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LBL 5328

Evaluation of the Amperex 56 TVP Photomultiplier

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Summary

Characteristics have been measured for the Amperex 56 TVP 42-mm-diameter photomultiplier. Some typical photomultiplier characteristics -- such as gain, dark current, transit and rise times -- are compared with data provided by the manufacturer. Photomultiplier characteristics generally not available from the manufacturer, such as the single photoelectron time spread, the relative collection efficiency, the relative anode pulse amplitude as a function of the voltage between the photocathode and focusing electrode, and the position of the photocathode sensing area were measured and are discussed for two 56 TVP's. The single photoelectron time spread, the relative collection efficiency, and the transit time difference as a function of the voltage between photocathode and focusing electrode were also measured and are discussed, particularly with respect to the optimization of photomultiplier operating conditions for timing applications.

Introduction

Amperex 56 TVP is a fourteen-stage photomultiplier having a S20 photocathode with a peak response at 420 ± 30 nm. The useful diameter of the photocathode is approximately 42 mm. This photomultiplier has been used in the receiver subsystem for the NASA satellite laser ranging work at the Goddard Space Flight Center.[1] The photomultiplier combines a number of characteristics useful in ranging applications, such as high

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gain, high output current capability, gating capability, and low cost. All measurements described in this report were made with the NASA modified manufacturer's voltage divider, shown in Fig. 1, with an applied voltage of +20 V between the photocathode and the focusing electrode. It was found experimentally that at this potential the photomultiplier parameters, such as the single photoelectron time spread and the relative collection efficiency, have their optimum values. In the case of the dc gain and dark current measurements, the voltage divider was slightly modified to allow the focusing electrode voltage to have a value that was approximately equal to 0.05 times the voltage between the photocathode and the first dynode. This was done so that the measured photomultiplier characteristic can be more easily compared with the manufacturer's specifications.

Gain and Dark Current Measurements

Measurements of gain and dark current were made with the system described in Ref. 2. Figure 2 shows the gain and dark current characteristics of the photomultiplier as functions of voltage applied between cathode and anode. Both photomultipliers have very similar dc gain characteristics. The measured gain was 1×10^8 at 2500 V. The measured dark currents at 2500 V were 3.5×10^{-8} and 5.5×10^{-8} A for serial numbers 31216 and 31223, respectively. The dark current of the 31223 photomultiplier showed a strong internal dc leakage current component, particularly at lower applied voltages. An external cleaning of the photomultiplier did not decrease the dc leakage current component. The Amperex data under these voltage conditions and at an ambient temperature of 25° C for the gain and dark current are 1×10^{8} and 5×10^{-6} A (maximum value), respectively.

<u>Single Photoelectron Time Spread and Relative Collection Efficiency Measurements</u>

The amount of electron transit time spread of a photomultiplier depends upon photomultiplier geometric characteristics, its operating conditions, and the number of photoelectrons released from the photocathode. Since the time spread varies approximately inversely as the square root of the number of photoelectrons, the time-behavior information of single photoelectrons is particularly helpful in predicting the transit time spread for an arbitrary number of photoelectrons. Furthermore, it is also helpful in the evaluation, selection, and comparison of photomultipliers, as well as in determining the optimum operating conditions in critical timing applications.[3]

In addition to the single photoelectron time spread, the relative collection efficiency also is an important photomultiplier parameter. Relative collection efficiency is the ratio between the efficiency of counting light pulses at a given potential between the photocathode and the focusing electrode and the efficiency of counting light pulses at optimum potential between the photocathode and the focusing electrode. The collection efficiency varies with the voltage between the photocathode and focusing electrode, and its value can be optimized for a photomultiplier. However, the voltage value which maximizes relative collection efficiency does not necessarily minimize the single photoelectron time spread. To determine the optimum photomultiplier operating conditions, including the effect of the voltage between the photocathode and the focusing electrode, measurements were made by using the system described in Ref. 3. Single photoelectron time spread, relative collection efficiency, and transit time difference were measured as functions of the voltage value between the photocathode and the focusing electrode. Results of the measurements are shown in Figs. 3A and 3B for the 56 TVP photomultipliers serial numbers 31216 and 31223, respectively. The effects of the focusing electrode voltage on the single photoelectron time spread and the relative collection efficiency are shown as solid curves, and the dashed curves represent typical transit time differences. All measurements were made with full photocathode illumination.

Figures 3A and 3B show that the single photoelectron time spread has a value, FWHM, of 720 psec and 780 psec for photomultiplier serial numbers 31216 and 31223, respectively, with 20 V between the photocathode and the focusing electrode. The time spread amounts can be only slightly decreased by increasing this voltage. Furthermore, the relative collection efficiency has a maximum value for a voltage of 20 V between the photocathode and the focusing electrode. Consequently, for both photomultipliers, the photoelectron time spread can be easily optimized without a significant deterioration of collection efficiency.

Using the same measuring system, the single photoelectron time spread was measured as a function of the position of the light flash on the photocathode. A light-emitting diode, the Ferranti XP-23, driven by an avalanche transistor pulse generator, was used as a light source. A positioning disc with overlapping 5-mm holes spaced 4.5 mm apart was attached to the photomultiplier window, along lines parallel to and perpendicular to the long axis of the first dynode.

To prevent the electromagnetic field of the light pulser from interfering with photomultiplier operation, a 12-inch-long American Optical LG 3 light guide was used to guide the light pulse to the photocathode. Whenever a particular area of the photocathode was to be illuminated, the light guide was placed in a corresponding hole of the positioning disc. Successive scanning was done along X and Y axes, with the longer side of the rectangular first dynode as the X axis. Exact position designations of the first dynode are given in Figs. 4A and 4B. The illuminated area of the photocathode was no larger than 1.6 mm in diameter. Figures 4A and 4B show photoelectron time spread as a function of the position of the photocathode sensing area along the X and Y axis for the 56 TVP photomultiplier, serial numbers 31216 and 31223. These figures show that the single photoelectron time spread variation is less than $^{-0.023}_{-0.085}$ nsec and $^{+0.035}_{-0.088}$ nsec, respectively, within 18 mm of the center of the photocathode. Furthermore, these figures show that the time spread variation is less than $^{+0.173}_{-0.085}$ nsec and $^{+0.062}_{-0.088}$ nsec, respectively, within 22.5 mm of the center of the photocathode.

Relative collection efficiency was also measured as a function of the position of the photocathode sensing area by using the same system. The light pulser, the fiber optics light guide, and the positioning disc were the same as for the transit time spread measurements. Results of the measurements are shown in Figs. 5A and 5B for photomultiplier serial numbers 31216 and 31223. These figures show that the relative collection efficiency variation is less than $^{+0.44}_{-0.31}$ nsec and $^{+0.42}_{-0.34}$ nsec, respectively, within 22.5 mm of the center of the photocathode.

