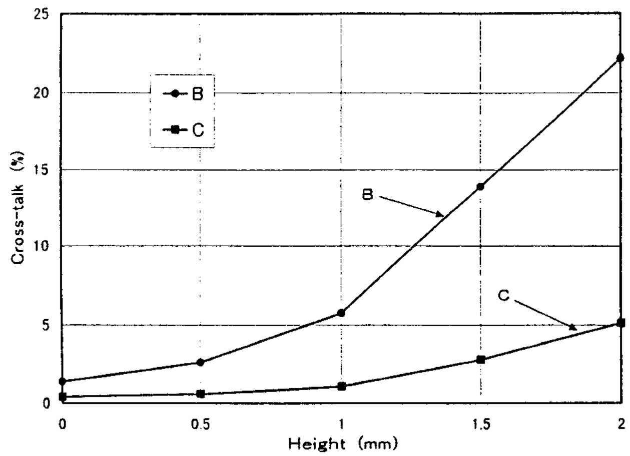

Figure 9: The cross-talk of pixel B and C in accordance with the height of the fiber

the cross-talk data at the heights of 0 mm and 0.5 mm. In this data, each square corresponds to each pixel and the numbers in the squares show relative values of anode output signal. Figure 9 shows cross-talk data of pixels B and C at the height from 0 mm to 2.0 mm. The symbols B and C correspond to pixels which are shown in Figure 5. It was confirmed that the height should be less than 0.5 mm if the cross-talk would be kept within 3 %.

B. Anode Uniformity

Anode uniformity is one of the important characteristics of multi anode PMTs. Uniform response in all of pixels is desired. However, R5900-00-M64 has common dynodes for 64 pixels, even though photocathode response is quite uniform, the gain variation between pixels is occurred. It's due to a difference of the secondary emission yield in accordance with the position of the dynode. As an example, the anode uniformity of R5900-00-M64 for all of pixels is shown in Figure 10. In this uniformity test, W (tungsten) lamp was used as uniform DC light source. All of useful area of the cathode was illuminated, and anode signal from each pixel was measured. It's shown as a height of a pole in this figure. The variation between pixel to pixel is within factor 3 in this data. This is typical variation at present.

Figure 11 shows an anode uniformity of one pixel. In this test, the SCSF78 was also used as DC spot light source. It was moved with 0.1 mm step around the pixel and the anode signal was measured at each position. The two peaks correspond to two channels of metal channel dynode in one pixel.

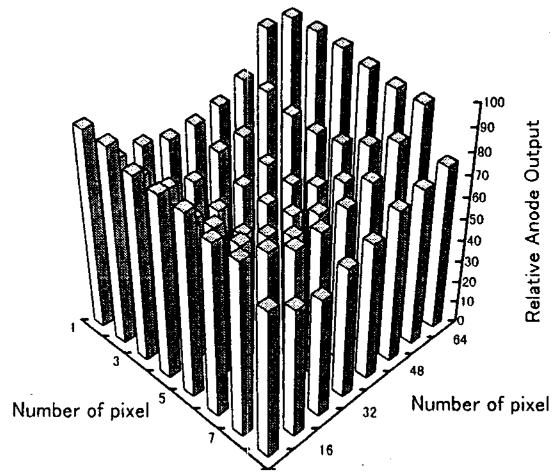

Figure 10: Anode uniformity for all of pixels

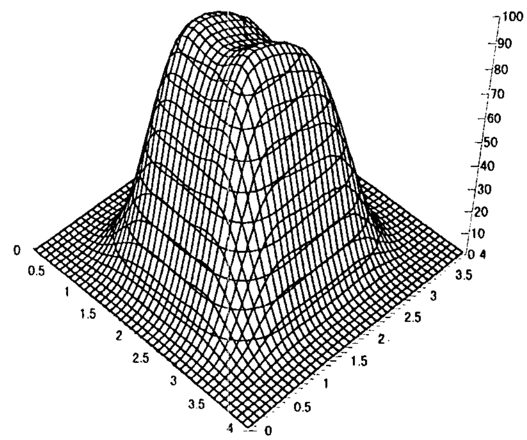

Figure 11: Anode uniformity of one pixel

C. Pulse Height Distribution with Single p.e.

In general, light yield of a scintillating fiber read out in a tracking detector is around several photoelectron (p.e.) s, good pulse height distribution (PHD) with single p.e. is also important to set its lower level discrimination with high detection efficiency. As an example, PHD of 4 pixels with single p.e. is shown in Figure 12. It was confirmed that the single p.e. peak can be seen with reasonable peak to valley ratio.

