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Authors
Leskovar, B.
Jerbic, E.J.
Zizka, G.

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Lawrence Berkeley Laboratory
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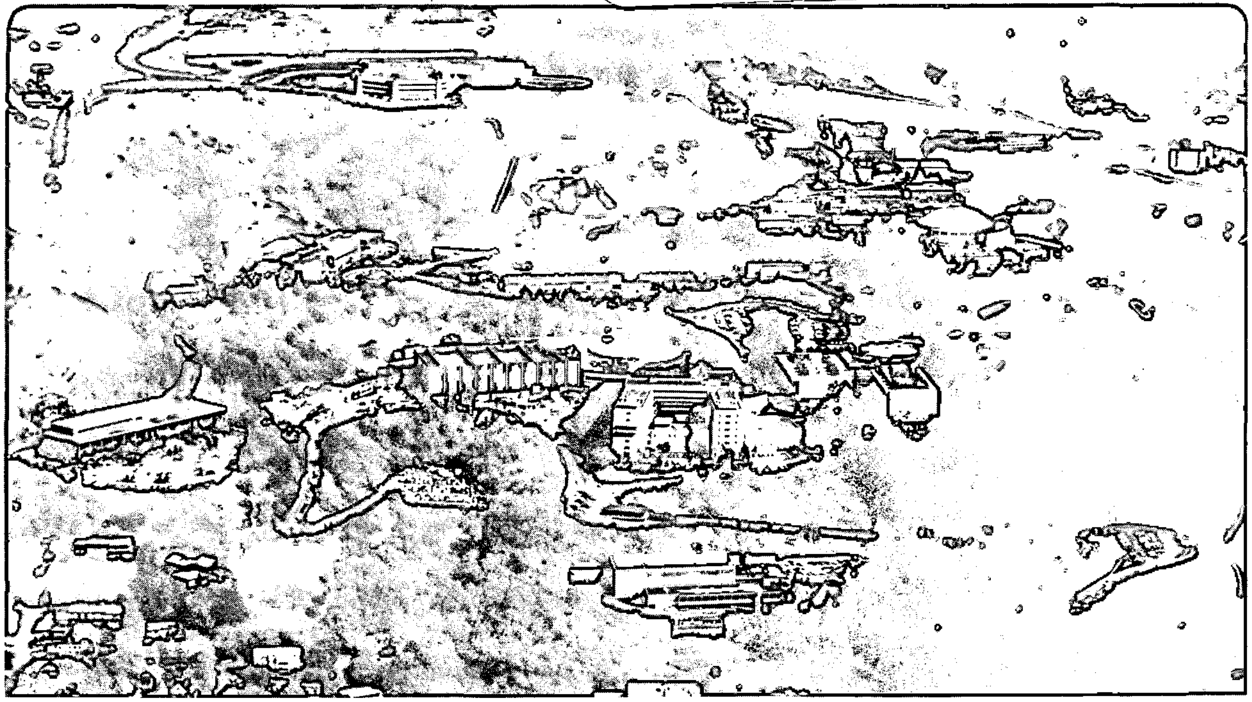

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PERFORMANCE CHARACTERISTICS STUDIES OF IMAGE INTENSIFIER HAVING SHORT LUMINESCENCE DECAY TIME

B. Leskovar* E.J. Jerbic** and G. Zizka*

*Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

**Lawrence Livermore National Laboratory
University of California
Livermore, California 94550

ABSTRACT

The characteristics of a modified first generation 40 mm-diameter VARO 1248-1 image intensifier which uses a very short luminescence decay time phosphor screen (P-46) have been investigated. Some typical intensifier characteristics - such as luminous gain and spatial resolution - are compared with data provided by the manufacturer for nonmodified device. Characteristics which are not generally available from manufacturer were also measured. These include the phosphor spectral emission characteristics and luminescence decay time. The measuring techniques used and description of measuring systems are given.