Relative Anode Pulse Amplitude Measurements

These measurements give information on the product of quantum efficiency and collection efficiency at various illuminated areas of the photocathode. A description and a block diagram of the system for measuring the relative anode pulse amplitude are given in Ref. 3. The same light pulser, fiber optics light guide, and positioning disc were used as in the case of the transit time spread measurements. Results of these measurements are given in Figs 6A and 6B for photomultiplier serial numbers 31216 and 31223, respectively. The solid curves show the relative pulse amplitude obtained when the photomultipliers were scanned with a light spot in a direction perpendicular to the first dynode and through the center of the photocathode. Light pulse amplitude was kept constant during the measurements. The dashed curves are a result of scanning in a direction parallel to the first dynode. Figures 6A and 6B show that the relative pulse amplitude varies less than 2 to 1 for a distance ±22.5 mm, measured from the center of the photocathode of photomultiplier serial numbers 31216 and 31223. The largest anode pulse variations occurred at the edge of the photocathode, primarily because of reduced collection efficiency.

In addition to the relative anode pulse amplitude measurements, the transit time dependence on anode pulse amplitude was also measured. The anode output pulse of the photomultipliers was adjusted to have an amplitude of 5 V. By using neutral density filters in front of the photocathode, the output anode pulse amplitude was reduced to 500-mV levels, with the 56 TVP operating voltage fixed at 2500 V. There was no transit time dependence observed as a function of the input light signal level. The small amount of time walk measured as a function of the input light amplitude was due entirely to the time walk and resolution characteristics of the timing constant-fraction discriminator used in the measuring system.

Single Photoelectron Pulse Response

The single photoelectron pulse response of the Amperex 56 TVP was measured by using the system described in Refs. 3 and 4. The photomultiplier was operated at 2500 V. Before the single photoelectron pulse response measurement was made, the system rise time was measured and found to be 400 psec, with a 28-psec rise time tunnel diode pulse generator as the signal source. Figure 7 shows the single photoelectron pulse shape obtained by using 200-psec light impulse excitation from the Ferranti XP-23 electroluminescent diode biased in the reverse direction. The single photoelectron pulse risetime and pulse width (FWHM) were 1.8 ±0.1 and 2 ±0.2 nsec, respectively.

Dark-Pulse Spectrum Measurements

Dark-pulse spectrum measurements were made by using the system described in Ref. 2. The spectrum is shown in Fig. 8. As expected, the photomultiplier pulse height resolution is not good enough to show one, two, and three photoelectron peaks in the measured spectrum. The dark-pulse summation, taken from 1/8 photoelectron to 16 photoelectrons, was also measured, at a photomultiplier temperature of 24°C. Calibration of the 1/8-photoelectron point was made with an RCA 8850, whose high pulse height resolution made the calibration possible.[6] The dark-pulse count for the photomultiplier serial number 31216 was found to be

$$\sum_{1/8 \text{ photoelectron}}^{16 \text{ photoelectrons}} \approx 40 \times 10^3 \text{ counts per second.}$$

For the photomultiplier serial number 31223 the dark-pulse count was

$$\sum_{1/8 \text{ photoelectron}}^{16 \text{ photoelectrons}} \approx 12 \times 10^3 \text{ counts per second.}$$

Throughout calibration and measurements both photomultipliers were operated with +20 V between the photocathode and the focusing electrode.

Conclusions

Our measurements of single photoelectron time spread and relative collection efficiency have shown that there is a strong dependence for this type of photomultiplier on the potential between the photocathode and the focusing electrode. The photomultiplier optimum operating conditions that minimize the photoelectron time spread and maximize the relative collection efficiency were found to be at a voltage of approximately +20 V between the photocathode and the focusing electrode, for the supply voltage of 2500 V. The average dark-pulse count for the two photomultipliers was 26 × 10^3 counts per second at a temperature of 24°C.

Acknowledgments

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References

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2. C. C. Lo and B. Leskovar, Evaluation of the 8850 Photomultiplier with Cesiated Gallium Phosphide First Dynode, Lawrence Berkeley Laboratory Engineering Note EE-1383, 1971.
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6. B. Leskovar and C. C. Lo, Performance Studies of Photomultipliers Having Dynodes with GaP(Cs) Secondary Emitting Surface, IEEE Trans. Nucl. Sci. NS-19, No. 3, 50-62 (1972).

Figure Captions

Fig. 1. Schematic diagram of divider used in the measurements.

Fig. 2. Gain and dark current as a function of voltage between anode and cathode.

Fig. 3A. Single photoelectron time spread, relative collection efficiency, and transit time difference as functions of voltage between photocathode and focusing electrode for Amperex 56 TVP photomultiplier, serial number 31216.

Fig. 3B. Single photoelectron time spread, relative collection efficiency, and transit time difference as functions of voltage between photocathode and focusing electrode for Amperex 56 TVP photomultiplier, serial number 31223.

Fig. 4A. Single photoelectron time spread as a function of the position of the photocathode sensing area, for Amperex 56 TVP photomultiplier, serial number 31216.

Fig. 4B. Single photoelectron time spread as a function of the position of the photocathode sensing area for Amperex 56 TVP photomultiplier, serial number 31223.

Fig. 5A. Relative collection efficiency as a function of the position of the photocathode sensing area for Amperex 56 TVP photomultiplier, serial number 31216.

Fig. 5B. Relative collection efficiency as a function of the position of the photocathode sensing area for Amperex 56 TVP photomultiplier, serial number 31223.

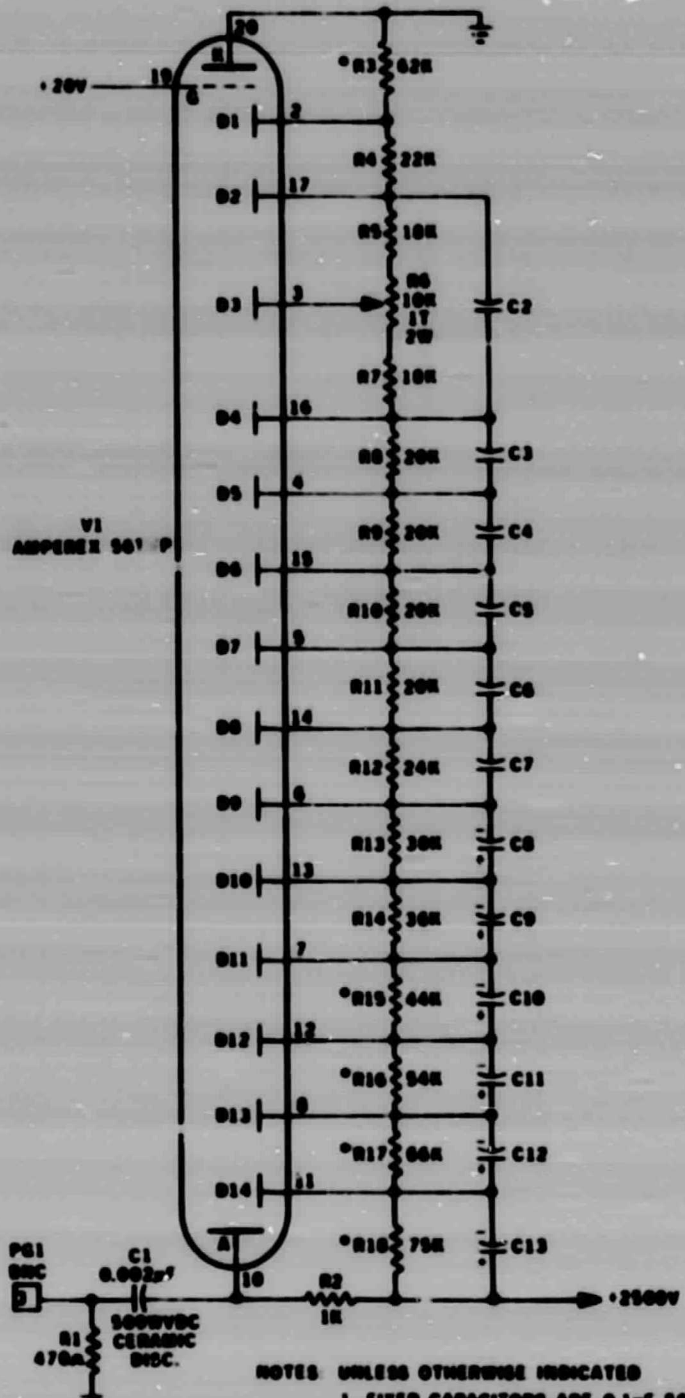
Figure Captions (cont'd.)

