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PERFORMANCE STUDIES OF VARIAN VPM-154D.6D VPM-154A/1.6L STATIC CROSSED FIELD PHOTOMULTIPLIERS

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Table of Contents

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1. Summary

Characteristics have been measured for the Varian VPM-154D.6D and VPM-154A/1.6L Static Crossed Field Photomultipliers. Some typical photomultiplier characteristics - such as: gain, dark current, quantum efficiency, and rise-time - are compared with data provided by the manufacturer. Photomultiplier characteristics generally not available from the manufacturer, such as: transit time, FWHM of the output pulse, peak output current measurement and multiphotoelectron time resolution were measured and are discussed.

2. Introduction

The Varian VPM-154D.6D and VPM-154A/1.6L Static Crossed Field Photomultipliers being tested for NASA were both six-stage devices. The VPM-154D.6D has a S-20 photocathode with a sapphire window and has a maximum signal spot diameter of 0.25". The VPM-154A/1.6L has a 0.2" diameter InGaAsP photocathode. This photocathode should be stored and operated at temperatures below -10°C to preserve it from degradation, but the photomultiplier supplied to us by NASA had been at room temperature a long time and the photocathode had lost most of its sensitivity above 800 nm.

3. Quantum Efficiency Measurement

Both the VPM-154D.6D and VPM-154A/1.6L were tested for their quantum efficiency between 400 and 1060 nanometer. An EGG Radiometer, different detector heads and a thermopile detector were necessary to make the measurements through this spectral range. Figure 1 shows the quantum efficiency of the two crossed field photomultipliers. The VPM-154D.6D has a peak quantum efficiency of 17% at 500 nanometer dropping to .01% at approximately 870 nm. The VPM-154A/1.6L, which has the InGaAsP photocathode, exhibits a peak quantum efficiency of 6.4% at 500 nm dropping to .012% at approximately 800 nm where the Q.E. should be around 7%. Both devices failed to respond at 1.06 μm. At 900 nm 154D.6D has a Q.E. of 0.0012% and 154A/1.6L has a Q.E. of 0.0019% (not shown in graph).

4. Gain and Dark Current Measurements

Gain and dark current measurements were performed in the same way as described in Reference 1. To obtain the photocathode current in these two photomultipliers, the rail, dynodes and case were tied together and a positive voltage of 500V was applied to them. The photocathode was connected to ground through a picoammeter to read the photocathode current, which was used as the reference in the gain measurement. Figure 2 and 3 show the gain of VPM-154D.6D and VPM-154A/1.6L, respectively. The rail voltages used on the tube were optimized to yield the best gain performance. The VPM-154D.6D with a rail voltage of +800V, yielded a gain of 5.5×10^4 at 3300V; the dark current under these conditions was 1.3×10^{-7}A. The VPM-154A/1.6L, with a rail voltage of +650V, yielded a gain of 2.5×10^5 at 3700V; and a dark current of 7×10^{-10}A.

5. Electron Transit Time Measurement

The electron transit time of a photomultiplier is the time between a photon(s) incident on the photocathode and the occurrence of the anode output pulse. The measuring system used was similar to the one used in Reference 1. A light emitting diode (LED) provided the light pulse and the electrical pulse used to drive the LED was used as the reference pulse. The electrical pulse was divided into two parts for calibration purposes. An adjustable air line was used to bring the two pulses into coincidence on the oscilloscope hence establishing zero time reference. The VPM-154D.6D and VPM-154A/1.6L were then put in place, and the delays of the output signals were measured. After corrections for transit times due to cable lengths, etc., the tube transit times were found to be 10.5 ns for the VPM-154D.6D and 8.9 ns for the VPM-154A/1.6L. The transit time was observed to be independent to within a resolution of 80 ps over a dynamic range of light pulse intensity greater than 30:1.

