NsG-438

A SIMPLE CLOSED-OPEN-CLOSED SPECTROGRAPH SHUTTER FOR EXPOSURE TIMES IN THE TEN MICROSECOND RANGE

*

Technical Report No. 5

By

G.L. Grasdalen, Martin Huber and

G.H. Newsom

Harvard College Observatory

August 1967

Spectroscopic measurements on high temperature light sources frequently make it necessary to use a fast spectrograph shutter. In this paper we describe a reliable and reproducible shutter developed for use in quantitative absorption spectroscopy on pressure-driven shock tubes.

This application requires that the shutter be triggered by the observed event, since the time of initiation of the shock depends on a process which cannot be triggered with precision, that is, the rupture of a diaphragm. This precludes using rotating mirrors or perforated discs which are open at random delay times after shock reflection. Furthermore, in our experiments, wavelengths of interest extended down to 2000Å, and the background intensity was limited so that no attenuation by the shutter could be tolerated. The use of a Kerr cell was therefore not feasible.

An open-closed capping shutter of the type described by Wurster (1957) was found to be satisfactory at wavelengths below 4000Å up to a shock temperature of 6000°K (Huber and Tobey 1967). A flash of 30,000°K brightness temperature and 3 μs duration was used as background source in that experiment. But higher temperatures or longer wavelengths required the use of an initially closed shutter because the shock-heated gas radiated for at least 120 μs before local thermodynamic equilibrium was reached, temperature measured and an absorption spectrum photographed (Grasdalen 1967, Newsom 1967). Line emission becomes an appreciable fraction of the line absorption when the shock temperature is increased or longer wavelengths are studied (see Fig. 1).

Closed-open-closed spectrograph shutters described by others (Camm 1960, Clayton 1963) must be mounted within a few ten thousands of an inch in front of the spectrograph slit. Their fast shutter action is derived from the high angular velocity obtained by mounting a sliding slit in very close proximity to the spectrograph slit. It is impossible to mount this kind of shutter on many commonly used spectrographs because screws, vacuum flanges, etc. often project beyond the slit plane.

To avoid these difficulties we developed the new shutter assembly design shown in Fig. 2. The shutter itself is a free-flying piece held initially by two small bar magnets at a distance of 5.9 mm in front of the slit plane. In this position its outermost portion occults the spectrograph slit. When the assembly is triggered, a wire explodes and a shock wave confined within a channel (1.6 mm x 4.4 mm bore) drives the shutter in a direction normal to the slit length. At a certain time the slot in the shutter will be aligned with the optical axis of the spectrograph, i.e., the shutter will be open. Further on it will again intersect the beam. After completely obstructing the light path the shutter is stopped by a buffer (Q-compound, for example).

The obvious advantage of this arrangement is the frictionless motion of the shutter. Costly precision-worked sliding surfaces are avoided and the displacement is insensitive to external influences of temperature and humidity.

Alnico bar magnets were selected so that their pull on the shutter kept it in place. The shutter was constructed of two pieces of .25 mm thick magnetic stainless steel, which were glued together with epoxy; its total weight was 160 mg. The insulating parts of the shutter assembly consisted of LE Phenolic.

The exploding wire (.125 or .175 mm diameter music wire) was mounted as shown in Fig. 2. Twenty-five joules stored on a 2 μF capacitor were discharged through the wire, using a spark gap activated by a 7 kV trigger pulse. A circuit diagram of the electronics is shown in Fig. 3.

The performance of the shutter is dependent on the apparent width, w, of the grating; the distance, f, from spectrograph slit to grating; and the distance, d, between the slot in the shutter and the spectrograph slit. The slot width, a, in the shutter is selected so that the grating is slightly overfilled, viz.,

$$a \geqslant \frac{d \cdot w}{f}$$

Increasing the value of a over $\frac{d \cdot w}{f}$ provides an increased time during which the grating can be completely illuminated, i.e. it produces a flat top when a record of grating illumination vs. time is taken.

We tested the shutter on eleven consecutive firings by measuring its transmission vs. time with a photomultiplier tube. Oscilloscope records like the one shown in Fig. 4 were obtained with a DC light source on a 3 m McPherson spectrograph with a grating of apparent width w = 8 cm. The shutter was mounted so that d = 5.9 mm and its slot width was a = .26 mm. The times of maximum shutter opening after explosion of the wire averaged 43.2 μs; the scatter of maxima about the mean had a standard deviation of 0.6 μs. Hence, if the slit in the shutter is made wide enough to allow the grating to be completely filled for 3 μs (2 x 2.33 x standard deviation), the shutter will be fully open in 98 per cent of the exposures if the flash tube is timed to discharge at the average time of maximum.