Fig. 6A. Relative anode pulse amplitude as a function of the position of the photocathode sensing area for Amperex 56 TVP photomultiplier, serial number 31216.

Fig. 6B. Relative anode pulse amplitude as a function of the position of the photocathode sensing area for Amperex 56 TVP photomultiplier, serial number 31223.

Fig. 7. Single photoelectron pulses from an Amperex 56 TVP operated at 2500 V, using 200-psec impulse excitation from the Ferranti XP23 electroluminescent diode in the reverse direction.

Fig. 8. Dark-pulse height spectrum.



NOTES: UNLESS OTHERWISE INDICATED
1 FIXED CAPACITORS ARE 0.1µF 500WVDC CERAMIC DISC
2 POLARIZED CAPACITORS ARE 4µF 450VDC ELECTROLYTIC
3 RESISTORS ARE 1W 5% CARBON COMPOSITION
*4 RESISTORS ARE 2W 5% CARBON COMPOSITION

XBL 767 8715

Fig. 1

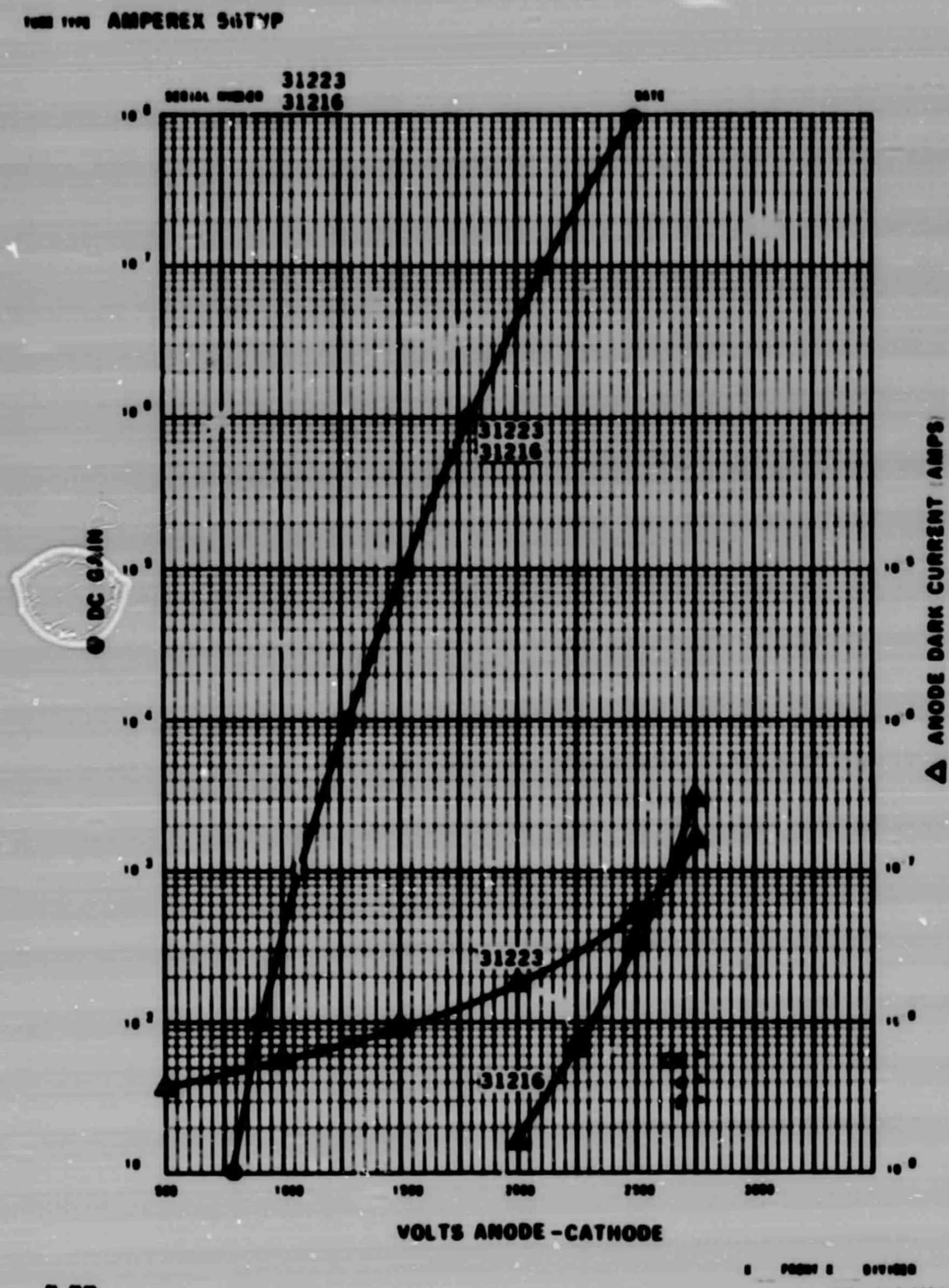
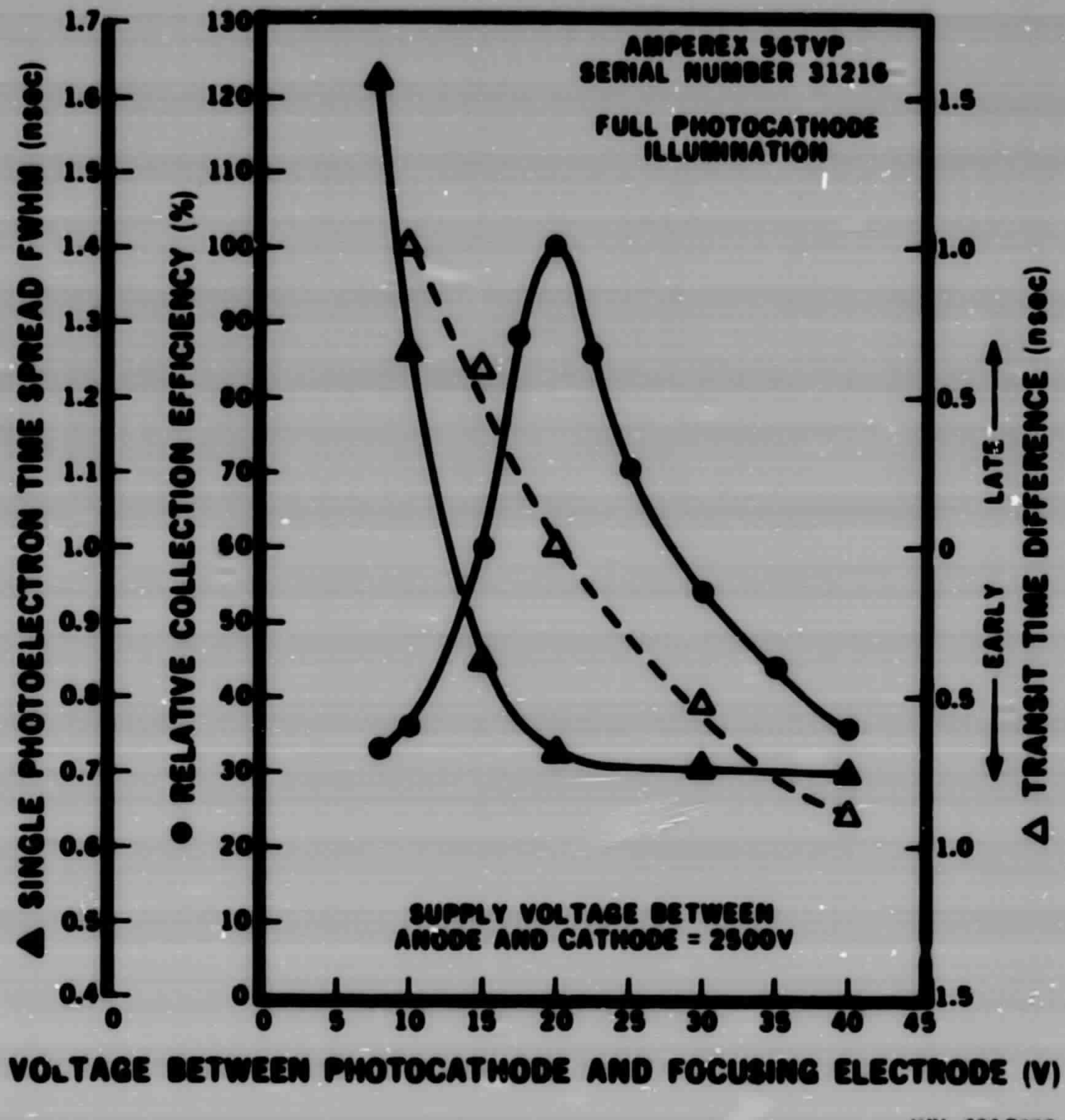
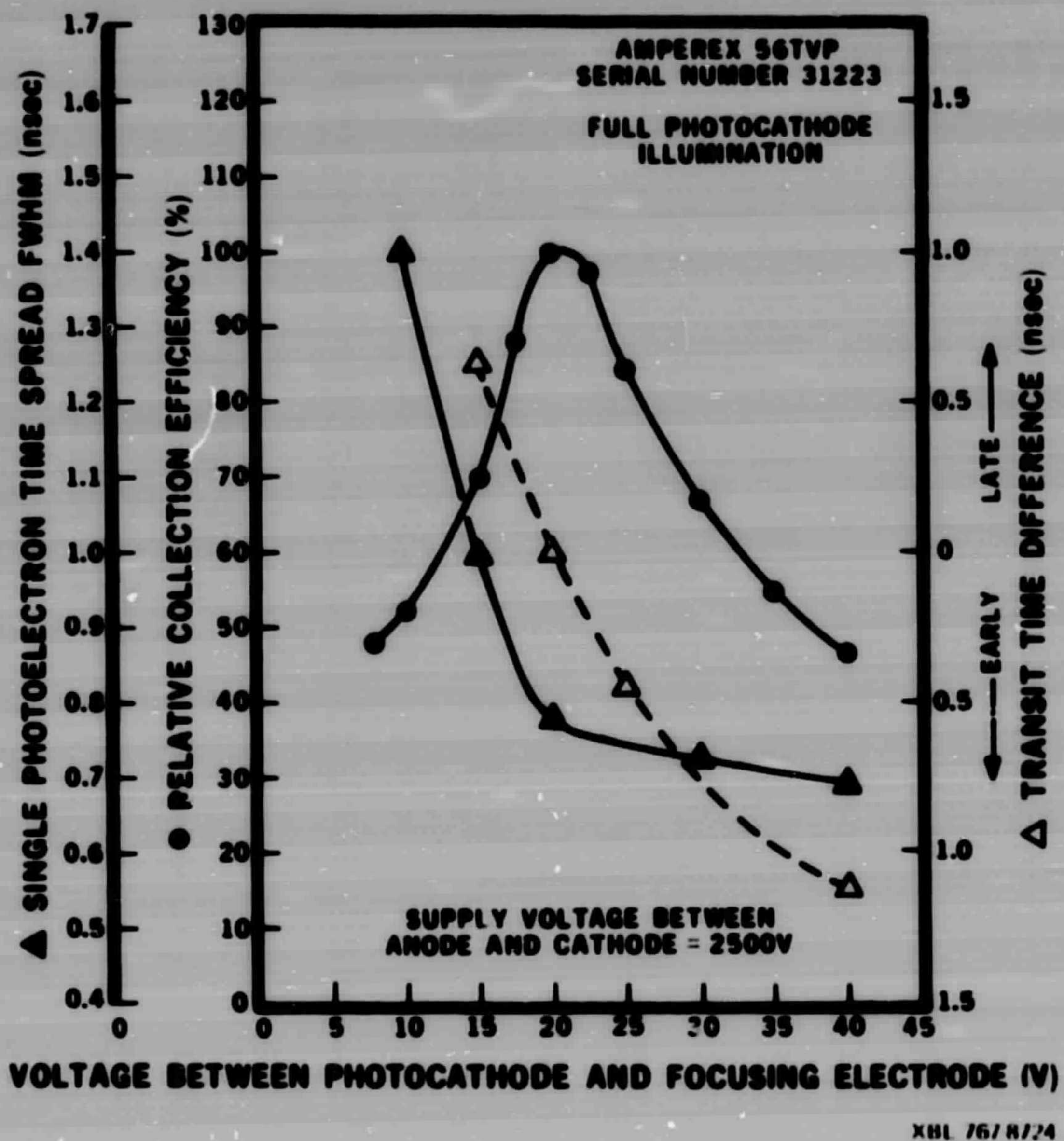

