LA-UR - 81-1126
CONF- 810429--18

MASTER

TITLE: NANOSECOND-GATING PROPERTIES OF PROXIMITY-FOCUSED MICROCHANNEL-PLATE IMAGE INTENSIFIERS

AUTHOR(S): N.S.P. King, Los Alamos Laboratory, Group P-15
G.J. Yates, Los Alamos Laboratory, Group P-15
S.A. Jaramillo, Los Alamos Laboratory, Group P-15
J.W. Ogle, J.L. Detch Jr., EG&G Inc. Santa Barbara Operations

SUBMITTED TO: SPIE
Conference on Optics, Santa Fe, NM, April 1981

DISCLAIMER

University of California

LOS ALAMOS SCIENTIFIC LABORATORY
Post Office Box 1663 Los Alamos, New Mexico 87545
An Affirmative Action/Equal Opportunity Employer

NANOSECOND-GATING PROPERTIES OF PROXIMITY-FOCUSED MICROCHANNEL-PLATE IMAGE INTENSIFIERS

ABSTRACT

Nanosecond-Gating Properties of Proximity-Focused Microchannel-plate Image Intensifiers. N.S.P. KING, G.J.YATES, S.A. JARAMILLO, Los Alamos National Laboratory, J.W. OGLE+, J.L. DETCH JR., EG&G Inc.--Some fundamental properties of 18-mm-diam gated proximity-focussed microchannel-plate (MCP) image intensifiers used as fast image shutters in the 1 to 10 ns range have been identified and studied. Light pulses (~ 5 ps wide) from a modelocked dye laser optically sample the gated MCP. Shuttering is achieved by applying a forward-biasing electrical gate pulse to the quiescently reverse-biased photocathode-MCP interface. Variable delay (~ 30 ps jitter) between the gate pulse and the laser pulse permit tracing the MCP's optical response. Gating speeds, turn-on and turn-off patterns, the asymmetric spatial dependence of the MCP optical response, and resolution effects as functions of gate pulse width and photocthode-MCP bias have been characterized. Shutter times of >750 ps with ~ 5 lp/mm resolution were observed. Variations in the intensity profiles of the phosphor's spatial response for uniform photocathode illumination are measured with a calibrated silicon-intensified-target (SIT) focus projection, scan (FPS) television camera and a high-speed video digitizer while photomultipliers monitor the laser pulse and the phosphor's spatially integrated output intensities. The characterization system, gating and biasing circuits, and experimental results will be presented.

+Now at Los Alamos

Introduction

The motivation for the present study was to characterize presently available microchannel plate proximity-focussed image intensifiers for use as fast optical shutters in the nanosecond time domain. The results also contribute to gaining insight concerning important parameters limiting performance in shutter width and resolution as well as to suggesting design modifications for future improvement. Although the present techniques are new this study forms an extension of some earlier work[1]

Characterization System

A laser system is utilized to provide light pulses much narrower than the optical shutter times of interest. This allows the examination of MCP image intensifier optical behavior during different times throughout the shuttering sequence.

The characterization system is built around an Argon-ion synchronously pumped dye laser with a pockel cell for discrete pulse selection. The argon ion modelocker is driven by a 40 MHz sine wave which also drives a synchronous counter. The counter provides synchronized triggers, selectable from 1 to 360 Hz. The trigger is split four ways. One leg triggers the pockel cell which transmits one 5 ps pulse. The second trigger is connected to the MCP gate pulser through a variable passive time delay unit. The jitter between the gated laser pulse and the MCP gate is $\pm$ 15 ps. The third leg resets the scan on a silicon intensified FPS TV camera.[2] The fourth leg enables a digitizer. The video from the FPS camera is then digitized by an analog to digital converter and stored in a multiplexed memory for later transfer to a 9-track magnetic tape or disc. The digitized image is 511x255 pixels with 255 gray levels.

The light path contains a 4% beam splitter to allow beam intensity monitoring by an RCA 4832 PMT. The primary laser pulse is then expanded by a negative lens and diffused by crown glass in close proximity to the MCP image intensifier. The diffuser is necessary to eliminate interference effects from the coherent light source. A resolution pattern is placed on the back side of the diffuser and a relay lens used to image a resolution pattern on the MCP photocathode. For other studies this pattern is removed. The phosphor of the MCP is imaged through another relay lens onto a SIT FPS camera. A relative measure of the total output is obtained from a PMT viewing the entire phosphor surface. The phosphor time delay signal is integrated by an electrometer and recorded to determine gate duration characteristics.

The relative timing between the MCP gate and the optical sampling pulse is accomplished using the variable passive delay unit. With this unit the laser-MCP gate relative timing has a range of 99.9 ns in 0.1 ns steps.

Intensifiers

A cross-sectional view of the MCP image intensifiers[3] utilized are shown in Fig. 2. Shuttering is accomplished by applying a negative 80V electrical pulse of ~ 1.5 ns FWHM duration to the reverse-biased PC-MCP gap. The voltage divider network and the avalanche pulser circuit[4] are shown in Fig. 3. The divider and MCP assemblies are packaged independently (Fig. 4) and interconnected via banana plugs. The pulser is connected via 50Ω transmission cables.

Measurements

One of the parameters varied was the effective gating pulse amplitude. This was done by changing the reverse-bias voltage and observing the change in optical gate width. The results are summarized in Fig. 5. The input electrical pulse is shown with the time correl .. resultant integrated light output from the MCP phosphor as measured by a PMT. A number of features are readily apparent: 1) A time delay of ~ 2 ns exists between the leading edge of the electrical gate pulse at the intensifier input leads and the initiation of the optical gate; 2) As the difference between the peak gating puls and reverse-bias voltages is increased the optical gate width increases much faster than the effective electrical pulse width. The amplitudes of the "full on" optical signals in Fig. 6 have been normalized to 100%. The actual increase in optical gain is slight, with <10% increase between the narrowest and widest gates shown with gate width. The greatest effect from varying the back bias is therefore to change the optical gate width rather than gain.

The utility of MCP image intensifiers for optical shuttering requires understanding the spatial distribution of light across the output phosphor throughout the shuttering sequence. An ideal shutter should turn on and off with uniform optical gain over the entire area of the intensifier with a small percentage of the gating time involved in the actual shutter period. Unfortunately these conditions are not met for the fastest shutter times as shown in Fig. 6 in which intensity profiles are correlated with their relative times during gating are shown. Profile H is that obtained when the intensifier was forward biased and therefore continuously on. The sequence shown is representative of a number of intensifiers studied. The profiles are along a diameter giving the maximum variation in peak gain during initial turn on. Profiles on the perpendicular diameter show nearly equal peak gains. The construction of the intensifiers are asymmetric in the location of the electrical input leads. A single tab provides the input point for the MCP portion of the photocathode-MCP geometry.