INTRODUCTION

Streamer chambers used for the study of complex final states encountered in the collision of high energy heavy ions are triggerable 4π detectors for charged particles.[1,2] The chamber makes visible the charged particle trajectories in a gas volume by amplifying primary ionization by a factor 10^8 by means of a very short high voltage pulse. The light emitted as the gas molecules de-excite from the streamers discharge is photographed with three large aparture lens cameras using fastest available films. The track projections on the film planes are digitized and used to reconstruct the particle trajectory in space. Its parallax is determined with reference to fixed fiducial marks. The resulting picture quality is sufficient to obtain high precision momentum measurements and good multitrack resolution.

However, in very high resolution streamers chamber experiments the light intensity from the tracks is too low for direct recording even on very fast film. Therefore, it is necessary to use an image intensifier between the streamer chamber and the recording camera. The image intensifier should have high spatial resolution, adequate luminous gain and an appropriate phosphor. A phosphor with good characteristics should be used particularly with respect to its luminescence decay time, emission spectrum and efficiency.

This paper discusses some performance characteristics of modified first generation 40-mm diameter VARO 1248-1 image intensifier. This single stage image intensifier has extended red S-20 photocathode deposited on a fiber optics substrate, an electrostatic focusing arrangement and fiber optics plate on which thin film of phosphor screen is deposited. The phosphor screen is coated with a thin opaque film of aluminum. Modified intensifier employs a P-46 phosphor material which has a very short luminescence decay time. This phosphor was introduced by Thomas Electronics, Inc. in 1972. The phosphor chemical composition is yttrium aluminate: cerium.[4]

The nonmodified version of the 1248-1 intensifier[3] uses P-20 phosphor screen which spectral output peaks at approximately 560 nm. This phosphor screen has persistance, from initial brightness to the 10% decay point, in the range of 50 μs to 2 ms depending upon device operating conditions. Because this is not fast enough in certain applications, the P-46 phosphor with significantly shorter decay time was incorporated in the 1248-1 intensifier. However, this phosphor has a lower luminous conversion efficiency and poorer resolution capabilities due to the higher percentage of large phosphor particles. Consequently, several specific measurements were necessary to determine whether this modified intensifier could be used effectively with a high resolution streamer chambers where a short luminescence decay time of the phosphor over a wide dynamic range of light intensity is important.

The operating voltage was 15 kV for the gain, spatial resolution and phosphor emission spectra measurements. For the luminescence decay time measurement, the operating voltage was 13 kV.

LUMINOUS GAIN MEASUREMENTS

The luminous gain of an image intensifier is defined as the ratio of phosphor screen luminance in footlamberts (fL) to the photocathode illuminance in footcandles (fc). This gain measurement was made using the system described in Ref. 3 with slight modification. The calibrated radiation source was a standard Tungsten-filament lamp operating at a color temperature of 2870°K. The lamp was followed by two light diffusers, a neutral density filter and a calibrated aperture. The intensifier output image luminance was measured with a Spectra-Pritchard Photometer, Model 1980. The photometer was calibrated using the National Bureau of Standard glass no. 161122-2 and lamp no. 8689.

The input illuminance of the intensifier photocathode was 4.47×10^{-3} fc. The phosphor screen luminance was 0.118 fL. Consequently, the image intensifier gain was 26.4 fL/fc at operating voltage of 15 kV. This gain is significently smaller than the gain of the same device operating at 15 kV with the P-20 phosphor[3] which is typically 100 or more.

SPATIAL RESOLUTION MEASUREMENT

The spatial resolution measurement of the image intensifier was made by projecting an Air Force 1951 Resolving Power Test Target (100% contrast) onto the photocathode using white light. A magnification of one half was used. The Test Target positive pattern was used having black lines on a white background. Furthermore, a microscope with a magnifying power of 20 was employed to observe the image of the test target on the fiber optic piece. The number of resolved line pairs per millimeter at the center of the device was 57 at operating voltage of 15 kV.