31223
31216
DC GAIN
ANODE DARK CURRENT (AMPS)
VOLTS ANODE-CATHODE

Fig. 2



AMPEREX 56TVP
SERIAL NUMBER 31216
FULL PHOTOCATHODE ILLUMINATION
SUPPLY VOLTAGE BETWEEN ANODE AND CATHODE = 2500V
▲ SINGLE PHOTOELECTRON TIME SPREAD FWHM (nsec)
● RELATIVE COLLECTION EFFICIENCY (%)
△ TRANSIT TIME DIFFERENCE (nsec)
EARLY
LATE
VOLTAGE BETWEEN PHOTOCATHODE AND FOCUSING ELECTRODE (V)
XBL 767 8723

Fig. 3 A



AMPEREX 56TVP
SERIAL NUMBER 31223
FULL PHOTOCATHODE ILLUMINATION
SUPPLY VOLTAGE BETWEEN ANODE AND CATHODE = 2500V
▲ SINGLE PHOTOELECTRON TIME SPREAD FWHM (nsec)
● RELATIVE COLLECTION EFFICIENCY (%)
△ TRANSIT TIME DIFFERENCE (nsec)
EARLY
LATE
VOLTAGE BETWEEN PHOTOCATHODE AND FOCUSING ELECTRODE (V)
XBL 767 8724