Work is being done in documenting this asymmetric behavior. Some intensifiers showed less extreme gain variations while others displayed a different turn on/off pattern (Fig. 7). Most fast gateable intensifiers have the "normal" pattern.

The variations found in minimum attainable gating times prompted us to look for a passive parameter which coulld be correlated to the minimum obtainable optical gate period for a given intensifier. The minimum gating time was established by varying the back bias until an intensifier would just turn on fully. The resistance and capacitance of the photocathode to MCP gap was measured with an RF impedance analyzer (HP4191). The results are tabulated together with the measured minimum optical gate width (Table I) at a frequency of 10 MHz. The capacitance is relatively constant at 30.9 $\pm$ 2.0 pf whereas the photocathode resistance increases from <10Ω to ~ 26Ω with a strong correlation to observed gate width. The measured capacitance is in good agreement with the calculated value for the total MCP assembly. The calculated value of the photocathode to MCP gap is ~ 33% of the total so that with redesign of the package, the total capacitance can be significantly reduced. The MCP number 788/10 was double undercoated to reduce its "resistance." The other units were given no special treatment during manufacturing. Based on this data set, if one measures a PC resistance (@ 10 MHz) ~ 12Ω for an image intensifier, it should be gateable in the few nanosecond time domain. Also, an estimate of its potential minimum optical gate width in nanoseconds can be obtained from $\Delta t \sim 3.5 \times 10^{13} (RC)^{e-1/e}$. The theoretical model relating R and C to the MCP gating properties is presently being developed.[5]

The ability to resolve details of interest in the image forms the dominant criterium in whether gated image intensifiers can be used. To better understand gated behavior under the present experimental conditions, measurements of intensifier gain and CTF were first taken in the forward biased, ungated condition. The relative gain of the entire optical system vs the forward bias is given by the solid dots in Fig. 8. A linear response is indicated once more than ~ 6 volts is applied. The nonlinear response for high bias levels is not associated with MCP saturation. Evidence for inadequate proximity focussing can be seen in the CTF for both 2.3 and 4.6 lp/mm when the photocathode-MCP's accelerating voltage is less than 20 volts.

Above 20 volts the resolution of the image intensisfier has only a weak dependence on this voltage indicating that once an effective voltage in the gated mode exceeds this, little improvement should be expected. Figure 9a shows a typical resolution pattern in the forward bias condition. Group 2 element 2 and Group 3 element 2 are 2.25 lp/mm and 4.5 lp/mm respectively. Figures 9b and 9c show the effect on resolution in the central region of a gated intensifier for optical gates shown in Fig. 5 for 30 and 48V respectively. It is obvious that for the narrowest gate width, the effective forward bias in the gated mode is less than the 20V required to give good proximity focussing. The gate width corresponding to 30V back bias is very close to the required voltage for proximity focussing in that 2.25 lp/mm is easily resolved and 4.5 lp/mm is approaching 20% CTF. The fact that the effective forward bias is calculated to be 80-30=50V is clearly an overestimate for the central region of the MCP. This can be understood based on the profile data showing non-uniform gain throughout the gating sequence. The question next arises, under what conditions does the difference between the back bias and gate pulse amplitude lead to essentially the overall gain and resolution observed for the same forward bias in the ungated mode?

A series of measurements were done which involved measuring intensity profiles with the SIT-FPS camera with fixed amplitude at given electrical gate widths from 1.5 ns to 10 ns FWHM and varying the back bias. For gate widths less than 10 ns the slope and SIT-FPS camera voltage signal were less than that given in Fig. 8 in the ungated mode. The 10 ns wide gate pulse gave the same MCP behavior as the ungated intensifier when the effective forward bias was determined as the difference between the gate pulser and back bias voltages. This suggests the combined time responses of the gating network and the MCP assembly restrict good correlation between gated and ungated optical gain functions for gates < 10 ns.

Conclusions

Competing efforts limit the minimum useful optical gating periods of proximity-focused MCP intensifiers. As the effective gating forward bias is increased by decreasing the back bias between the photocathode and MCP for a fixed amplitude gate pulse, the optical gate period increases. For optical gates < 2 ns, the minimum forward bias voltage of < 20V required to obtain good proximity focusing over the entire photocathode is not reached. For gating times > 2 ns the resolution observed is ∼ 4.5 lp/mm.

The major problem to be solved in decreasing the optical shuttering time to shorter than 2 ns would appear to be understanding and eliminating the increase in optical gate period to times greater than the input electrical gate period when this back bias is reduced.

Acknowledgments

The authors would like to express appreciation to Mr. Mel Nelson and T. Davies of EG&G Santa Barbara for their enthusiastic assistance and support for this project. Bruce Noel of Los Alamos has provided considerable theoretical guidance as well as assistance in the passive RC measurements.

Valuable discussions were held with Dick Lear and Lamar Olk of Livermore National Laboratory.

References

1) Albert J. Lieber and H. Dean Sutphin, "Nanosecond High Resolution Framing Camera," Review of Scientific Instruments, Vol. 42, No. 11, Nov. 1971, pp. 1663-7.

A.J. Lieber, "Nanosecond Gating of Proximity Focused Channel Plate Intensifiers," Review of Scientific Instruments, Vol. 43, No. 1, Jan. 1972, pp. 104-8.

H. Dean Sutphin and Albert J. Lieber, "Nanosecond Framing Cameras Using Proximity Focused Image Intensifiers," LA-4937-MS, April 1972.

George J. Berzins, Ki S. Han, Albert J. Lieber, and John S. McGurn, "Nanosecond Photography of radiochromic Processes," Proceedings of the Technical Program, Electro-Optical Systems Design Conference, Sept. 18-20, 1973, New York, pp. 167-71.

A.J. Lieber, R.F. Benjamin, H.D. Sutphin, and G.H. McCall, "Applications of Ultra-Fast High-Resolution Gated-Image Intensifiers to Laser-Fusion Studies," 11th International Conference on High-Speed Photography, SPIE (1974), pp. 144-9.

2) Camera built by Xedar Corp., Boulder Colorado.

3) All intensifiers were manufactured by ITT Fort Wayne Ind. Div.

4) Avalanche pulsing circuit design by R.D. Hiebert, Los Alamos.

5) J.L. Detch Jr. and B.W. Noel; B405 this conference.

