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Authors

Leskovar, B.
Shimizu, T.T.

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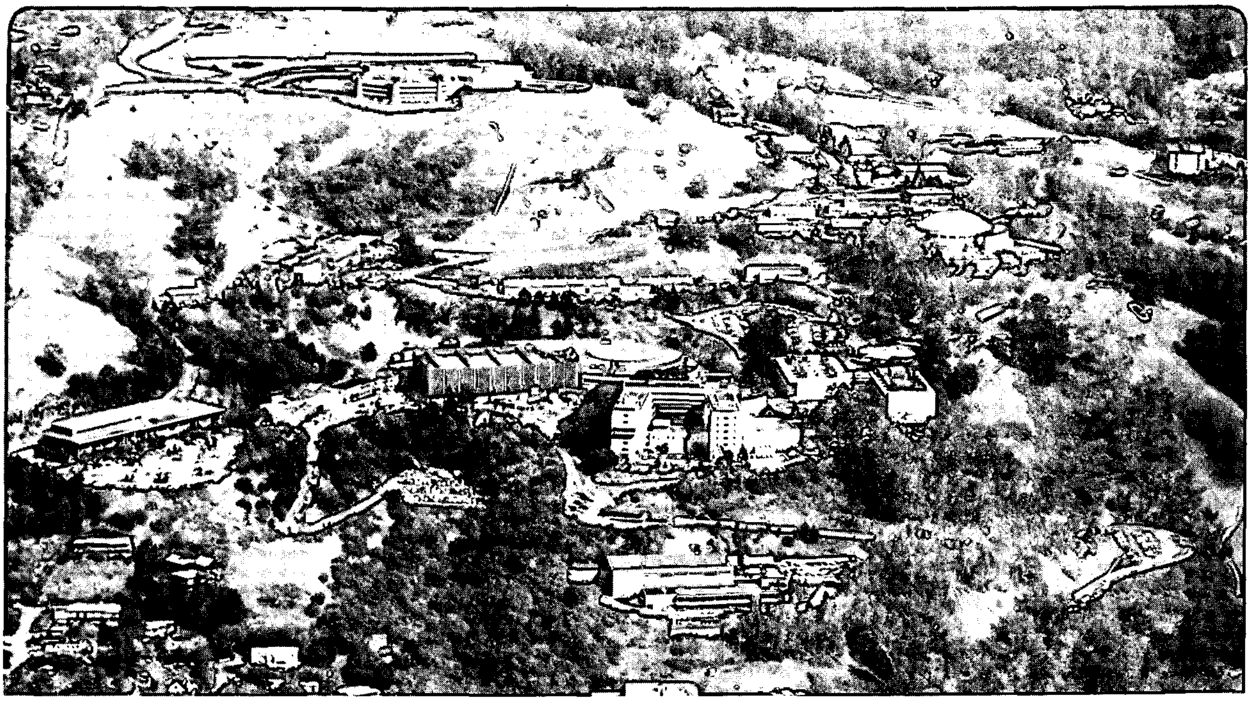

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TIME RESOLUTION PERFORMANCE STUDIES OF HAMAMATSU R1564U MICROCHANNEL PLATE PHOTOMULTIPLIER

Branko Leskovar and T.T. Shimizu

Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

ABSTRACT

Time resolution characteristics of the Hamamatsu R1564U 18 mm-diameter photomultiplier have been investigated. This new prototype high gain photomultiplier has two microchannel plates in cascade for electron multiplication. Some typical photomultiplier characteristics-such as gain, dark current, and output pulse rise and fall times are compared with data provided by the manufacturer. Photomultiplier characteristics, generally not available from the manufacturer, such as the single photoelectron time spread and pulse-height spectrum for full photocathode illumination were measured and are discussed.

INTRODUCTION

It was previously shown that the timing capabilities of photomultipliers, based on high-gain microchannel plates for electron multiplication and using proximity focusing are considerably better than those of conventional multipliers.[1-8] It was also shown that the sensitivity of the photomultiplier characteristics to ambient magnetic fields is significantly decreased by such configuration. The purpose of this paper is to study the time resolution characteristics of a new prototype high-gain photomultiplier having two microchannel plates in cascade for electron multiplication. The significant feature of the two microchannel plate electron multiplier is that its gain can be made considerably higher, typically between 10^6 and 10^7, than that obtainable with a single microchannel plate where the average multiplier gain is of usually less than 10^6.[1-8] Furthermore, the electron resolution of the photomultiplier was also studied. The pulse-height resolution capabilities of the photomultiplier are important for the detection and measurement of very low-light-level scintilations in which only a few electrons are produced. The high resolution permits the elimination of almost all single-electron dark pulses that accompany low-level scintilations. Application where high resolution is very important includes tritium counting, certain cases of carbon counting and Cerenkov counter applications.