Fig. 3 B

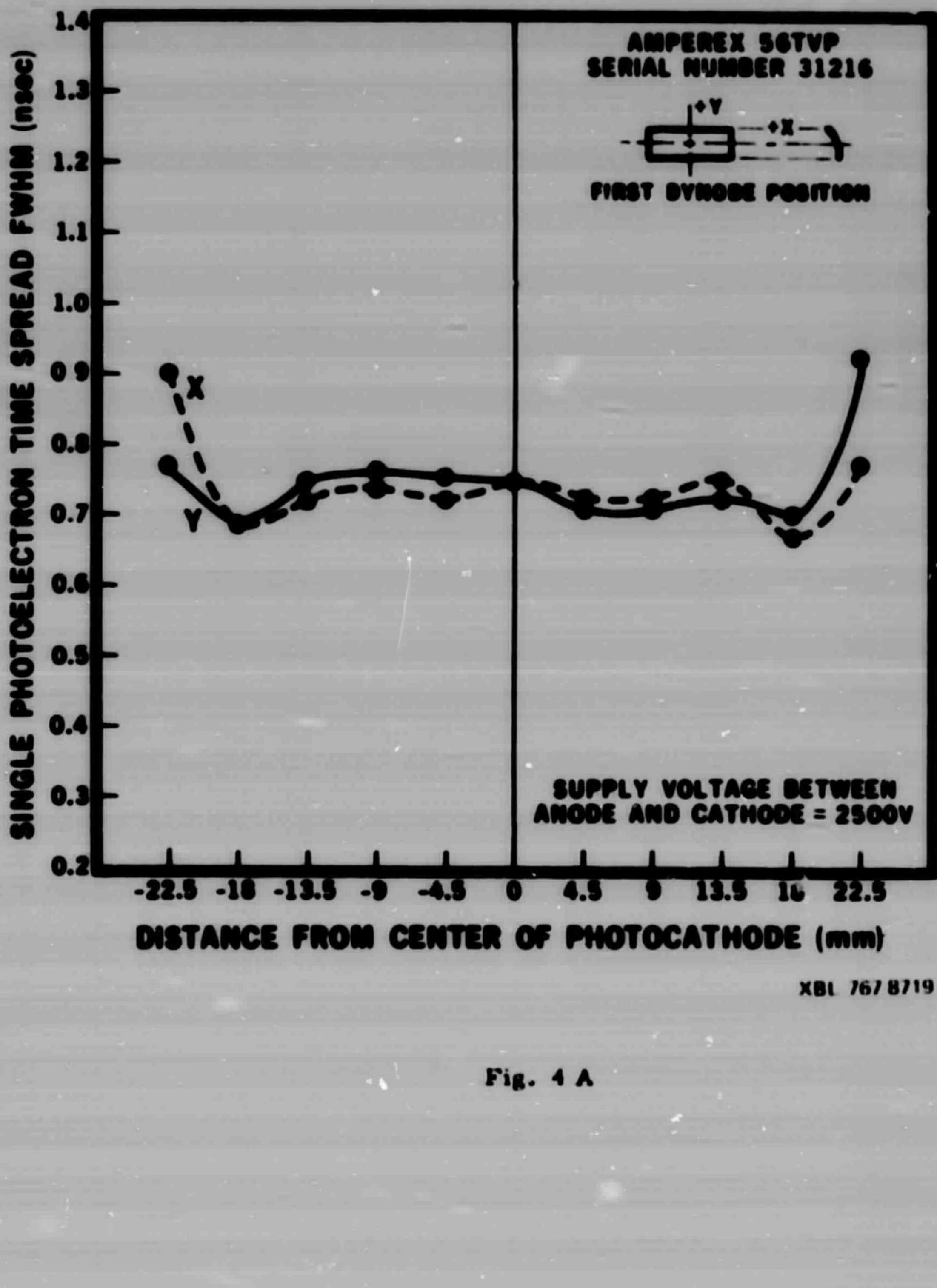
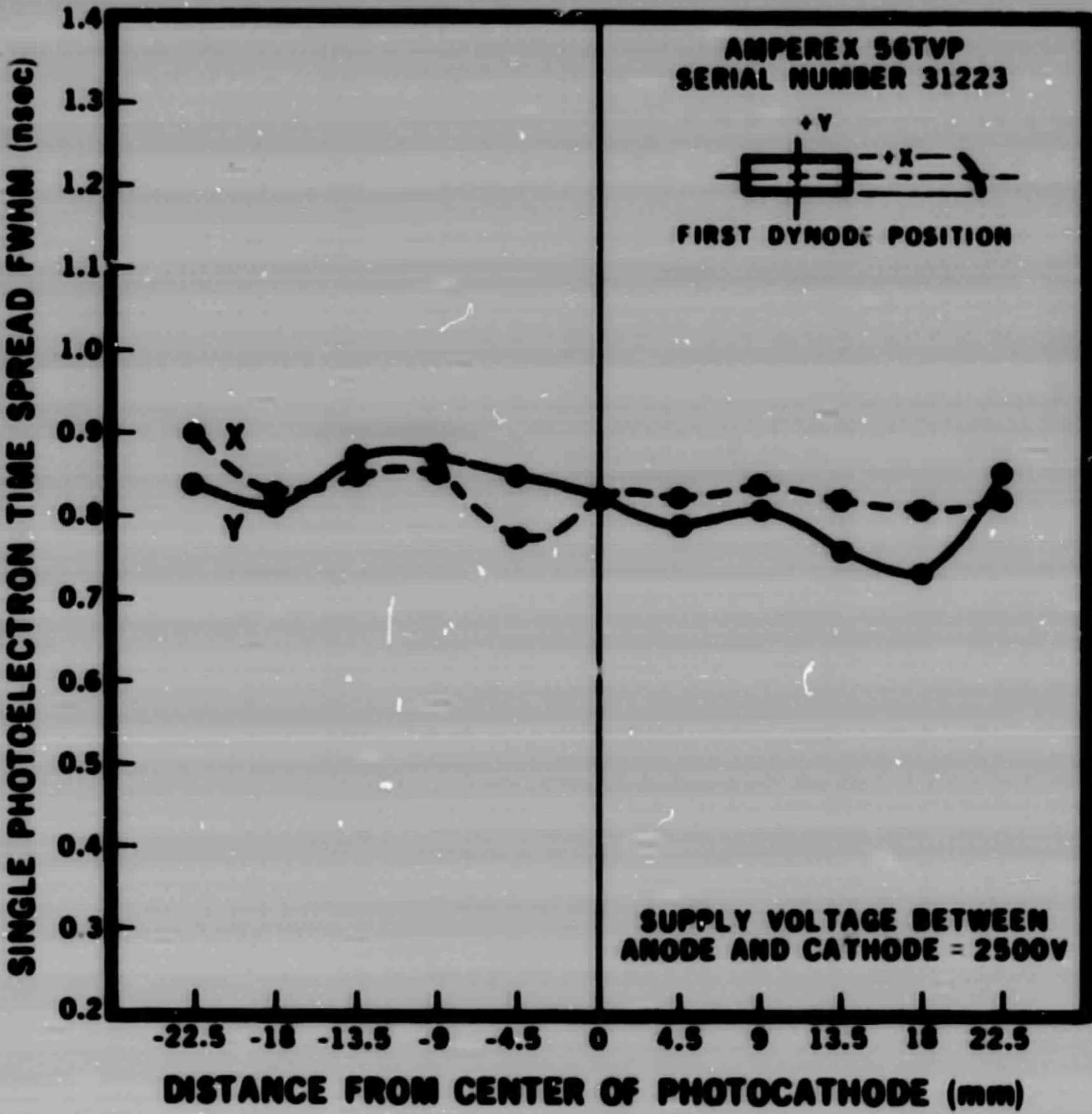
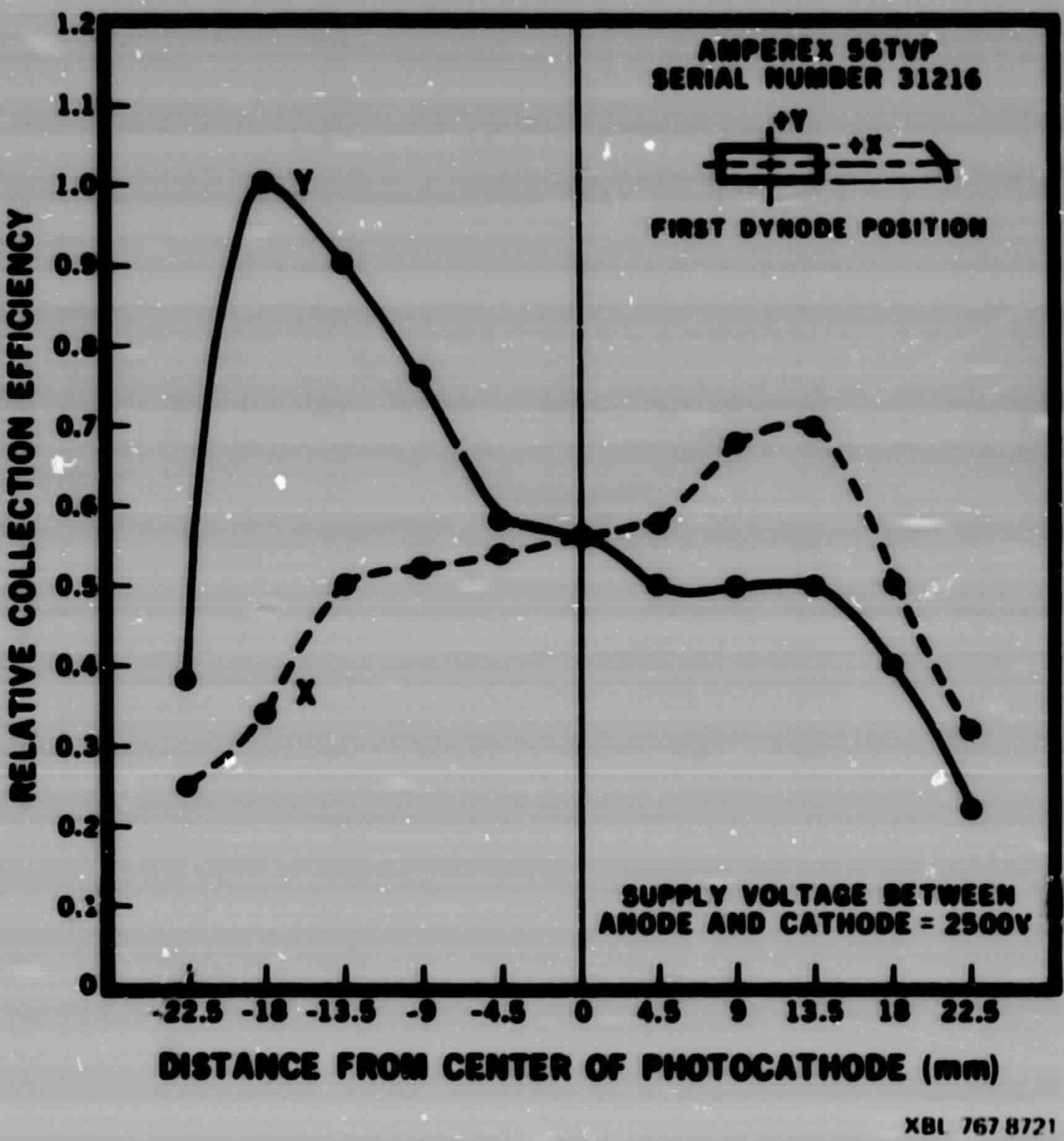

AMPEREX 56TVP
SERIAL NUMBER 31216
+Y
+X
FIRST DYNODE POSITION
SUPPLY VOLTAGE BETWEEN
ANODE AND CATHODE = 2500V
X
Y
SINGLE PHOTOELECTRON TIME SPREAD FWHM (nsec)
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
-22.5
-18
-13.5
-9
-4.5
0
4.5
9
13.5
18
22.5
DISTANCE FROM CENTER OF PHOTOCATHODE (mm)
XBL 767 8719