TABLE I

MCP #	C_{pc-mcp} (pf)	R_{pc} (Ω)	Minimum optical gate width (ns)	$3.5\times10^{13} \times (RC)^{e-1/e}$ (ns)
788/7	28.0	<10	1.2	< 1.24
788/10*	29.8	10.1	1.5	1.47
788/6	33.1	12.5	3.0	3.12
725/3	32.0	15.0	4.5	4.42
788/4	31.7	26	7.9	15.7

*double undercoated

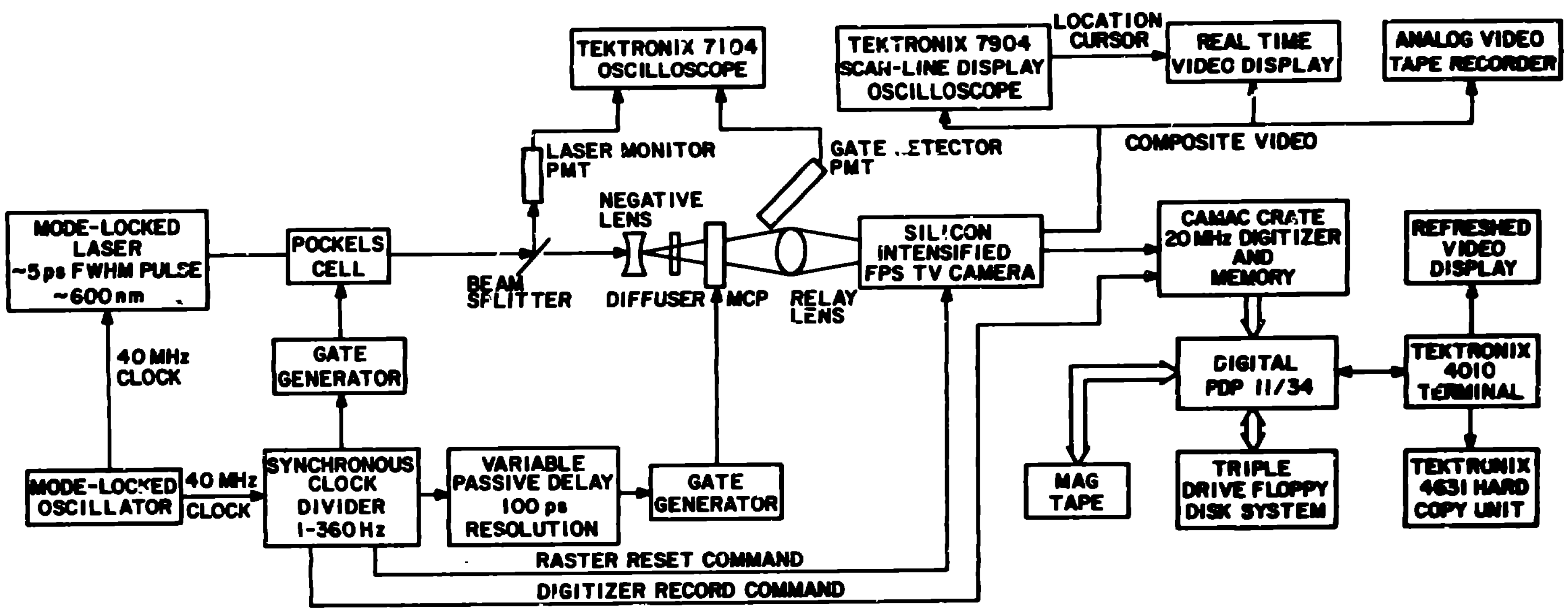

TEKTRONIX 7104 OSCILLOSCOPE
TEKTRONIX 7904 SCAN-LINE DISPLAY OSCILLOSCOPE
LOCATION CURSOR
REAL TIME VIDEO DISPLAY
ANALOG VIDEO TAPE RECORDER
LASER MONITOR PMT
GATE DETECTOR PMT
COMPOSITE VIDEO
NEGATIVE LENS
MODE-LOCKED LASER ~5 ps FWHM PULSE ~600 nm
POCKELS CELL
BEAM SPLITTER
DIFFUSER
MCP
RELAY LENS
SILICON INTENSIFIED FPS TV CAMERA
CAMAC CRATE 20 MHz DIGITIZER AND MEMORY
REFRESHED VIDEO DISPLAY
40 MHz CLOCK
GATE GENERATOR
DIGITAL PDP 11/34
TEKTRONIX 4010 TERMINAL
MODE-LOCKED OSCILLATOR
40 MHz CLOCK
SYNCHRONOUS CLOCK DIVIDER 1-360 Hz
VARIABLE PASSIVE DELAY 100 ps RESOLUTION
GATE GENERATOR
MAG TAPE
TRIPLE DRIVE FLOPPY DISK SYSTEM
TEKTRONIX 4631 HARD COPY UNIT
RASTER RESET COMMAND
DIGITIZER RECORD COMMAND