PHOSPHOR SPECTRAL EMISSION CHARACTERISTIC MEASUREMENTS

Spectral emission characteristic was measured with a spectroradiometer system, EG&G Model 580/585. This system consists of a beam input optics, a monochromator, a high sensitivity detector head and an indicator unit. The beam input optics diffuses the light from the screen and focuses it through the entrance slit of the monochromator onto a rotating reflective grating. The light incident upon the plane difraction grating is angularly dispersed according to wavelength. The grating is manually rotated to direct any selected wavelength into a concave mirror. This mirror collects the light and forms an image of the entrance slit on the exit slit by means of quartz collector lens. The exit slit of the monochromator is optically coupled to the photocathode of a photomultiplier which serves as a high sensitivity detector. The electrical output signal from the detector head is directly proportional to the input light level and it is precisely measured by an indicator unit. Figure 1 shows spectral energy emission characteristics of phosphor P-46, (dashed line). For comparison the typical spectral distribution of the same phosphor is shown by a full line as published in Ref. 4.

LUMINESCENCE DECAY TIME MEASUREMENT

A block diagram of the system for measuring the luminescence decay time is shown in Fig. 2. The system consists of a light pulse generator, a high gain photomultiplier, an oscilloscope and appropriate power supplies. All components used in the system are available commercially except the light generator. A high efficiency Gallium Arsenide Phosphide electroluminescent diode, Hewlett-Packard type HLMP-3315, driven by an transistor pulse generator was used as the light source. A separate standard type pulse generator, capable of supplying pulses with nanosecond rise times and amplitudes of – 3 V is required to operate light pulse generator. The electrolumiscence diode was driven by a current pulse of 60 mA with a shape having a FWHM of 5 ns. The voltage across the diode was 3.0 V. A schematic diagram of the electroluminescent diode driver stage is given in Fig. 2.

The output light pulse from the generator, as observed by a Hamamatsu R647 photomultiplier, is shown in Fig. 4. The image intensifier output light pulse observed by the same photomultiplier is shown in Figs. 5 and 6. The photomultiplier operating voltage was 1.1kV. It can be concluded from these figures that the luminescence decay time from initial brightness to the 10% decay point was approximately 160 ns. The relative brightness as a function of time after excitation is shown in Fig. 7. The reference electrical pulse from the standard pulse generator is also shown in Figs. 4, 5 and 6. For comparison, the brightness characteristics of phosphors P-11 and P-20 are also shown. In general, the luminescence decay time depends upon the anode current. For the phosphor P-11 the characteristics a and b are for the anode current 2.5 μA and 25 μA, respectively. Similarly, for phosphor P-20, the brightness characteristics c, d and e are for the current density 2 μA/cm^2, 20 μA/cm^2 and 50 μA/cm,^{2} respectively.[4]

CONCLUSIONS

Our measurements of the modified 1248-1 image intensifier approximately agree with all basic characteristics, except the luminous gain, with those given by manufacturer for the nonmodified device with P-20 phosphor screen. In both devices the phosphor screen is coated with a thin opaque film of aluminum. For the intensifier having P-20 phosphor, the spatial resolution at the center of the device is 72 lp/mm. Our measurements performed on the device with the short luminescence decay time phosphor exhibit the resolution of 57 lp/mm at the center. This is due to the higher percentage of large particles of the P-46 phosphor. Furthermore, because of production tolerances, there is a small difference between our measurements and the generally accepted typical spectral energy emission characteristic of the P-46 phosphor. However, there is a significant difference in the luminous gain between devices. Our measurements have shown that the intensifier with P-46 phosphor screen has significantly smaller luminous gain than the similar device with a P-20 phosphor. In general the luminous gain of a single stage image intensifier, defined as the ratio of the luminous output flux and the luminous input flux, is approximately given by

$$G_i \simeq S_{ph} (V_{pph} - V_e) \eta_s$$

where S_{ph} is the luminous sensitivity of the photocathode in A/lm, V_{pph} is the applied voltage between the photocathode and the phosphor screen in V, V_e is the effective voltage loss in the metallic overlay of the phosphor in V, and $\eta_s$is the luminous conversion efficiency of the aluminized phosphor screen in lm/W. The efficiency of phosphor screen depends upon the bulk material efficiency, the thickness of the phosphor screen, the losses in the aluminum film, the particle size of the phosphor and the applied voltage. The conversion efficiency for a screen using P-20 material is in the range from 40 to 50 lm/W. The screen efficiency of one using P-46 material is in the range from 6 to 15 lm/W, mostly due to the bulk material efficiency. This explains the difference in the luminous gain for intensifiers having the same photocathode, applied voltage and different phosphor materials.