6. Light Pulse Generator

Since the delta pulse response of the VPM-154D.6D and VPM-154A/1.6L are expected to be very fast, the light source for testing their response should be even faster, otherwise the measurements would not be on the detectors but the light source itself.

A solid state laser diode, RCA SG2001 was used in the Q-switched mode to generate the required light pulse. Figure 4 shows the solid state laser light pulse generator circuit diagram. A 5Ω strip line was used as the pulse forming line, and an avalanche transistor was used as a switch to generate the required electrical pulse. The 4.3Ω resistor serves as a current limiter as well as part of a 5Ω matching load. The other part of the 5Ω load was supplied by the forward-biased diode impedance.

A number of SG2001 diodes were tested and the one with the best response was selected to be used for these measurements. The d.c. supply to the avalanche transistor was adjusted to yield a single light pulse although in some cases the length of the 5Ω charging line had also to be changed. To test the light pulse structure an ITT photodiode, ITT 4014 with a S-1 photocathode, was used to view the light pulse output from the SG 2001. Figure 5 is the pulse output from the ITT 4014 as monitored on a sampling scope with a 38 ps risetime. The specified risetime of the ITT 4014 photodiode is 100 ps. In Figure 5 the 10-90% risetime of the pulse is 120 ps; hence, the light pulse risetime is approximately 55 ps after correction has been made for the photodiode and the oscilloscope risetimes; the light width at (full-width-at-half-maximum) is approximately 125 ps after correction for the ITT 4014 (S-1) pulse width has been made.

7. Pulse Response Measurements

Using this short light pulse, the delta function response of the VPM-154D.6D and VPM-154A/1.6L were measured by placing the laser diode close to the windows of the photomultiplier. Since the line emission of the laser diode is at 904 μm and the quantum efficiency of both VPM-154D.6D and VPM-154A/1.6L is below 0.002%, at this wavelength, large output signals were not expected from these two tubes. The outputs of the VPM-154D.6D and VPM-154A/1.6L tubes when operating at their maximum voltages are shown in Fig. 6 and Fig. 7, respectively. The 10-90% risetime and the FWHM pulse width of VPM-154D.6D are 320 ps and 400 ps, respectively, while those of the VPM-154A/1.6L are 260 ps and 400 ps, respectively.

8. Dependence of Time Resolution on the Light Pulse Intensity

The time resolution of the VPM-154D.6D and VPM-154A/1.6L were also measured with the mercury light pulse generator used in Reference 1. Since the photocathode of these two photomultipliers are approximately 0.25" diameter, and their gain is low in comparison to other photomultipliers it was necessary to increase the operating voltage and hence the width of the light pulse generator to obtain a light pulse of sufficient intensity. This was especially true for the VPM-154.6D which has a maximum gain of 5.5 x 10^4. Because of the fast risetime of the photomultipliers a piece of RG58U cable was used to decrease the risetime to approximately 800 ps before it was processed by the measuring system. The signal input to the constant fraction discriminator was kept constant by adjusting the gain of the HP8447F wideband amplifier. Figure 8 shows the time resolution of both the VPM-154D.6D and the VPM-154A/1.6L as a function of the number of photoelectrons per pulse. The 2.6 ns light pulse was used only on the VPM-154A/1.6L because the low gain of VPM-154D.6D made it impractical to generate the curve with the shorter light pulse. Using the 4 ns light pulse, with 3000 photoelectrons per pulse, the VPM-154D.6D has a time resolution of 67.5 ps at FWHM. With 760 photoelectrons per pulse, the VPM-154A/1.6L achieved a time resolution of 105 ps at FWHM.

Using the 2.6 ns light pulse, the VPM-154A/1.6L has a time resolution of 170 ps at FWHM with a 125-photoelectron pulse.