FIG. 1

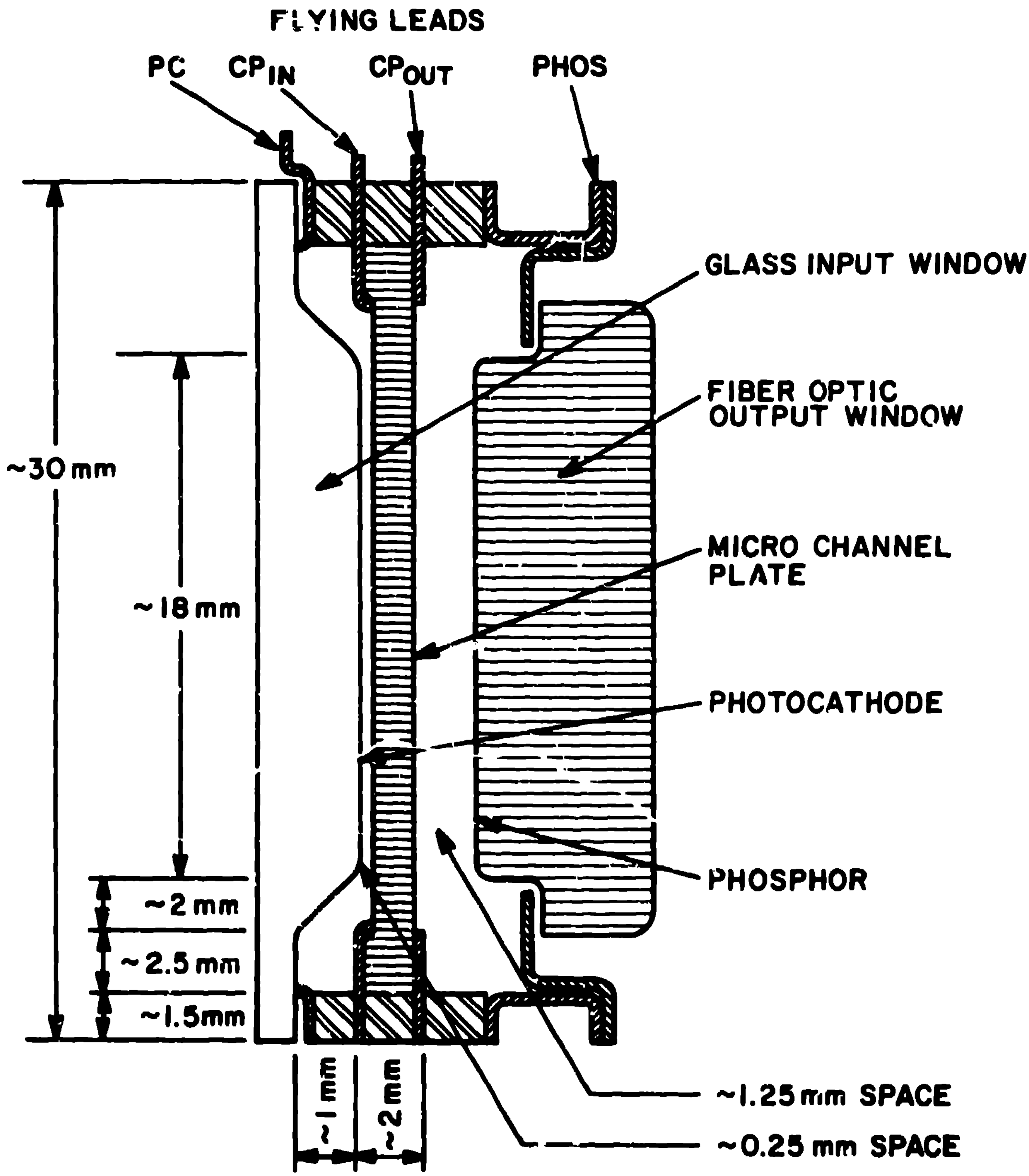
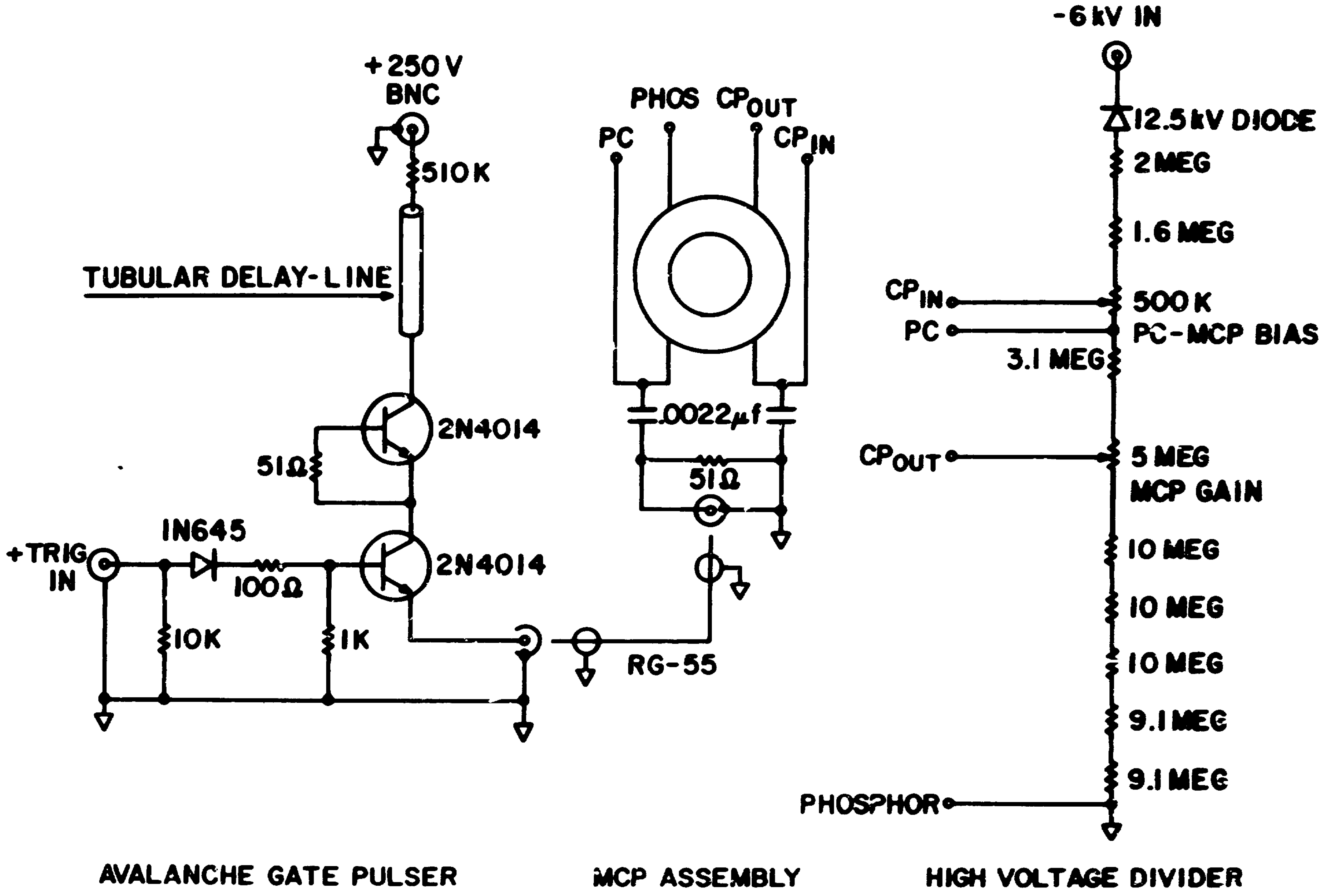

FLYING LEADS
PC
CP_{IN}
CP_{OUT}
PHOS
GLASS INPUT WINDOW
FIBER OPTIC OUTPUT WINDOW
MICRO CHANNEL PLATE
PHOTOCATHODE
PHOSPHOR
~30 mm
~18 mm
~2 mm
~2.5 mm
~1.5mm
~1 mm
~2 mm
~1.25 mm SPACE
~0.25 mm SPACE

