Laboratori Nazionali di Frascati

LNF-71/31

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Estratto da: Rev. Sci. Instr. 42, 519 (1971)

Reprinted from THE REVIEW OF SCIENTIFIC INSTRUMENTS, Vol. 42, No. 4, 519–522, April 1971
Printed in U. S. A.

The Light Output from ZnS:Ag Phosphor at Low Excitation Current Densities

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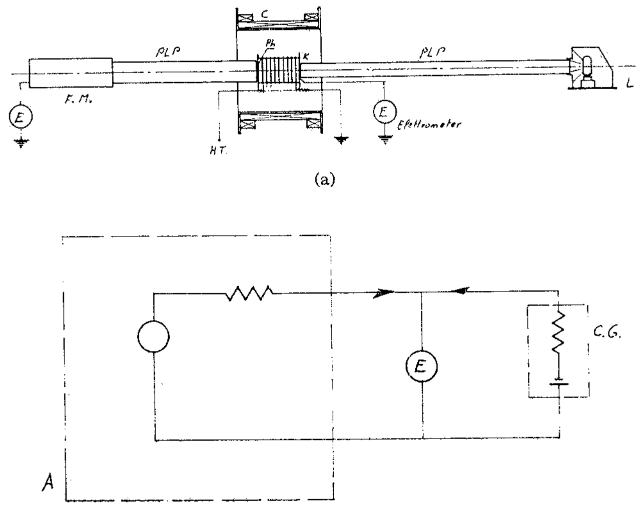
(Received 2 November 1970)

IN the case of composite phosphor ZnS(48%) CdS(52%): Ag, work of Lasof has been reported in Leverenz's book,[1] indicating a decrease of cathodoluminescent efficiency in the excitation current density range 10^{-6}–10^{-10} A/cm^2.

From the work of various experimenters the cathodoluminescence efficiency of ZnS:Ag phosphor has been observed to be constant in the excitation current density range of 10^{-9} A/cm^2 to a few microamperes per square centimeter. However, at very low excitation current densities some decrease in efficiency has been reported by Francis and Stoudenheimer.[2] The experimental results of these authors show that the efficiency of ZnS:Ag phosphor screens operated at 15.0 kV decreased from an almost constant value of 7.4 lm/W at the excitation current density of 10^{-11} A/cm^2 to a constant value of 4 lm/W at an excitation current density of 4×10^{-13} A/cm^2.



(a)

(b)

FIG. 1. (a) Schematic diagram of the experimental setup. E—Electrometer; PLP—Plexiglas light pipe; C—magnetic field coil; FM—photomultiplier; K—photocathode; L—light source; Ph—phosphor; HT—high voltage. (b) Background current balancing circuit. A—Equivalent circuit of image convertor; E—electrometer; C.G.—current generator.

A decrease of a factor of 2 in the cathodoluminescent efficiency at very low excitation current densities is rather alarming because ZnS:Ag phosphor screens are commonly used in image intensifiers for very low light level applications. For quantitative measurements a previous accurate calibration of the phosphor screen characteristics at very low excitation current densities is essential.

The purpose of our experiment was to investigate the relationship between the light output and the excitation current density for GNSFF grade of ZnS:Ag phosphor manufactured by Levy West, England, from the view point of calibrating its characteristics for ultimate use in image intensifiers constructed at our laboratories.

A single-stage magnetically focused image convertor, with an S-11 photocathode and a ZnS:Ag (P-11) aluminized phosphor screen of thickness 1 mg/cm^2, was constructed for this experiment. The phosphor under investigation is P-11, grade GNSFF manufactured by Levy West, Harlow, Essex, England.

The output light from the phosphor was measured by a photomultiplier (Philips 56 AVP with an S-11 photocathode) operated at 2.4 kV with a gain of 5×10^5. Two electrometers (GEC type 1230 A) were used to measure