As with previous photomultiplier work,[1-8] these measurements include such characteristics as: gain, dark current, single photoelectron time spread, and pulse height resolution of the Hamamatsu R1564U photomultiplier.

The photomultiplier has a bialkali photocathode with a useful diameter of 18 mm. Proximity focusing is used for the input and collector stages. Measurements of the photomultiplier characteristics were made using the voltage divider shown in Fig. 1. Measuring systems used in the photomultiplier studies were based on the systems described in Ref. 1.

GAIN AND DARK CURRENT MEASUREMENTS

Both the gain and dark current measurements were made with the system described in Reference 1. All electrodes except the photocathode were connected together to be used as the collector.

The photomultiplier was operated as a photodiode with 300V across it. It was placed in a marked position; the light level was then adjusted to yield a 10 mV peak-to-peak output signal across the 1 megohm input of an oscilloscope. The photomultiplier was then reconnected to the voltage divider shown in Fig. 1, and the voltage across the microchannel plate was increased until the output signal was 100 mV peak-to-peak which corresponds to a gain of 10 at this voltage. The light level was then attenuated with the same voltage across the microchannel plate to again give a 10 mV output signal. With this lower light level setting, the microchannel plate voltage was again increased to yield a 100 mV peak-to-peak output signal corresponding to a gain of 100. The same procedure was repeated until the maximum recommended plate voltages were reached. The two R1564U's measured had an average gain of 10^6 at 2900 V. The dark current at this voltage was 60 pA. Fig. 2 shows the average gain and dark current as a function of the overall voltage between the anode and cathode.

SINGLE PHOTOELECTRON PULSE RESPONSE

A system similar to the one given in Reference 1 was used for the single photoelectron response measurement. Before the single photoelectron pulse response measurement was made the system risetime was measured using a 28 ps risetime tunnel diode pulse generator and found to be 370 ps. Figure 3 shows the single photoelectron pulse shape of the R1564U. The 10-90% risetimes were found to be approximately 240 ps after corrections for the system risetime. The pulse width (FWHM) was 1.0 ns. The waveform was taken after 20 dB of amplification.

SINGLE PHOTOELECTRON TIME SPREAD MEASUREMENT

The system described in Reference 1 was also used for the time spread measurement. Two light pulse generators were used to obtain light pulse widths of from 250 ps to 10.0 ns. Since single photoelectron pulses of the R1564U are in the order of 8 mV to 18 mV, an amplifier giving more gain must be provided to amplify the signal amplitude to the acceptance level of the constant fraction discriminator. A voltage gain of approximately 30 dB was found to provide the best result, giving a signal amplitude of single photoelectron pulses at the input of the discriminators in the range from 240 to 450 mV. The outputs of the two discriminators, following the constant fraction discriminator and the LED driver, were connected to a time to amplitude converter whose output was processed and recorded in the multichannel analyzer. The system resolution was approximately 25 ps, FWHM.

With full photocathode illumination, and with a light pulse produced by a 200 ps electrical pulse, the single photoelectron time spread was 260 ps. Figure 4 shows the single photoelectron time spread of the MCP photomultipliers as a function of LED current pulse width. In extrapolating the curve in Fig. 4 to a LED current pulse width of 100 ps, the single photoelectron time spread of photomultiplier have upper limits of 180 FWHM. Electrical pulses wider than 200 ps were obtained with a Tektronix 110 pulse generator, using different lengths of charging cables. Two single photoelectron spread spectra are shown in Fig. 5 spaced 2 ns apart.

PULSE-HEIGHT SPECTRUM MEASUREMENT

Previous work has shown that most microchannel plate photomultipliers could resolve one, two, three or more photoelectron peaks.[1-8] The same system and procedure described in Reference 3 was used to evaluate the R1564U photomultiplier. The present design of the cascade of two microchannel plates has considerable advantages with respect to fabrication, timing characteristics, and other application of the photomultiplier. However, a cascade configuration without electrical connections to each microchannel plate does not allow a full optimization of operating conditions of the individual microchannel plates for a maximum pulse-height resolution. As shown by our previous measurements[6] optimization of operating conditions of each microchannel plate is required for a significant increase of pulse-height resolution capabilities of the photomultiplier. Minor modifications of the cascade configuration would result in increased photomultiplier pulse height resolution.