D. Pulse Linearity

A scintillating fiber in a tracking detector usually produces few photoelectrons as its signal. The pulse linearity, which corresponds to dynamic range of a multi anode PMT, isn't so important in this application. However, it's necessary to study

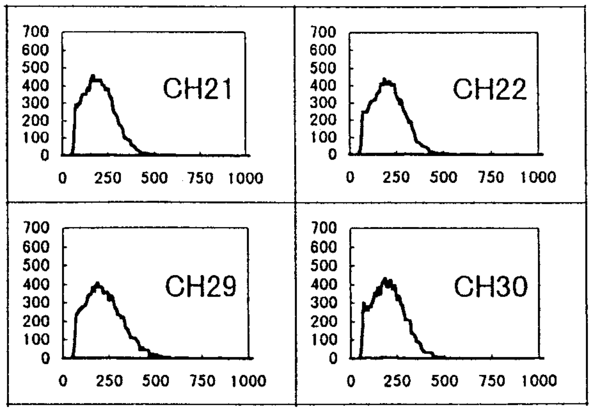

Figure 12: Pulse height distribution of 4 pixels with single p.e.

the pulse linearity to see its limitation.

Figure 13 shows the pulse linearity of R5900-00-M64. In this test, LED was used and was operated in a double pulsed mode. It means that the LED generated higher and lower pulse amplitudes alternately. They were fixed at a ratio of approximately 4:1. The FWHM of the output signal is around 30 ns (nanosecond). The repetition cycle is 1 K Hz. The distance between the LED and the PMT was changed to increase output signal for both of the pulse amplitudes. If the PMT keeps linearity for both pulses, its ratio is kept at 4:1. If the PMT starts to be saturated, the ratio becomes small such as 3.9 : 1. In this case, the deviation from linearity is calculated as -2.5 %.

In the figure, transverse axis shows anode output peak current and vertical axis shows deviation from linearity. All of pixels were connected together in this test. It was confirmed that the deviation from linearity is around 5 % at a peak current of 15 mA per 64 pixels, that is around 0.2 mA per a pixel at present. It corresponds to approximately 100 photoelectrons, if R5900-00-M64 is operated at gain of 3 x 10^5 and the FWHM of the output signal is 30 ns.

E. Other Characteristics

The other important characteristics as a multi anode PMT are QE (Quantum Efficiency), voltage dependence of gain and time