9. Single Photoelectron Measurements

Figure 9 shows the block diagram used for the measuring of the single photoelectron pulse response of the 154.A/1.6L. The signal was split into two parts: one was delayed by a delay line before entering the sampling lead of the HP141A; the other half was amplified by 40dB with an HP8447F amplifier and was used to trigger the sampling oscilloscope. The mean value of the output pulse amplitude was approximately 1.8mV. The risetime as shown in Fig. 10 was the total system risetime. Due to the low gains and fast risetimes of both the 154A/1.6L and 154D.6D photomultipliers it is difficult to make single photoelectron time resolution measurements with our present systems; hence, data on this subject will not be presented. However, multi-photoelectron time resolution has been reported elsewhere in the text.

10. Conclusion

The VPM-154D.6D and VPM-154A/1.6L perform as expected although the risetimes are slower than given in specification for similar photomultipliers. In the case of VPM-154A/1.6L the quantum efficiency was expected to be low especially in the red and infrared region, because the photocathode, which is supposed to be stored and operated around -10°C, was kept for a long period of time at room temperature. At room temperature the photocathode degenerated, resulting in the complete loss of responsivity above 800 nm.

11. Acknowledgments

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12. References

1. C. C. Lo, Pierre Lecomte, and B. Leskovar; Performance Studies of Prototype Microchannel Plate Photomultipliers, IEEE Transaction on Nuclear Science Symposium, Vol. NS-24, No. 1, February 1977, pp. 302-311.

13. Figure Captions

Fig. 1 Quantum efficiency as a function of wavelength for Varian VPM-154D.6D and VPM-154A/1.6L photomultipliers.

Fig. 2 D.C. gain and dark current as a function of the voltage between anode and cathode for VPM-154D.6D photomultiplier.

Fig. 3 D.C. gain and dark current as a function of the voltage between anode and cathode for VPM-154A/1.6L photomultiplier.

Fig. 4 Schematic diagram of the injection laser light pulse generator.

Fig. 5 Output pulse from an ITT 4014 photodiode using impulse excitation from an RCA SG 2001 Solid State Laser Diode. The vertical scale is 1mV per division and the horizontal scale is 100 ps per division.

Fig. 6 Delta function response of the VPM-154D.6D photomultiplier.

Fig. 7 Delta function response of the VPM-154A/1.6L photomultiplier.

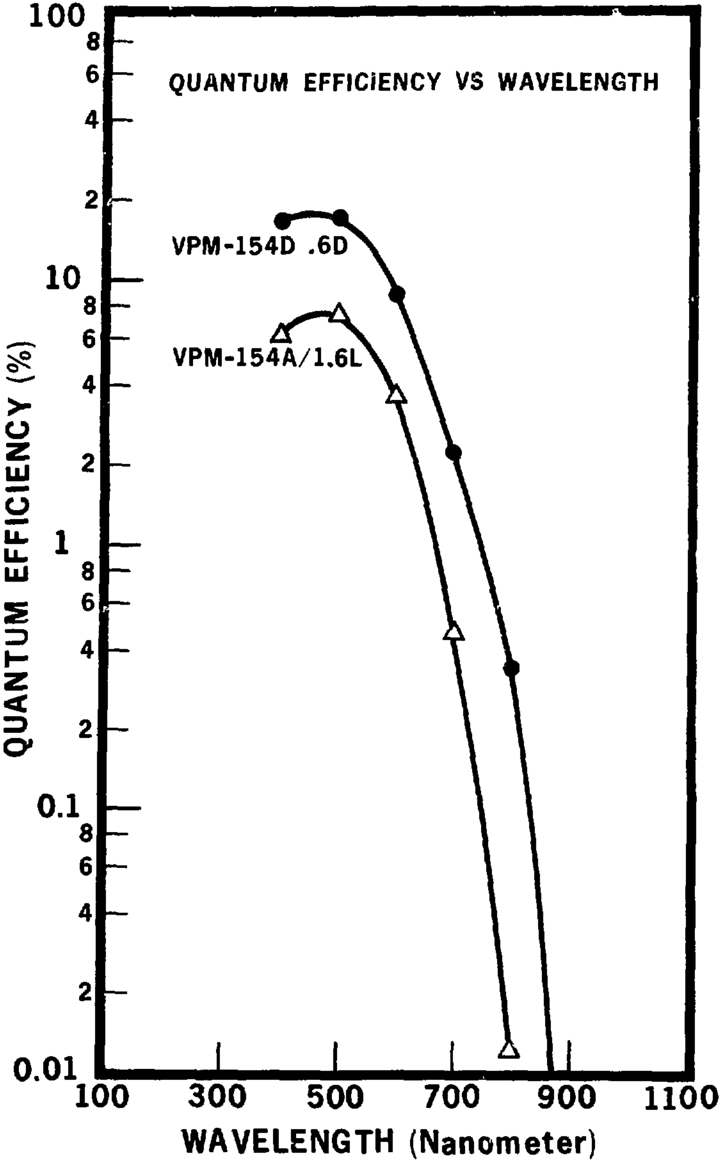
Fig. 8 Time resolution of the VPM-154D.6D and VPM-154A/1.6L photomultipliers as a function of number of photoelectrons per pulse, measured with 2.6 ns and 4 ns light pulse widths for full photocathode illumination.