From above considerations follow that the luminous gain of the single stage image intensifier with short luminescence decay time phosphor is too small for streamer chamber applications. Consequently, in such applications a multistage image intensifier should be used, where a gain from several hundred to several thousand can be obtained.

ACKNOWLEDGEMENT

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Reference to a company or product name does not imply approval or recommendation of the product by the University of California or the U.S. Department of Energy to the exclusion of others that may be suitable.

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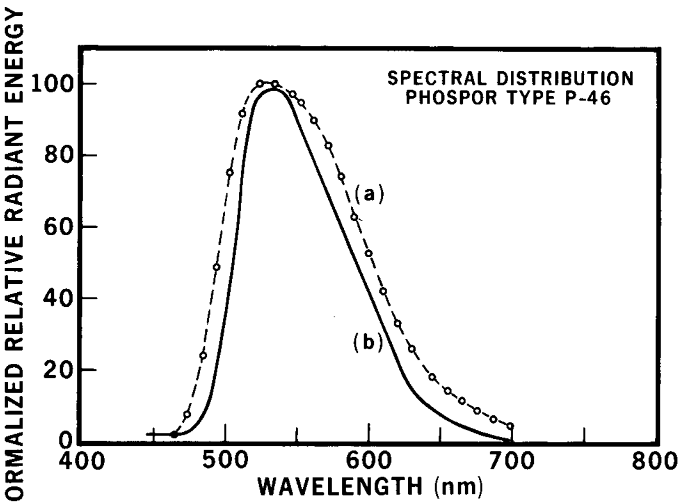

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Fig. 1 Spectral emission characteristics of P-46 phosphor screen.
(a) Measured spectral distribution
(b) Typical spectral distribution

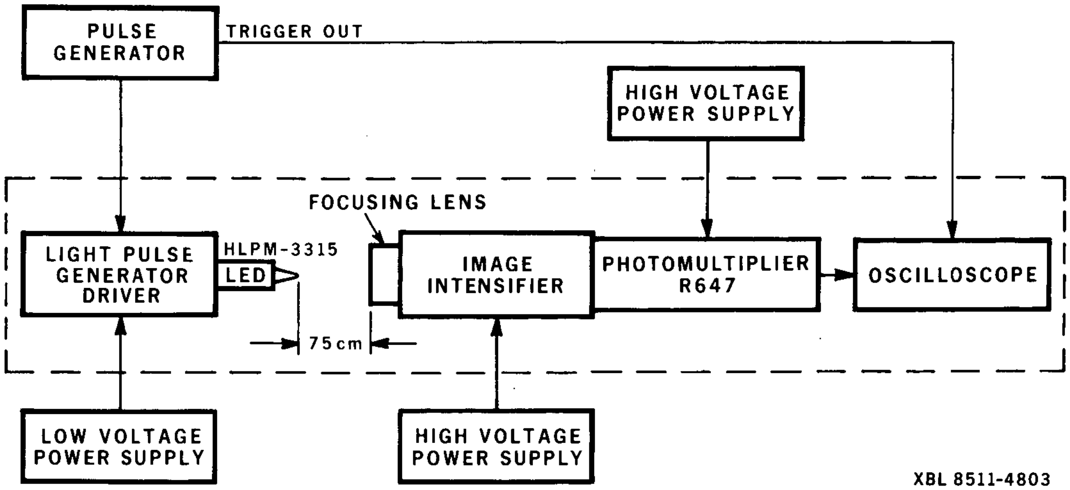

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Fig. 2 Block diagram of the system for measuring the luminescence decay time of fast image intensifiers.