FIG. 2



+250 V
BNC
510 K
TUBULAR DELAY-LINE
2N4014
51Ω
1N645
+TRIG IN
100Ω
10K
1K
2N4014
RG-55
PHOS
CP OUT
PC
CP IN
.0022μf
51Ω
-6 kV IN
12.5 kV DIODE
2 MEG
1.6 MEG
CP IN
PC
500 K
PC-MCP BIAS
3.1 MEG
CP OUT
5 MEG
MCP GAIN
10 MEG
10 MEG
10 MEG
9.1 MEG
9.1 MEG
PHOSPHOR
AVALANCHE GATE PULSER
MCP ASSEMBLY
HIGH VOLTAGE DIVIDER

FIG. 3

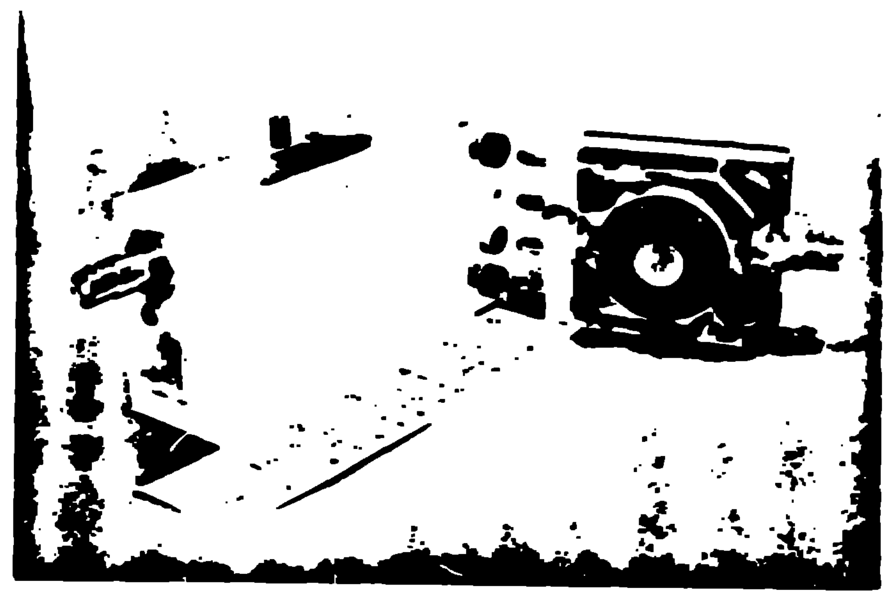
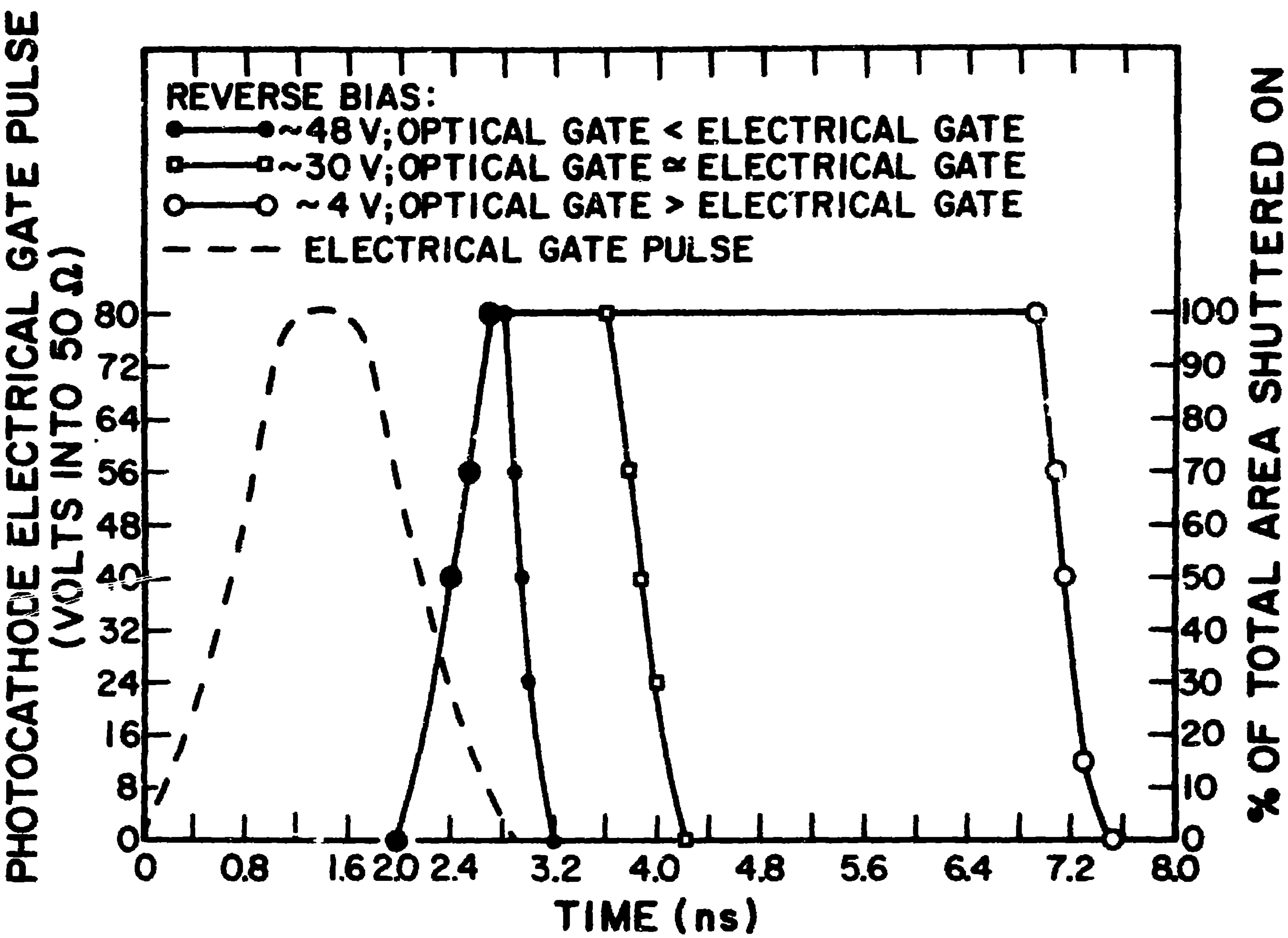


FIG. 4



REVERSE BIAS:
~48 V; OPTICAL GATE < ELECTRICAL GATE
~30 V; OPTICAL GATE ≃ ELECTRICAL GATE
~4 V; OPTICAL GATE > ELECTRICAL GATE
ELECTRICAL GATE PULSE
PHOTOCATHODE ELECTRICAL GATE PULSE (VOLTS INTO 50 Ω)
0 8 16 24 32 40 48 56 64 72 80
0 0.8 1.6 2.0 2.4 3.2 4.0 4.8 5.6 6.4 7.2 8.0
TIME (ns)
% OF TOTAL AREA SHUTTERED ON
0 10 20 30 40 50 60 70 80 90 100