The pulse-height spectrum of the R1564U was measured by illuminating the full photocathode with a light emitting diode whose light output intensity was controlled by varying the amplitude of the driving pulse. The photomultiplier output pulses were stretched before they were processed by pulse-height analyzer. The photoelectron peaks were calibrated with a RCA 8850 photomultiplier which could resolve 1, 2, 3 or 4 photoelectron peaks.

The pulse-height spectrum of the R1564U is shown in Fig. 6 with the photomultiplier operating at 2900 V which corresponds to a gain of 1×10^6.

With the applied voltage between the photocathode and anode of the R1564U of 2900 V, the device was unable to resolve one, two, three, or more photoelectron peaks.

The dark pulse spectrum of the photomultiplier was also measured. Typical spectra are shown in Figs. 7 and 8. The average dark pulse count of the photomultipliers when operating at the gain of 10^6 was found to be:

$$\sum_{1/8\ \text{photoelectron}}^{16\ \text{photoelectrons}} = 30\ \text{counts per second}$$

CONCLUSIONS

Characteristics studies of the two prototype high gain photomultipliers, having two microchannel plates in cascade for electron multiplication, show that the device exhibits excellent time resolution capabilities in comparison to the best conventionally designed photomultipliers. Furthermore, our measurements have shown that the basic characteristics of the R1564U approximately agree with those given by the manufacturer. Also, measurements have shown that the device was unable to resolve one, two, three or more photoelectron peaks in the pulse height spectrum. If electrical connections could be made to each microchannel plate in the cascade configuration, it would allow full optimization of operating conditions of each microchannel plate and would significantly increase the pulse-height resolution.

ACKNOWLEDGEMENTS

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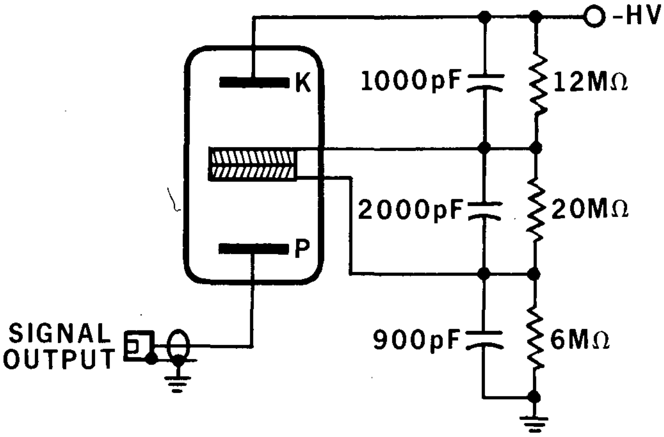

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Fig. 1. Microchannel plate photomultiplier voltage divider used in the measurements.