Fig. 4 A



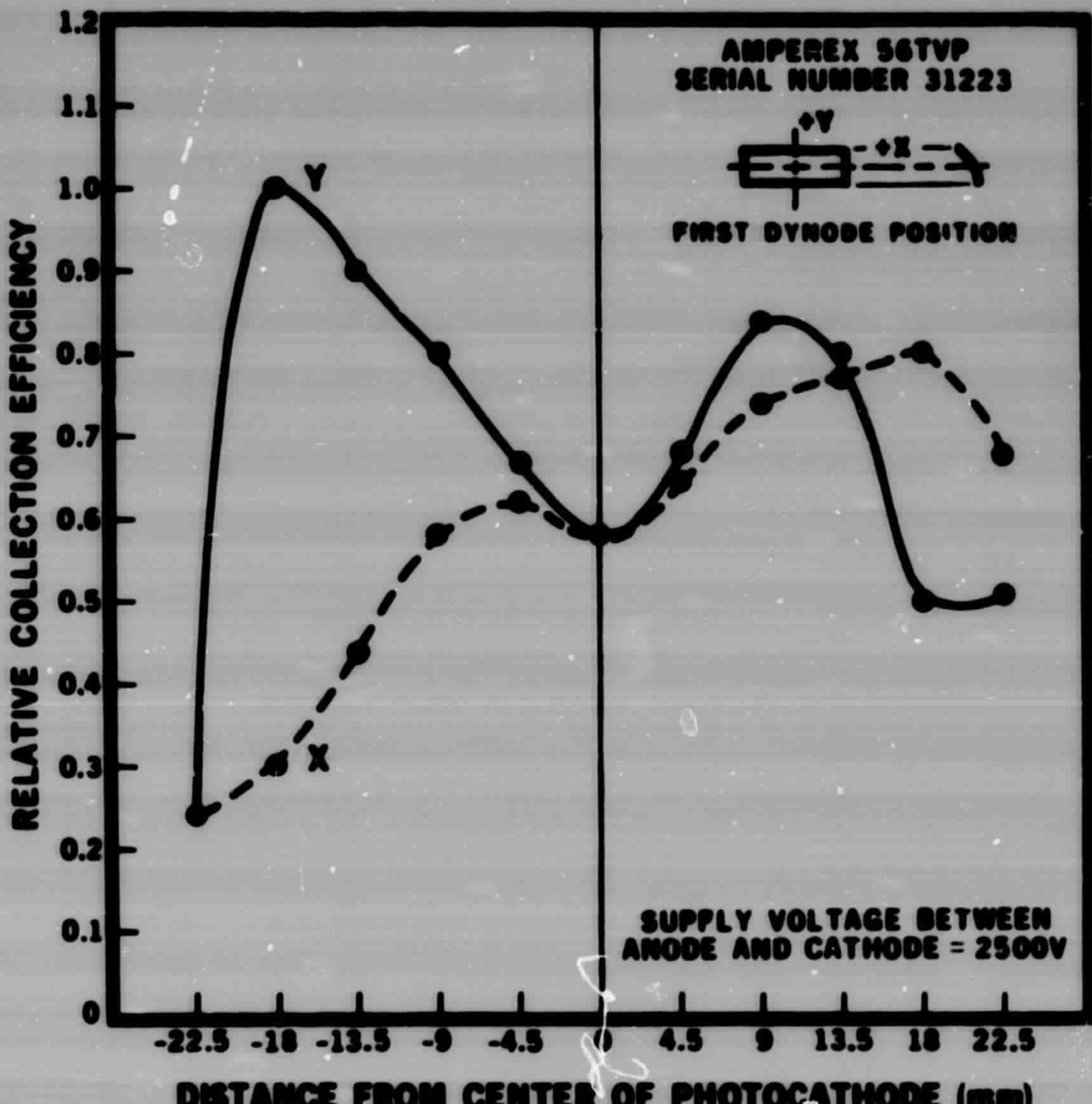
XBL 767 8720

Fig. 4 B



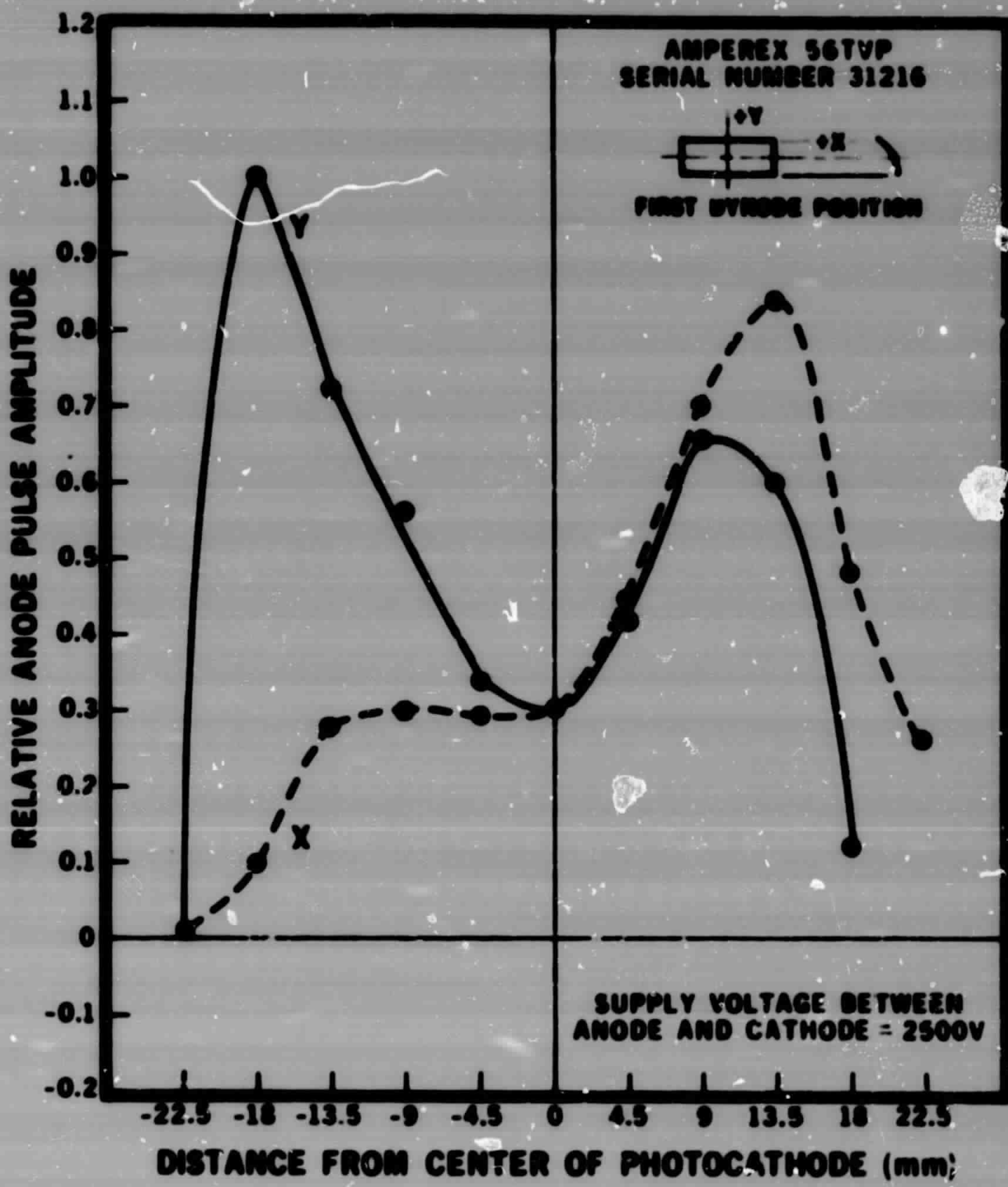
AMPEREX 56TVP
SERIAL NUMBER 31216
+Y
+X
FIRST DYNODE POSITION
Y
X
SUPPLY VOLTAGE BETWEEN
ANODE AND CATHODE = 2500V
RELATIVE COLLECTION EFFICIENCY
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-22.5 -18 -13.5 -9 -4.5 0 4.5 9 13.5 18 22.5
DISTANCE FROM CENTER OF PHOTOCATHODE (mm)
XBL 767 8721