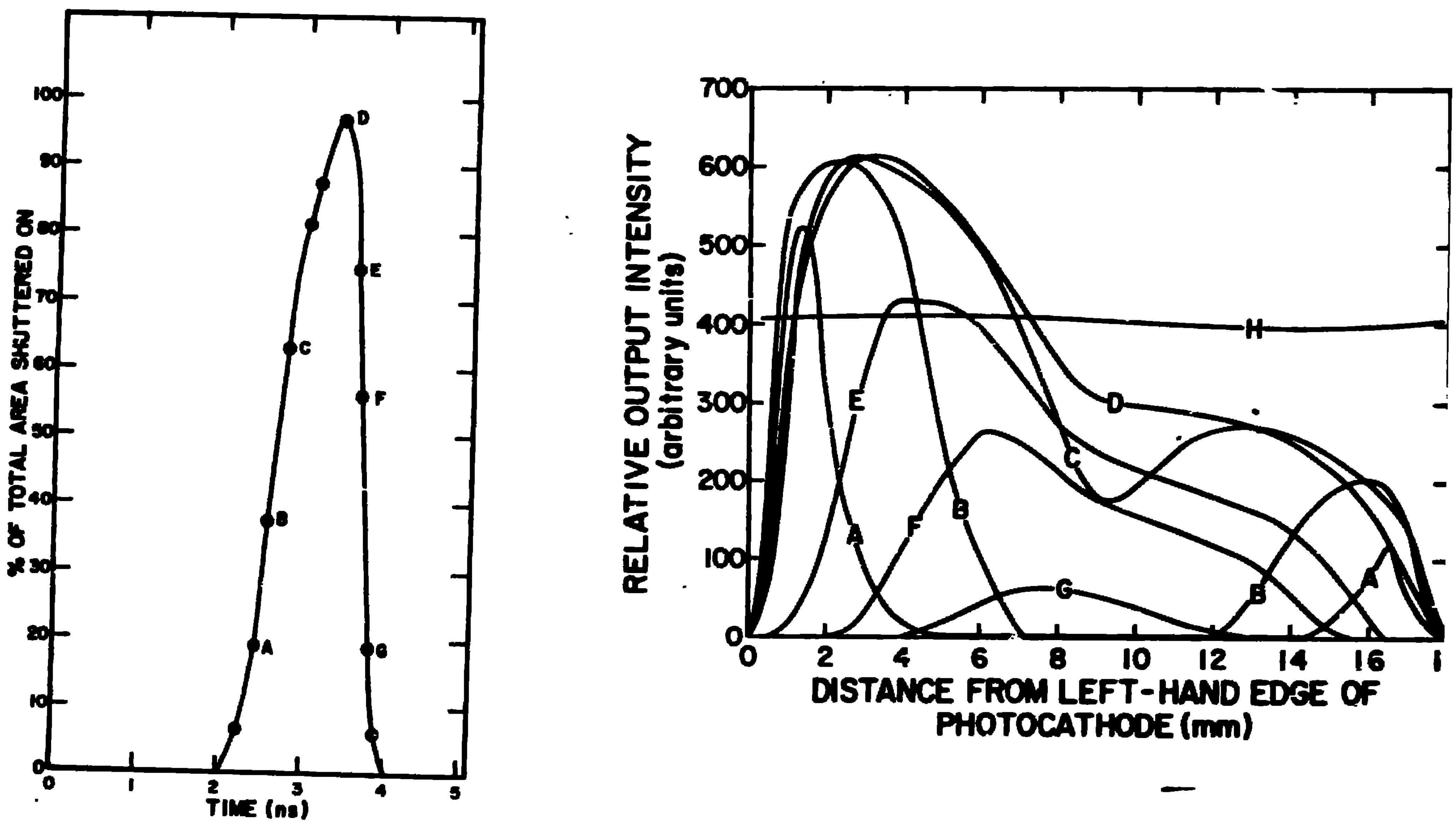
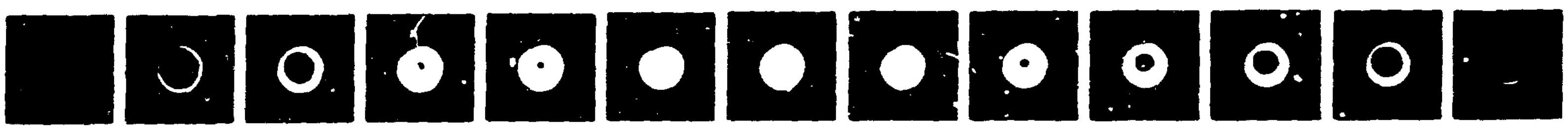

% OF TOTAL AREA SHUTTERED ON
TIME (ns)
A
B
C
D
E
F
G
RELATIVE OUTPUT INTENSITY
(arbitrary units)
DISTANCE FROM LEFT-HAND EDGE OF PHOTOCATHODE (mm)
H

FIG. 6

0.0 0.2 0.4 0.6 0.8 1.0 3.2 3.5 3.7 3.9 4.1 4.3 4.7 4.9

TIME (ns)