Fig. 9 Block diagram of the system for measuring the single photoelectron response.

Fig. 10 Typical single photoelectron pulses from the VPM-154A/1.6L.

Fig. 11 Peak anode pulse amplitude as a function of light transmission of the optical attenuator for VPM-154D.6D photomultiplier.

Fig. 12 Peak anode pulse amplitude as a function of light transmission of the optical attenuator for VPM 154A/1.6L photomultiplier.



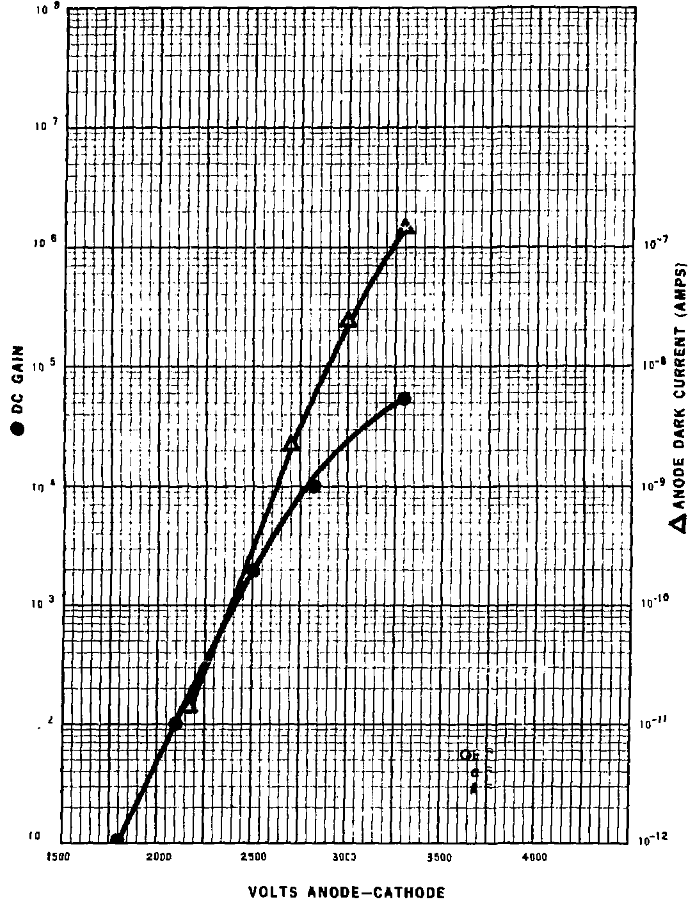