Fig. 5 A



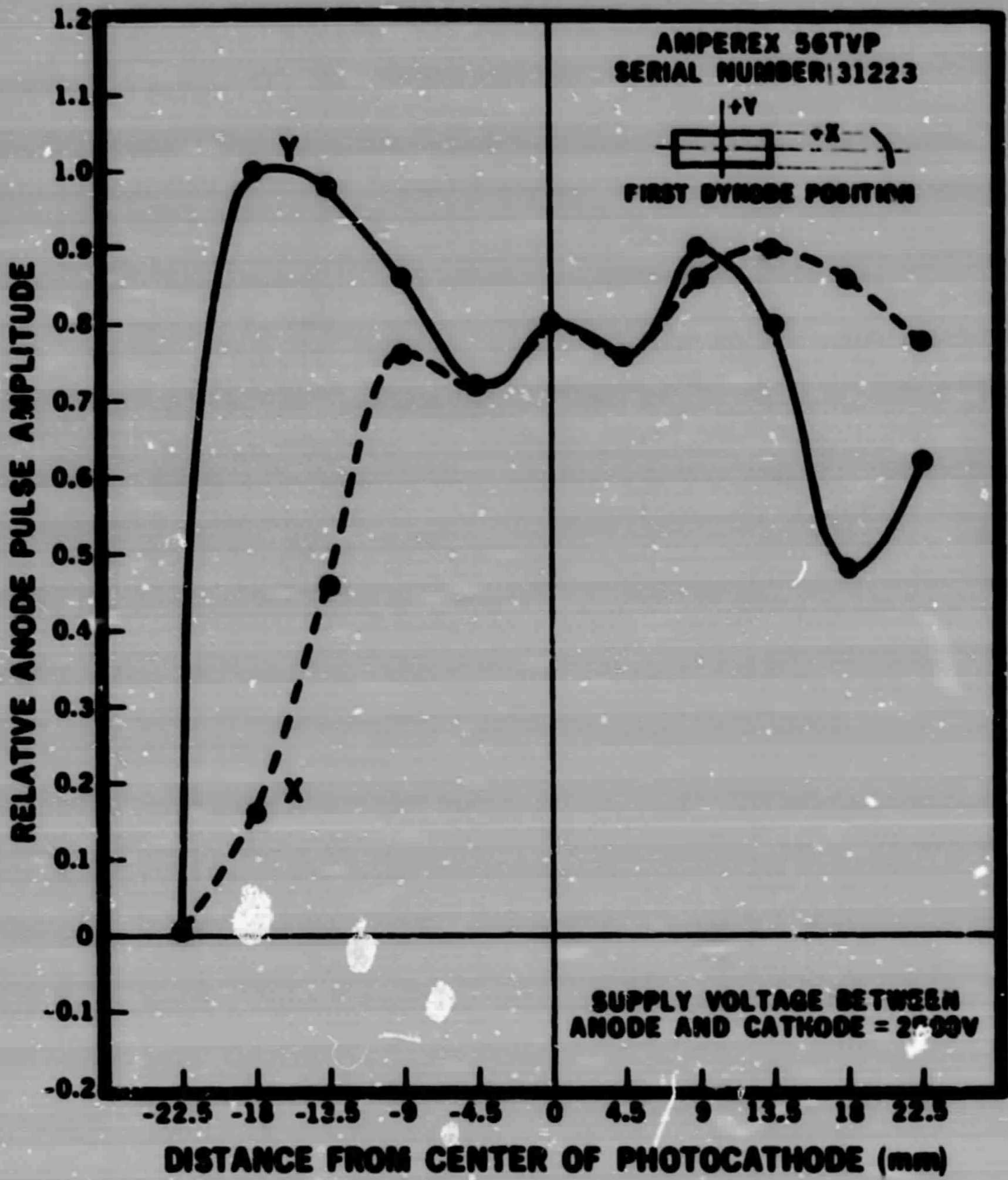
XBL 767 8727

Fig. 5 B



XBL 767 8717

Fig. 6 A

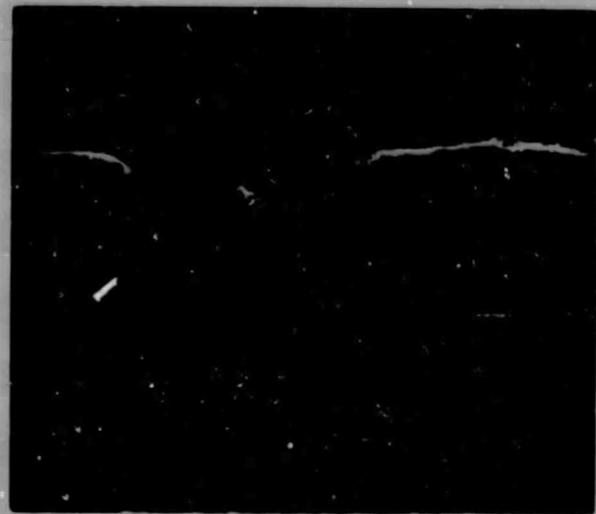


XBL 767-8718

Fig. 5 B

AMPEREX 56TVP

100mV/div



2nsec/div

SINGLE PHOTOELECTRON OUTPUT PULSE

Fig. 7

AMPEREX 56TVP

SUPPLY VOLTAGE BETWEEN
ANODE AND CATHODE = 2500V

NUMBER OF COUNTS
PER CHANNEL

1

PULSE HEIGHT-PHOTOELECTRON
EQUIVALENT DARK PULSE SPECTRUM

XBB 767-6026

Fig. 8