NORMAL MCP GATE SEQUENCE

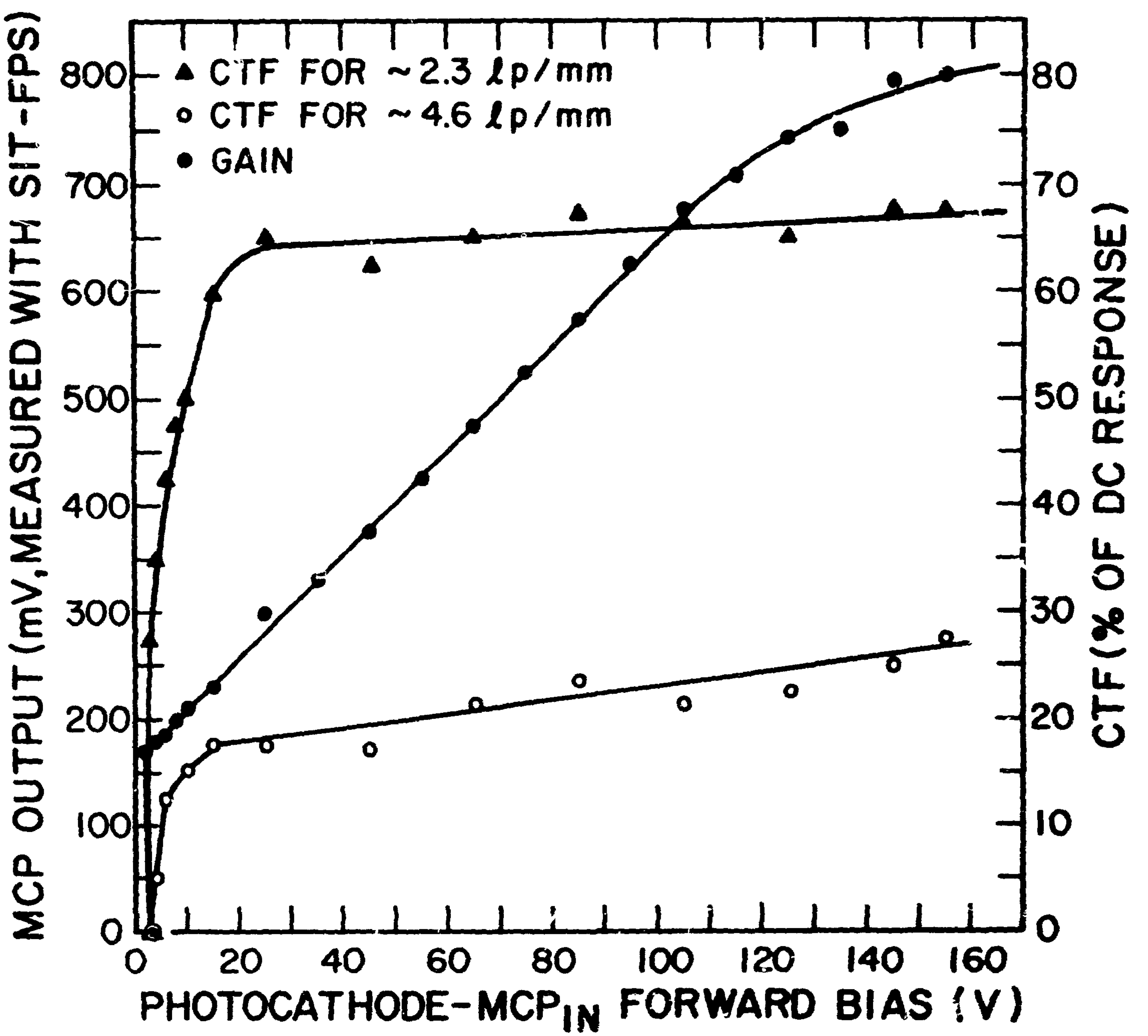


0.0 0.2 0.4 0.8 1.0 1.2 1.6 1.8 2.0 2.4 2.7 3.0 3.3

TIME (ns)

ABNORMAL MCP GATE SEQUENCE

FIG. [illegible]



CTF FOR ~2.3 ℓp/mm
CTF FOR ~4.6 ℓp/mm
GAIN
MCP OUTPUT (mV, MEASURED WITH SIT-FPS)
CTF (% OF DC RESPONSE)
PHOTOCATHODE-MCP$_{IN}$ FORWARD BIAS (V)
0
100
200
300
400
500
600
700
800
0
10
20
30
40
50
60
70
80
0
20
40
60
80
100
120
140
160