The velocity of the shutter as calculated from Fig. 4 is 26 m/sec.

REFERENCES

Camm, J.C., 1960, Rev. Sci. Instr. 31, 278.

Clayton, J.O., 1963, Rev. Sci. Instr. 34, 1391.

Grasdalen, G.L., 1967, Senior honors thesis, Department of Astronomy, Harvard University.

Huber, M. and F.L. Tobey Jr., 1967, Harvard College Observatory Shock Tube Spectroscopy Laboratory, Scientific Report #16.

Newsom, G.H., 1967, Ph.D. thesis in preparation, Harvard University.

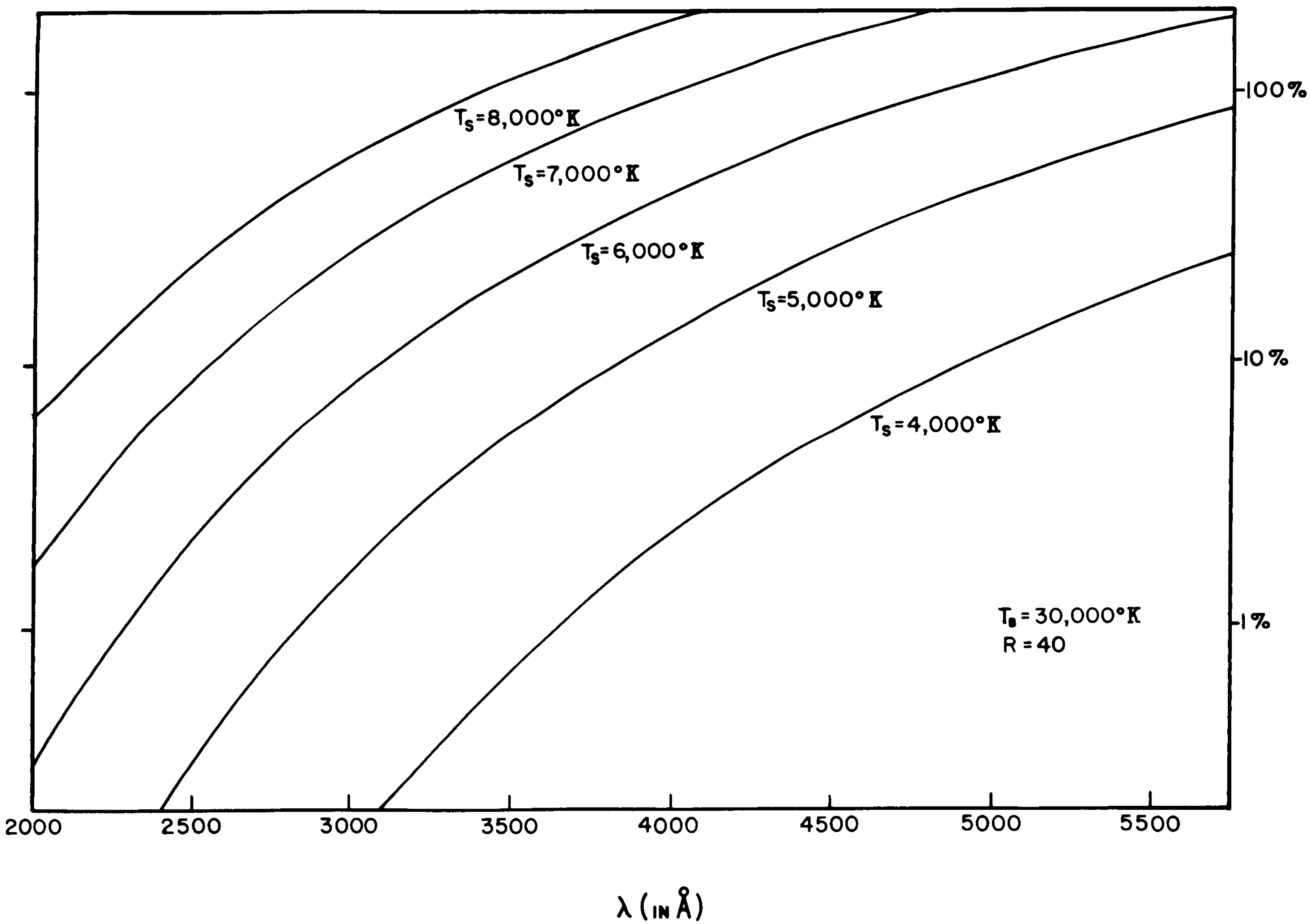
Wurster, W., 1957, Rev. Sci. Instr. 28, 1030.