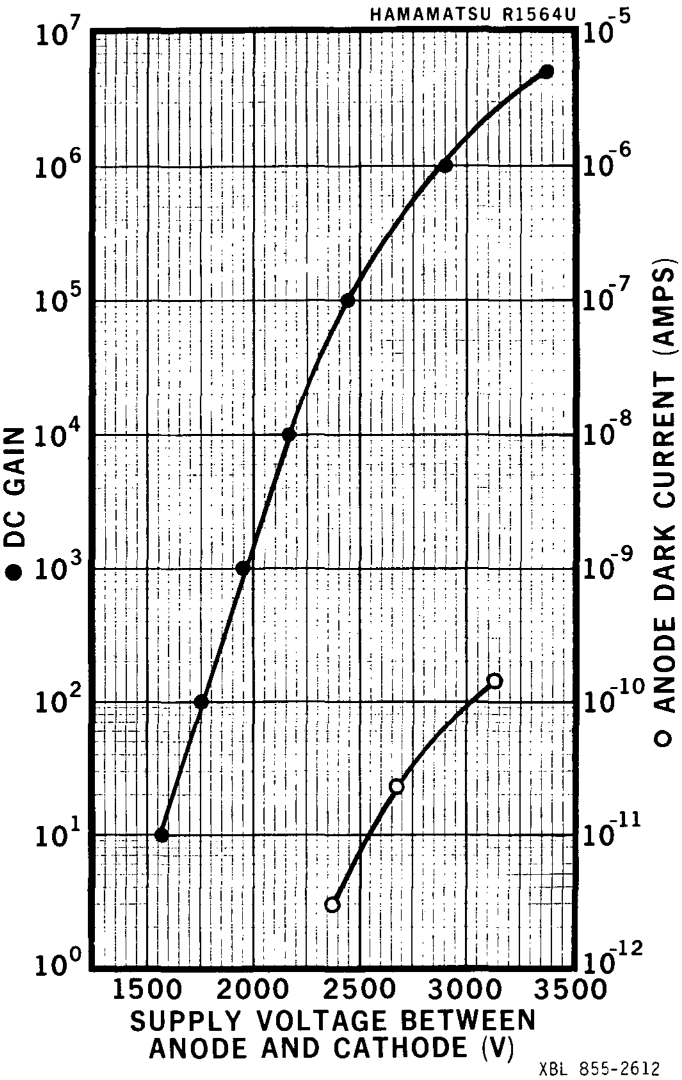

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Fig. 2. DC Gain and dark current as a function of the supply voltage between the anode and photocathode of R1564U photomultiplier.

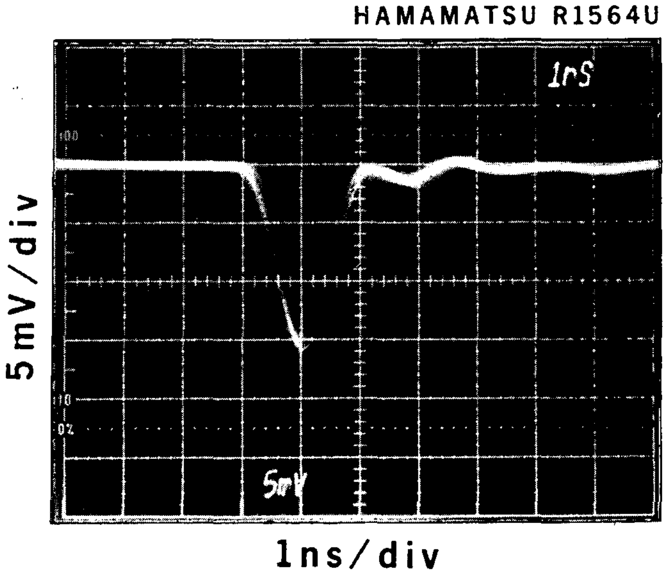

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Fig. 3. Single photoelectron pulses from the R1564U using a 200 ps light pulse excitation.

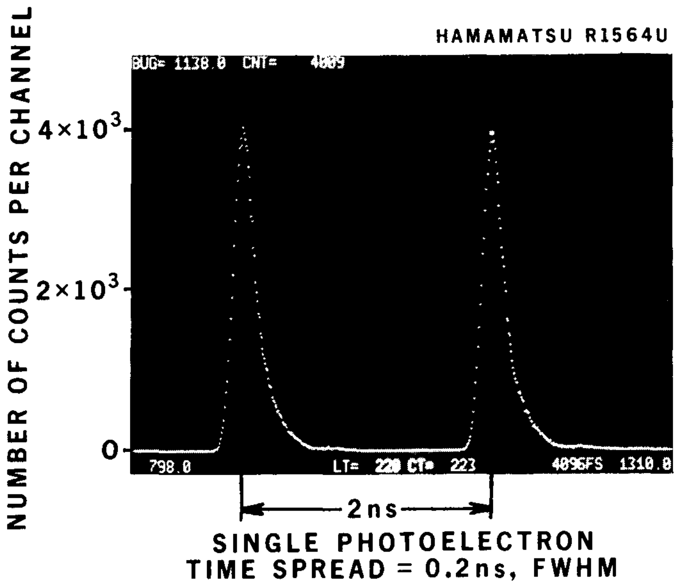

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Fig. 5. Single photoelectron time spread of the R1564U photomultiplier.

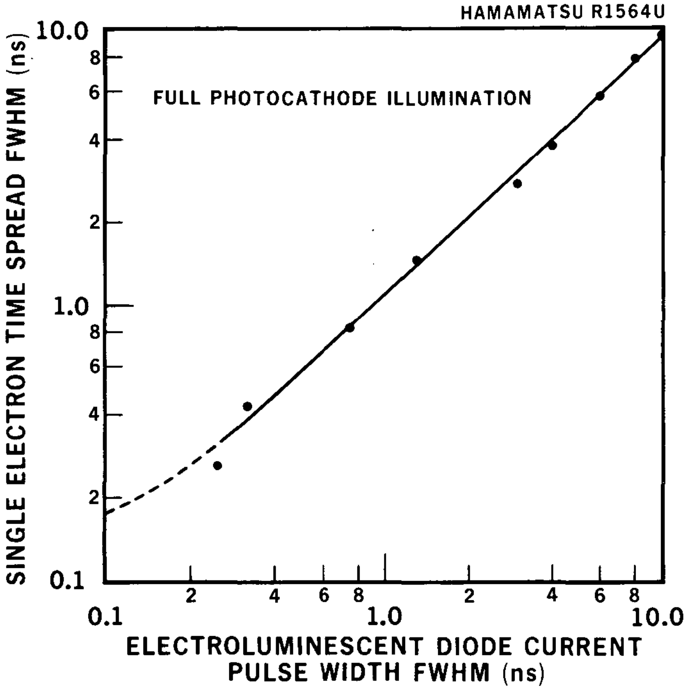

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Fig. 4. Single photoelectron time spread of the R1564U as a function of the width of the electroluminescent diode current pulse.