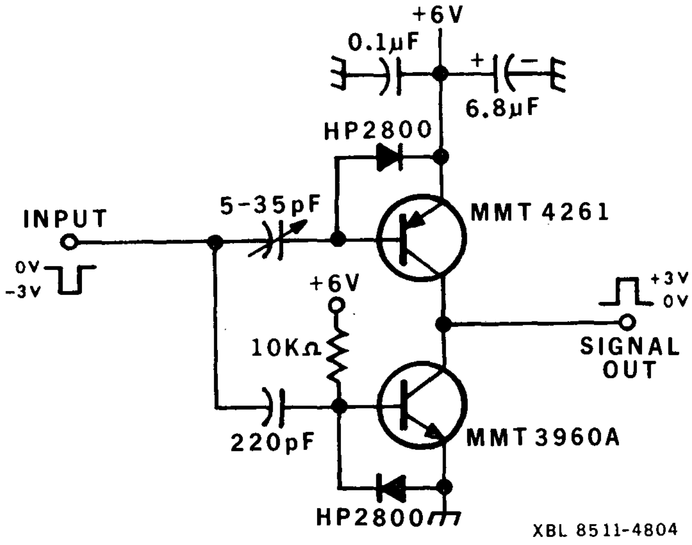

Fig. 3 Schematic diagram of the electroluminescent diode driver.

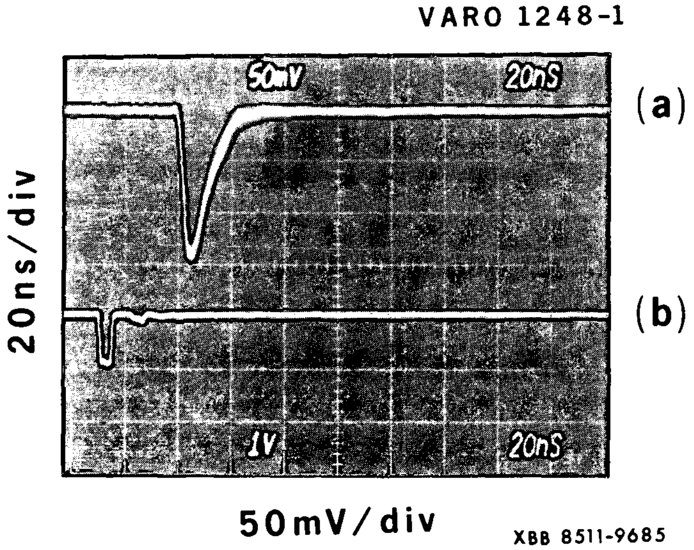

Fig. 4 (a) Output pulses from the electroluminescent Gallium Arsenide Phosphide diode as observed by a Hamamatsu R 647 photomultiplier. The photomultiplier operating voltage was 1.1 kV.
(b) Reference electrical pulse from the standard pulse generator.

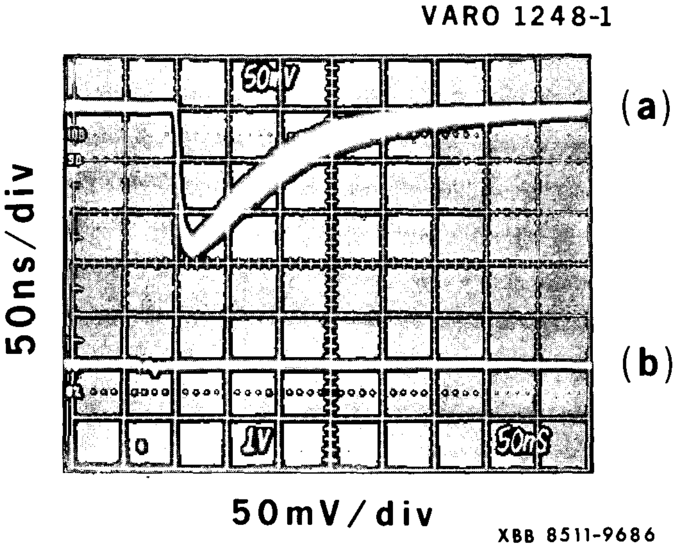

Fig. 5 (a) Output pulses from the image intensifier as observed by a Photomultiplier R 647.
(b) Reference electrical pulse from the standard pulse generator.