FIG. 8

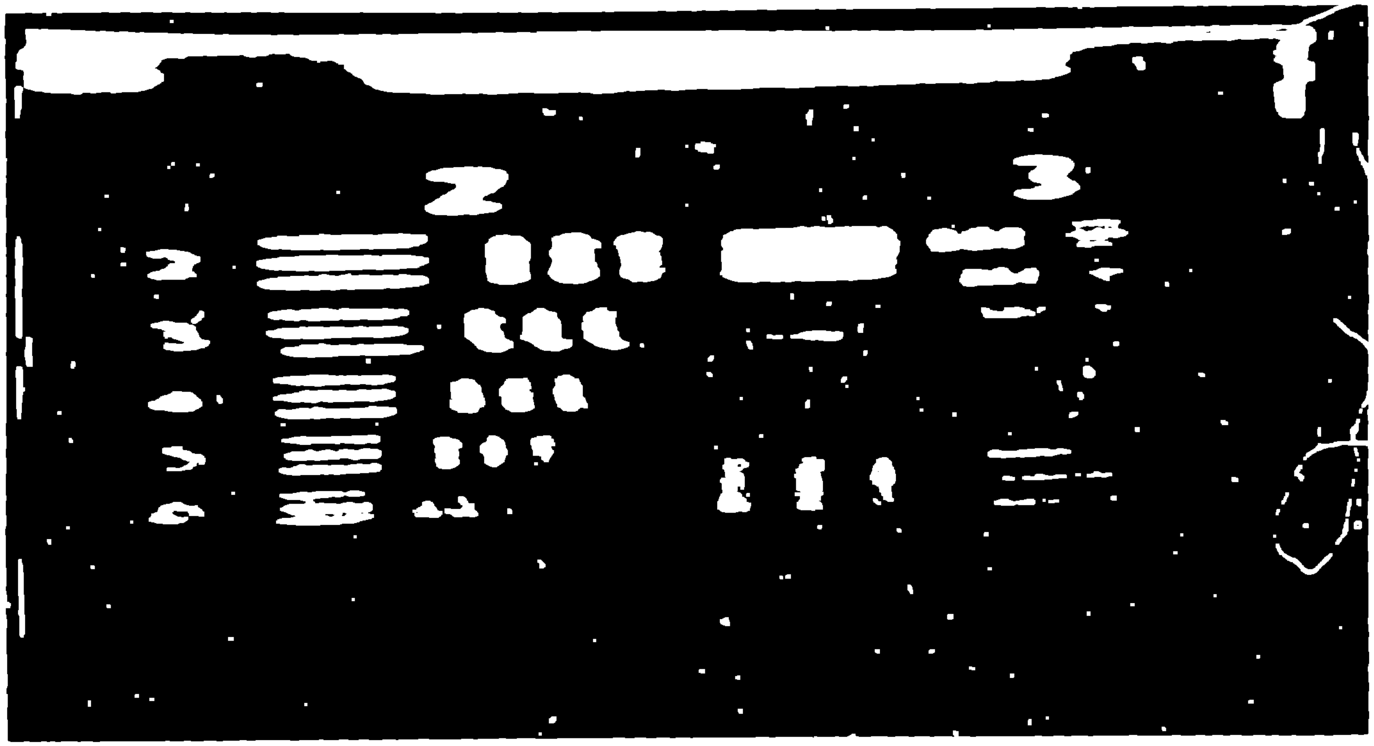


FIG. 9a

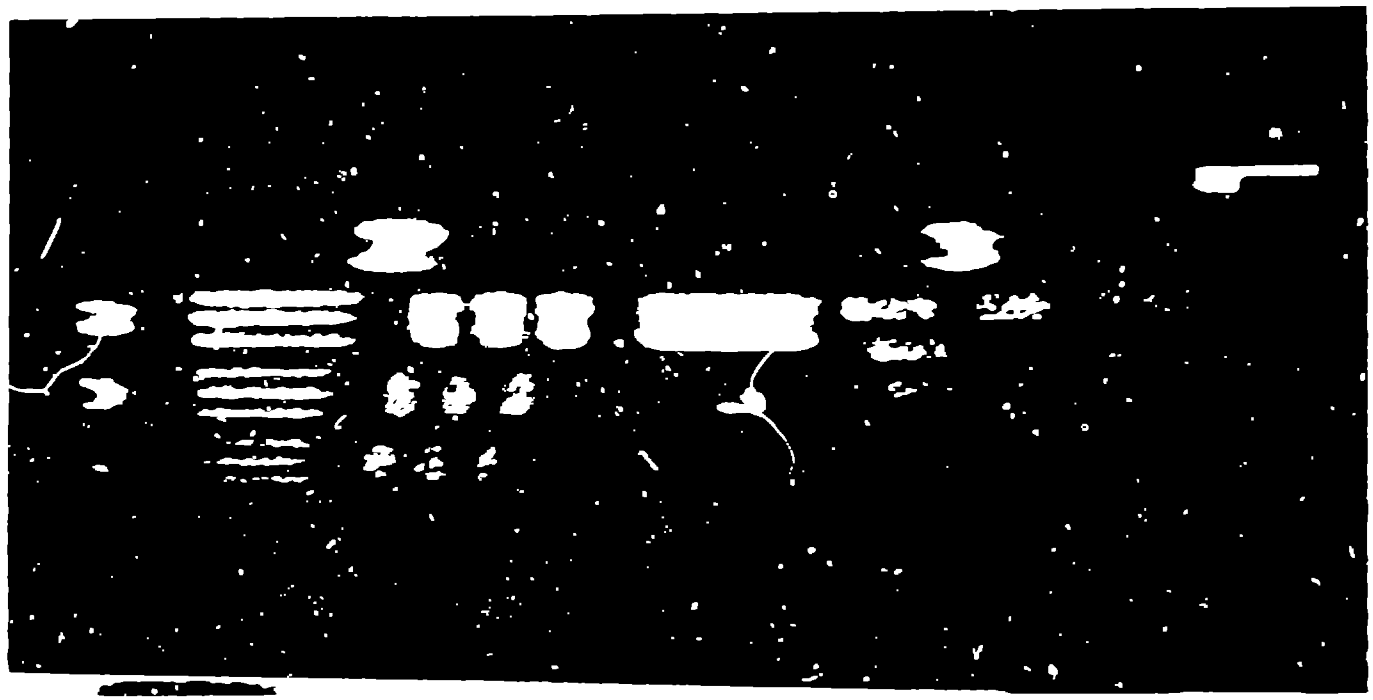


FIG. 9b

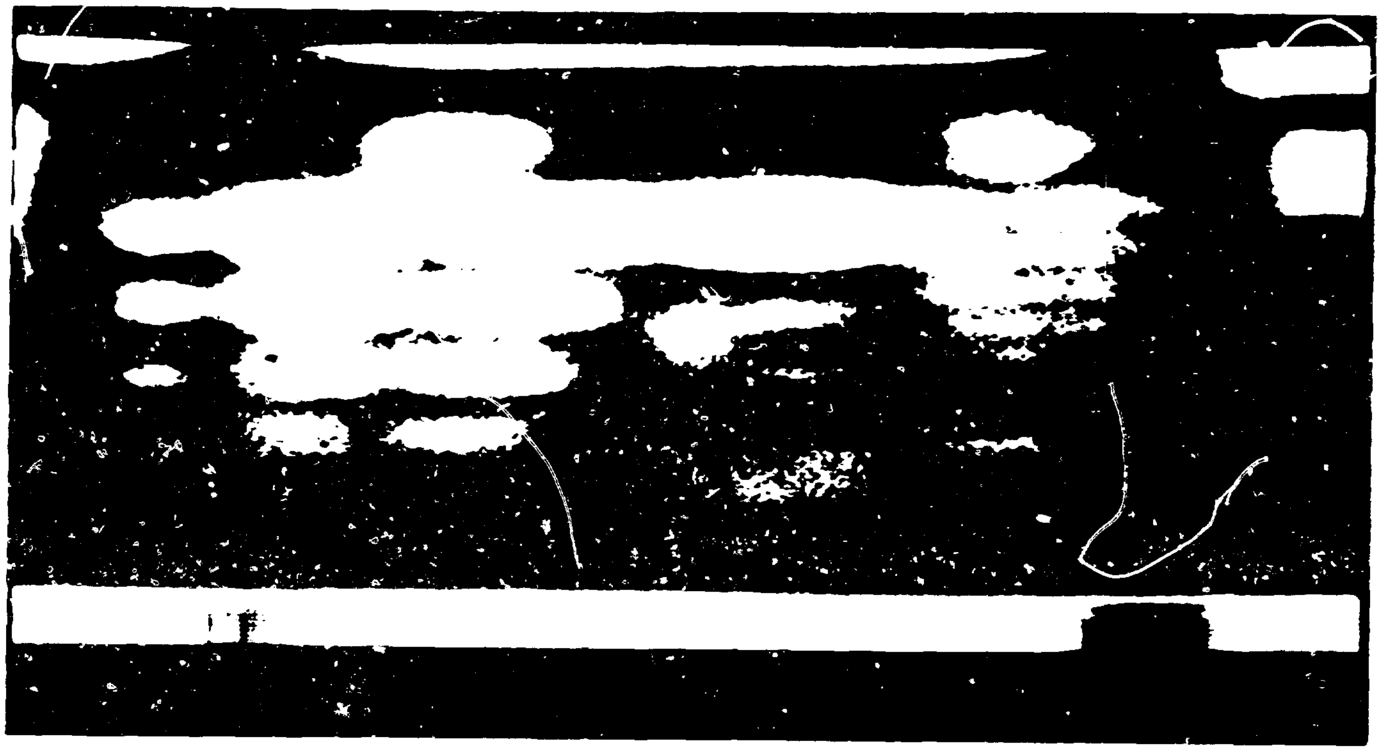


FIG. 9c