XBL 778-9851

Fig. 1

TUBE TYPE **VPM-154D .6D**

$V_R = +800V$

SERIAL NUMBER **058** DATE



X___ FRONT. X___ DIVIDER

RL-3930

XBL 778-9852

Fig. 2

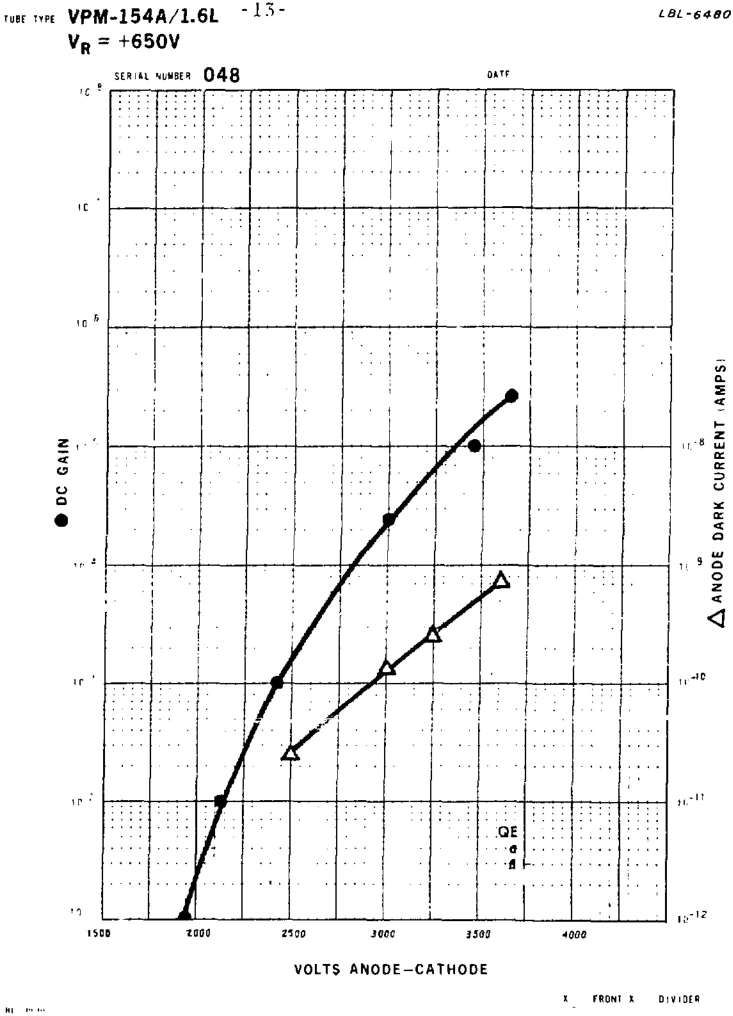


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Fig. 3

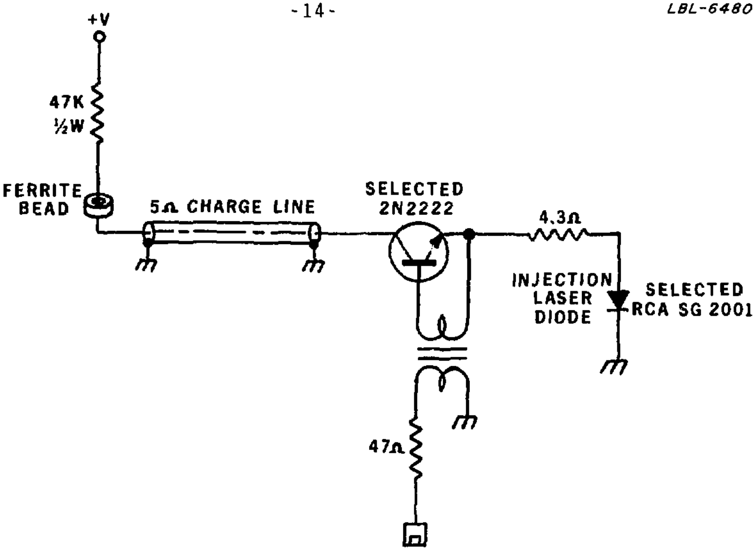

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Fig. 4

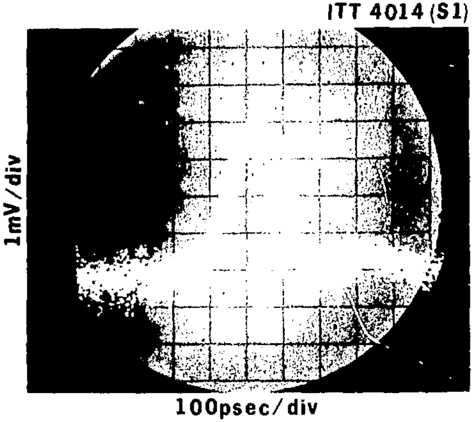