Three pieces of Teflon tape mounted over the channel and magnets (as shown in Fig. 2) contained the vaporized wire in the channel. Thus, line absorption by this vapor was avoided and no momentum was lost by escaping gas. The teflon stretched easily, providing an effective transfer of momentum. No loss of speed due to the tape was noticed. All test data were taken with tape over the channel.

Metallic deposits left by the exploded wire which might provide a conductive path in parallel to the wire are easily removed with acetone.

We wish to thank Mr. C. McDonald for his help in improving the mechanical design and Mr. D. Zitros for designing the triggering electronics. This work was supported by the National Aeronautics and Space Administration, Grant NsG-438.

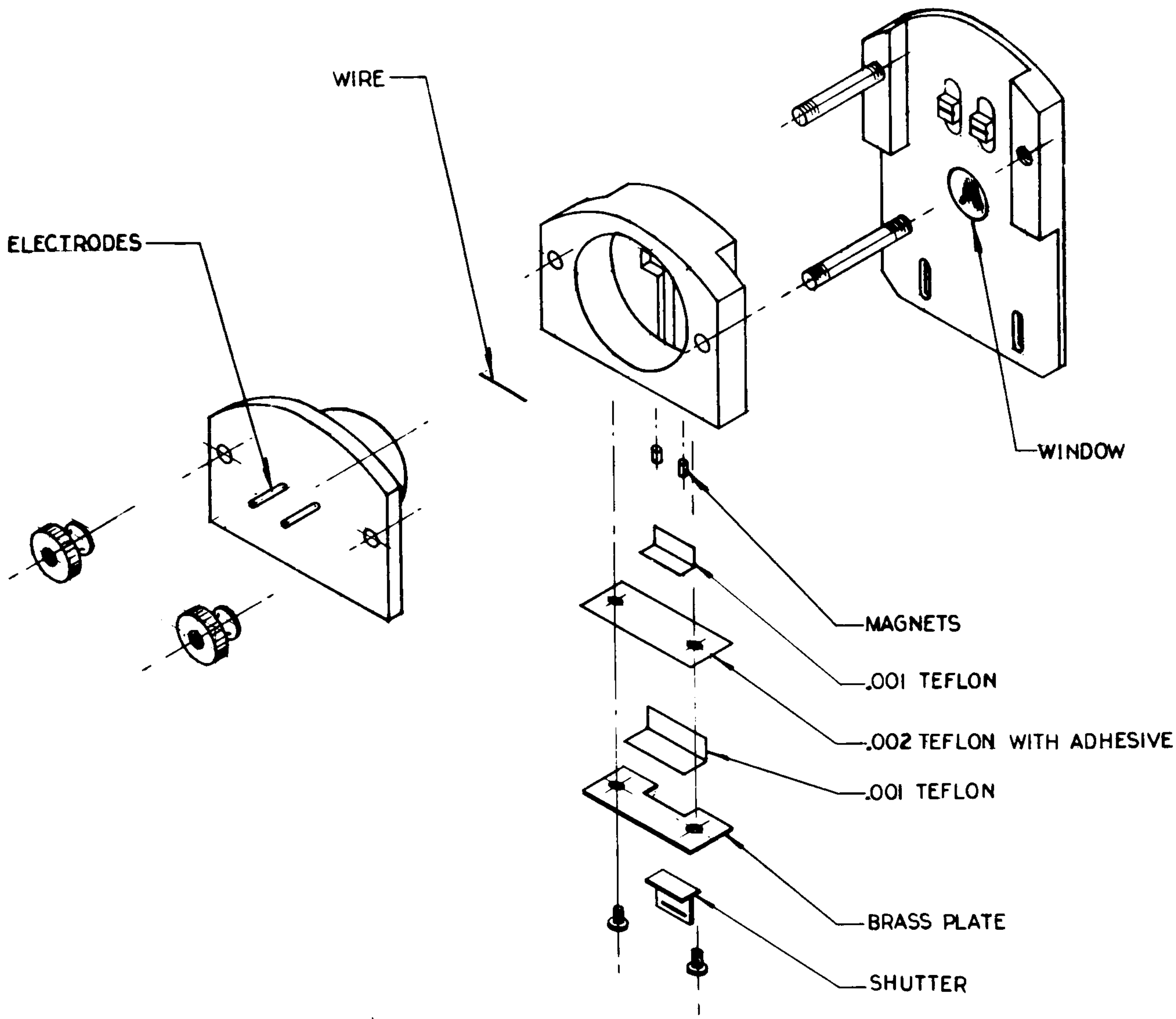
Figure 1 The ratio of emission to absorption by the shocked gas is shown, assuming a background continuum of 30,000°K brightness temperature and an exposure forty times longer than the duration of the flash.