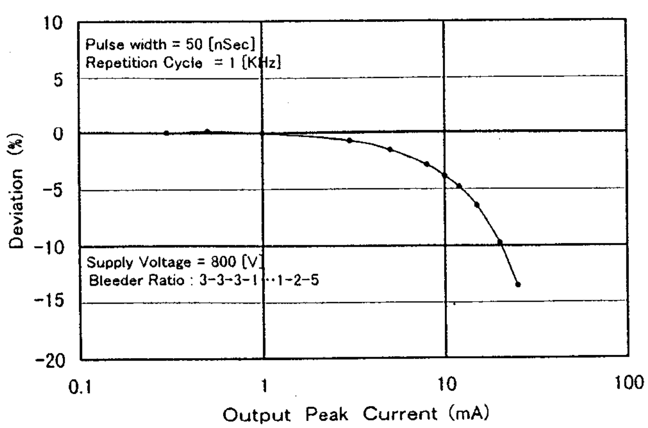

Figure 13: Pulse linearity of R5900-00-M64

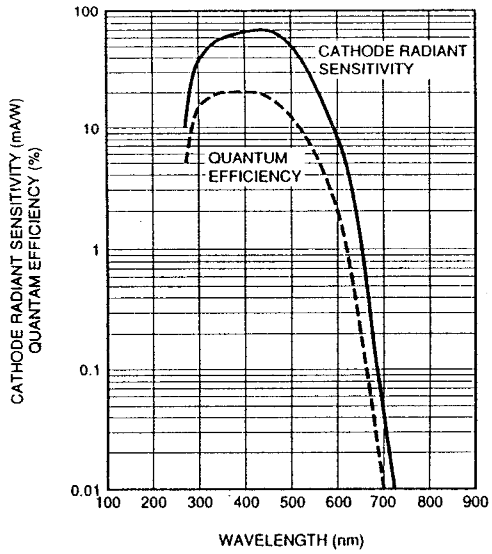

Figure 14: Typical QE curve of R5900-00-M64

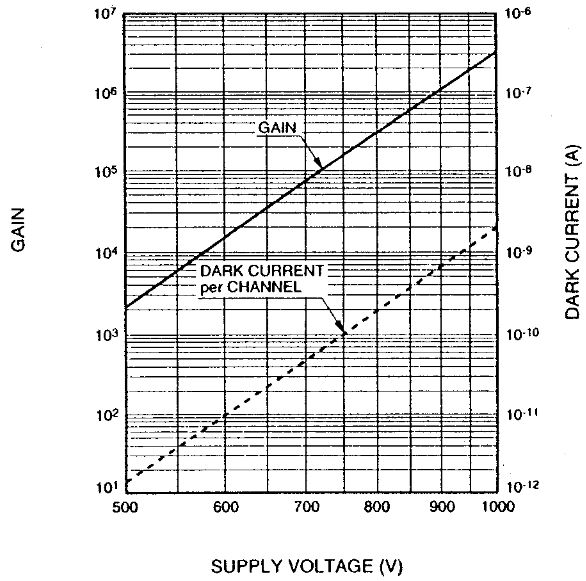

Figure 15: Typical gain and dark current of R5900-00-M64

response.

Figure 14 shows typical QE curve of R5900-00-M64, which has bialkali photocathode. In this data, the solid line shows the cathode radiant sensitivity and the dotted line shows the QE in accordance with wavelength. The response range is determined on the long wavelength side by the photocathode material and the short wavelength side by the window material. The QE is relatively low compared with standard bialkali photocathode. It's due to the proximity configuration. We are trying to improve the QE of R5900 series up to that of standard bialkali photocathode as close as possible, and are getting good result.

Figure 15 shows typical gain of R5900-00-M64 and its dark current per channel in accordance with supply voltage. The typical gain is 3 x 10^5 at 800V, but gain of 1 x 10^6 can be obtained at 900V.

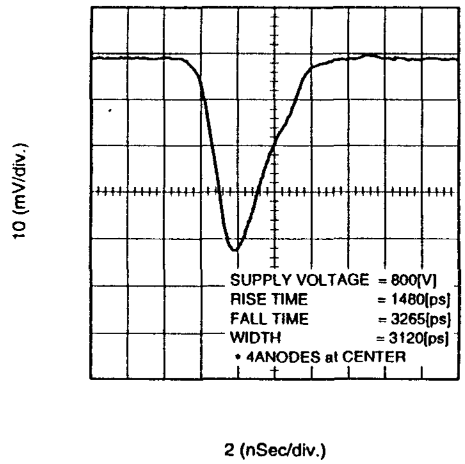

Figure 16: Typical time response of R5900-00-M64

Figure 16 shows typical time response of R5900-00-M64. The typical rise time and its FWHM are approximately 1.5 ns and 3.0 ns, respectively. The typical T.T.S. (Transit Time Spread) is 300 picosecond at its FWHM. Those fast time response are due to the proximity configuration and the compactness of the metal channel dynode. It was confirmed that R5900-00-M64 is suitable for timing measurement.

III. CONCLUSION

R5900-00-M64 has been developed as one of multi channel photodetectors, which offers low cost per channel. Its basic performances were studied and it was confirmed that R5900-00-M64 could be suitable for read out of scintillating or optical fibers.

IV. REFERENCE

[1] Hamamatsu catalog, "R5900-00-M64", Catalog No. TPMH1192E.
[2] Y. Yoshizawa, et al, "The latest vacuum photodetector", Nucl. Instr. and Meth. vol.A387, 1997, pp. 33-37.
[3] H. Kyushima, et al, "Photomultiplier Tube of New Dynode Configuration", IEEE Trans. Nucl. Sci., Vol.41, 1994, p.725.
[4] Hamamatsu catalog, "R5900U-00-M4", Catalog No. TPMH1126E.
[5] Hamamatsu catalog, "H6568, H6568-01", Catalog No. TPMH1137E.