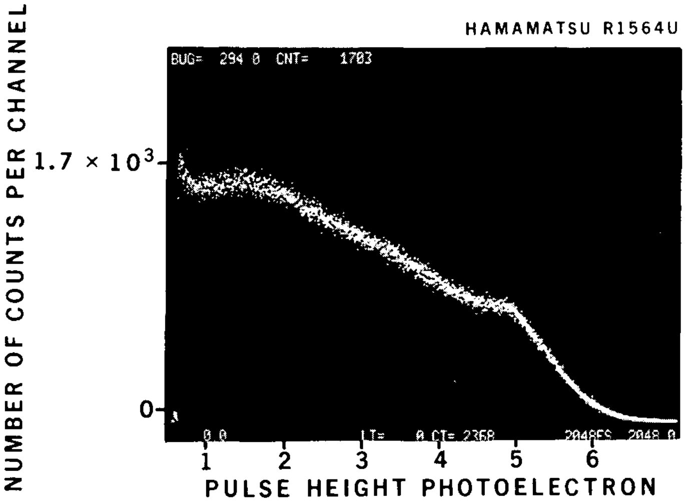

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Fig. 6. Pules-height spectrum of the R1564U photomultiplier.

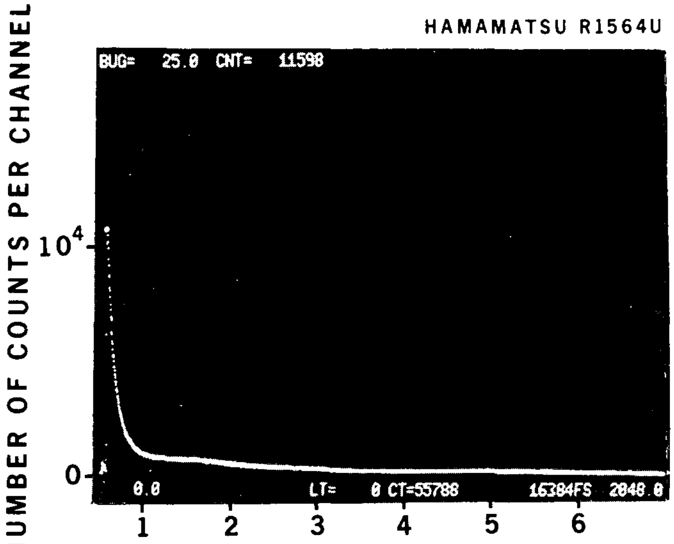

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Fig. 7. Typical dark pulse spectrum of the R1564U photomultiplier.

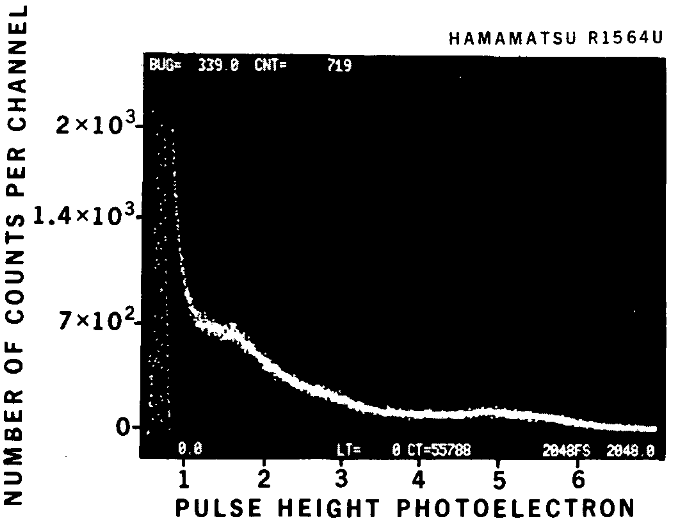

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Fig. 8. Dark pulse spectrum (expanded scale) of the R1564U photomultiplier.

LAWRENCE BERKELEY LABORATORY
TECHNICAL INFORMATION DEPARTMENT
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720