T_S=8,000°K
T_S=7,000°K
T_S=6,000°K
T_S=5,000°K
T_S=4,000°K
T_B=30,000°K
R=40
100%
10%
1%
2000
2500
3000
3500
4000
4500
5000
5500
λ (IN Å)

FIG. 1

Figure 2 An exploded view of the shutter.



SHUTTER ASSEMBLY

FIG. 2

Figure 3 A circuit diagram of the electronics used to supply power to the exploding wire.

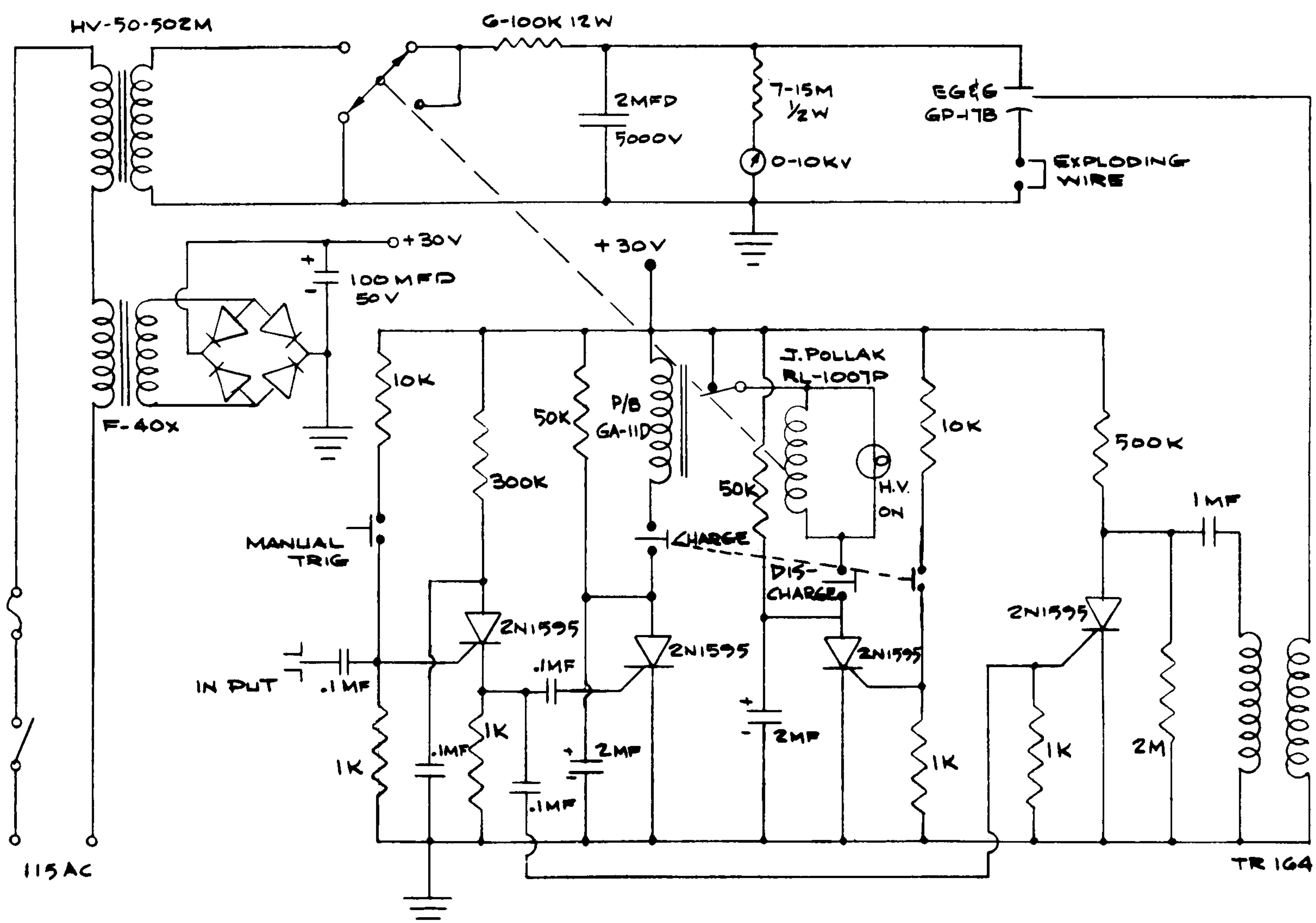

HV-50-502M
G-100K 12W
2MFD
5000V
7-15M
½W
0-10KV
EG&G