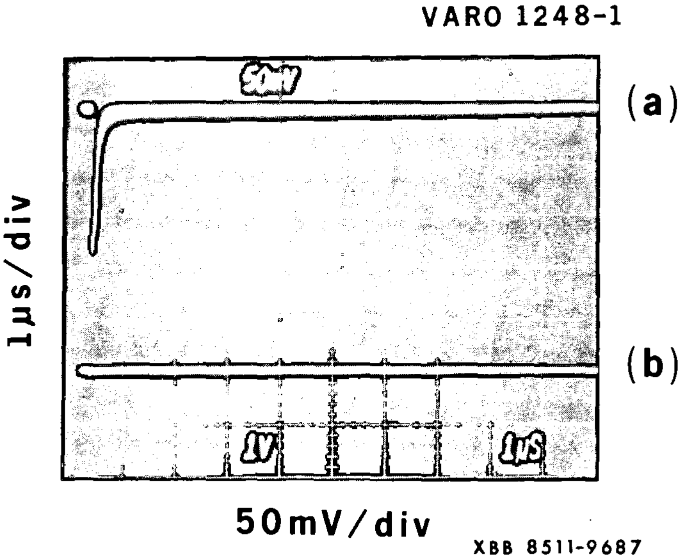

Fig. 6 (a) Output pulses from the image intensifier as observed by a Photomultiplier R 647.
(b) Reference electric pulse from the standard pulse generator.

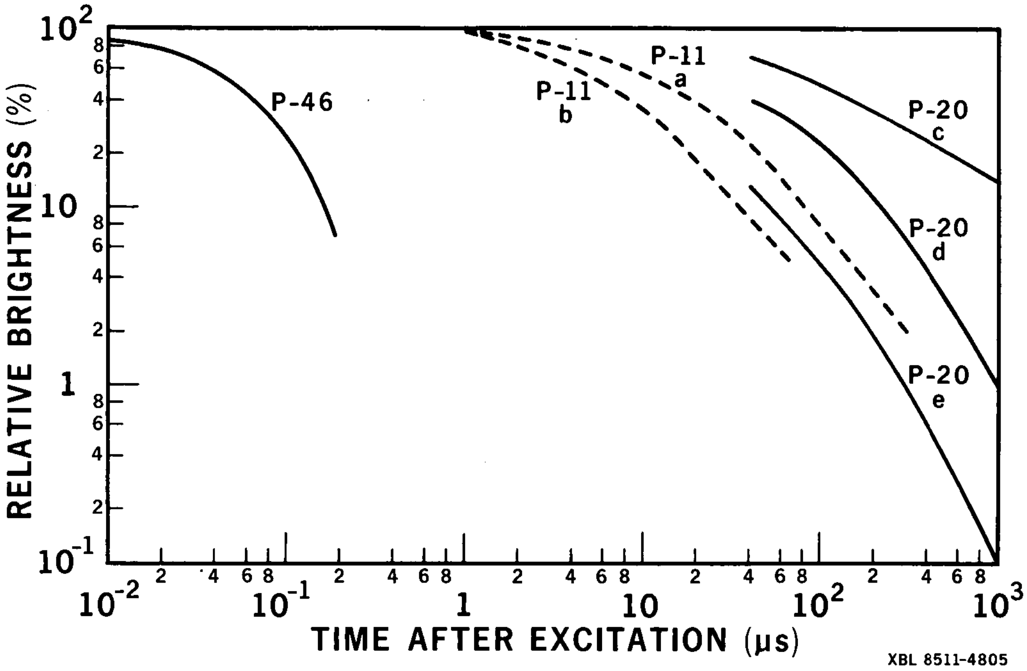

Fig. 7 Relative brightness as a function of time for phosphor screen P-11, P-20 and P-46. The curves a and b are for the anode current of 2.5 μA, and 25 μA, respectively. The curves c, d and e are for the current densities of 2 μA/cm^2, 20 μA/cm^2 and 50 μA/cm^2, respectively.

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