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Fig. 5

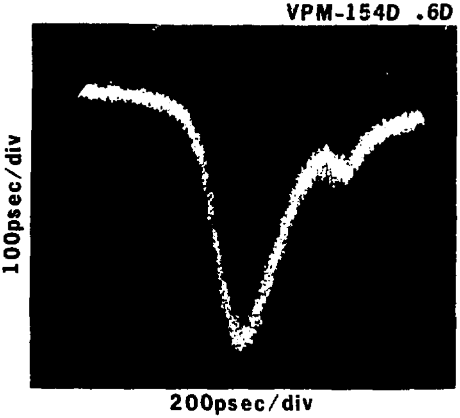

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Fig. 6

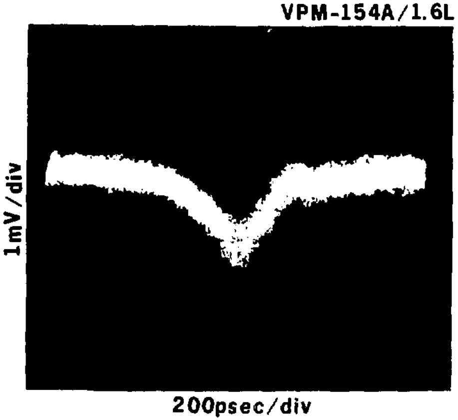

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Fig. 7

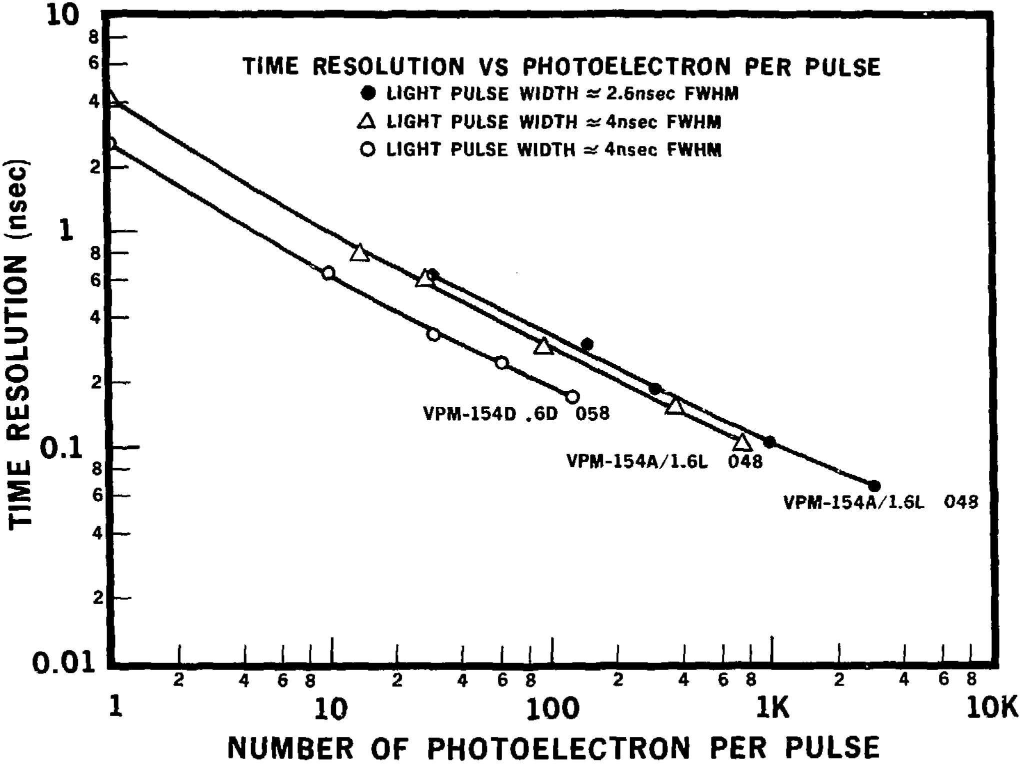

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Fig. 8

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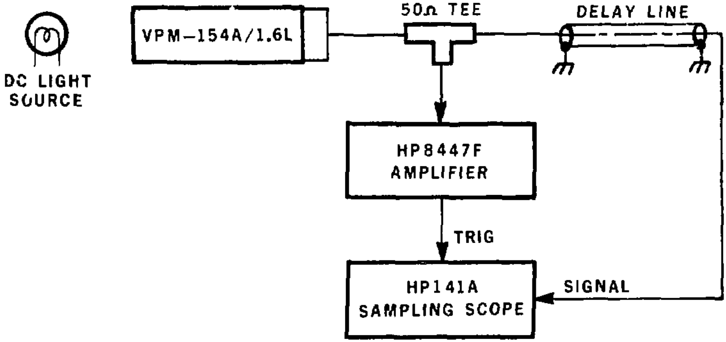