GP-17B
EXPLODING
WIRE
+30V
100MFD
50V
F-40X
+30V
10K
300K
50K
P/B
GA-11D
J. POLLAK
RL-1007P
50K
H.V.
ON
10K
500K
1MF
MANUAL
TRIG
CHARGE
DIS-
CHARGE
IN PUT
.1MF
2N1595
2N1595
2N1595
2N1595
.1MF
1K
.1MF
1K
2MF
.1MF
2MF
1K
1K
2M
115AC
TR 164

FIG. 3

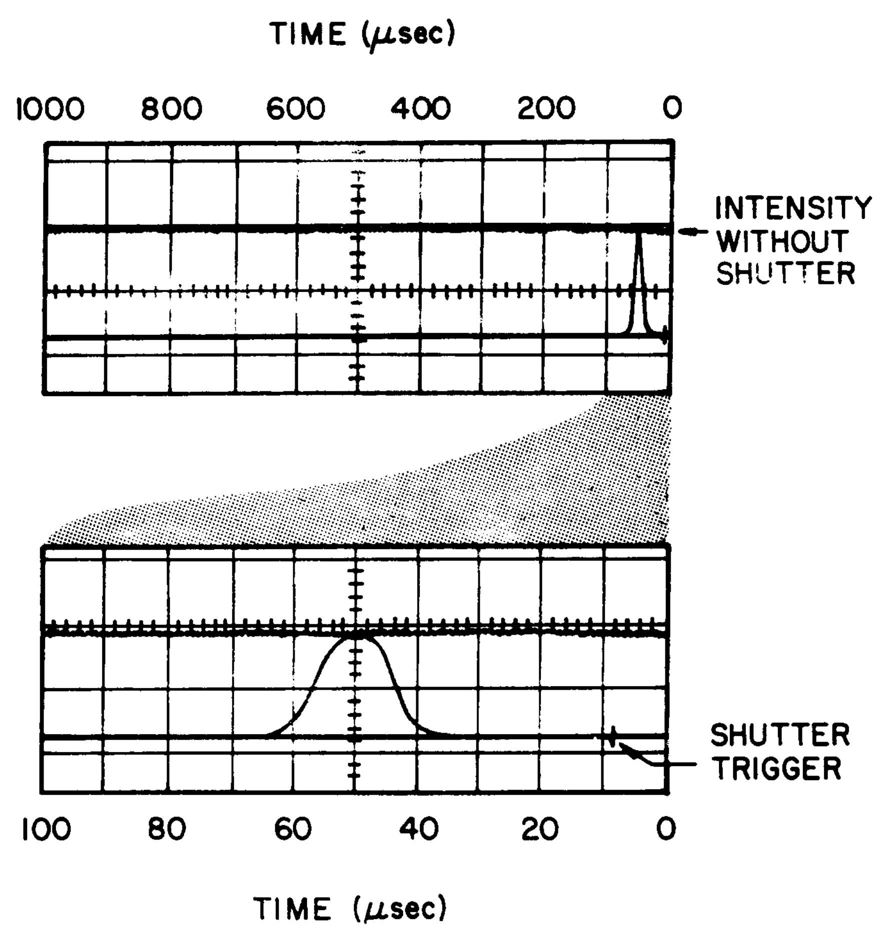

TIME (μsec)
1000
800
600
400
200
0
INTENSITY WITHOUT SHUTTER
SHUTTER TRIGGER
100
80
60
40
20
0
TIME (μsec)

FIG. 4