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Fig. 9

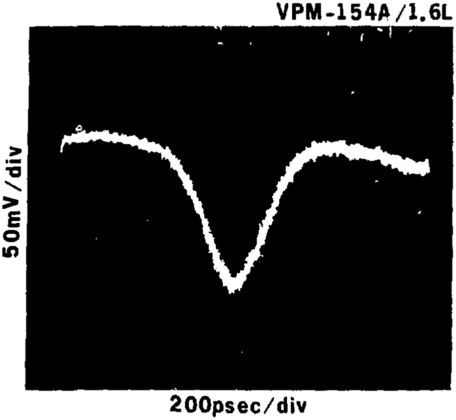

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Fig. 10

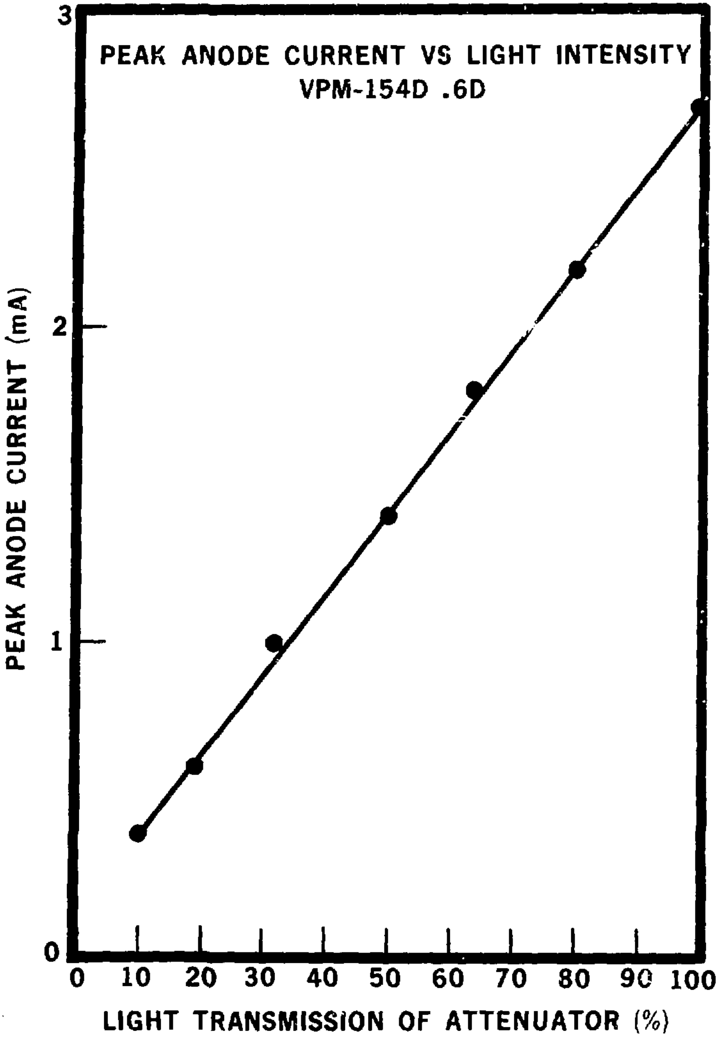

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Fig. 11

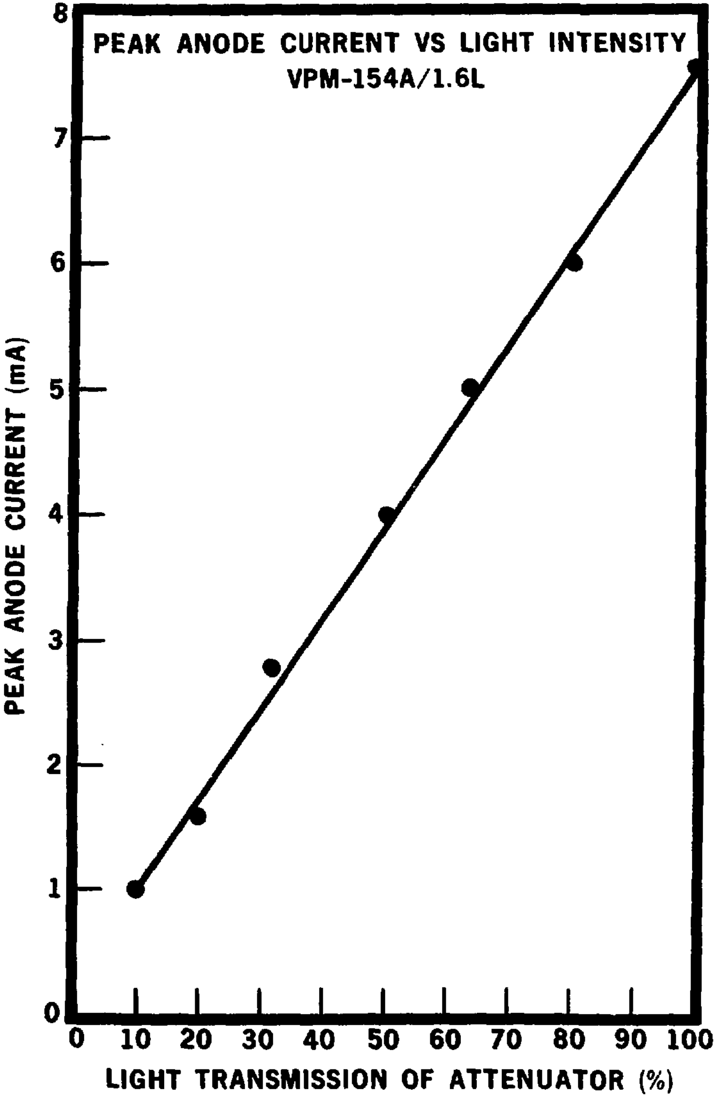

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Fig. 12