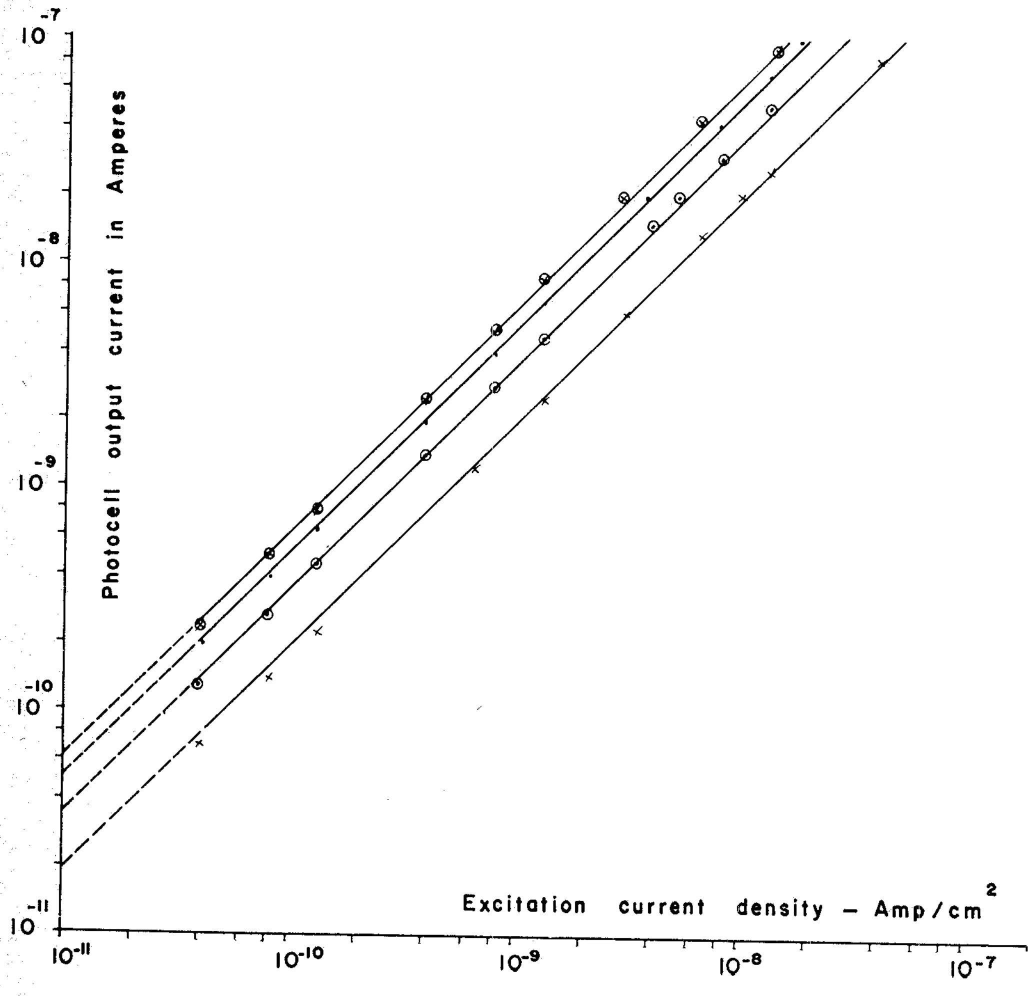


FIG. 2. Output light from the phosphor as a function of excitation current density in the range 4×10^{-11}–4×10^{-8} A/cm². ×—at 10.0 kV; ⊙—at 12.5 kV; ●—at 15.0 kV; ⊗—at 17.5 kV.

the output of the photomultiplier or photocell and the excitation current density at the photocathode of the image convertor. The lamp illuminating the photocathode of the image intensifier was powered by a dc power supply with 0.02% stabilization. A schematic diagram is shown in Fig. 1(a).

The background current of the image intensifier, operated at 15 kV, was 3.0×10^{-11} A. It was measured by grounding the photocathode of the image intensifier through an electrometer while one end of the bleeder chain of the image tube was earthed, the phosphor end being at a high positive potential as shown in Fig. 1(a). The background current (I_d) of the image convertor consists of many components,

$$I_d=I_l+I_{th}+I_{fe}+I_{se},$$

where I_l is the leakage current along the walls of the image tube, I_{th} is the thermionic emission current from the photocathode, I_{fe} is the field emitted electronic current, and I_{se} is the secondary emission electronic current. From experimental evidence it was ascertained that the background current of our experimental image intensifier was predominantly the leakage current along the tube walls and any contribution owing to other components was negligible, i.e., less than 10^{-14} A.

In order to make more accurate measurements of the photocurrent at the photocathode of the image convertor, its background current was balanced to zero by sending an equal and opposite current, from a current generator, through the measuring instrument. The background current balancing circuit is shown in Fig. 1(b). Thus precise measurements of excitation current densities could be made. From manufacturer's data the error of measurement of the instrument is 10% for full scale deflection in the current measurement range 10^{-14}–10^{-9} A. All other errors of measurement, grouped together, are estimated to be less than 10%.

The behavior of the excitation current density range 4×10^{-11}–4×10^{-8} A/cm² and the light output, as measured by a photocell, from the ZnS:Ag phosphor screen operated at four different voltages between 10.0 kV and 17.5 kV, is shown in Fig. 2. Similarly Fig. 3 shows the relationship between the excitation current density range 6×10^{-14}–4×10^{-11} A/cm² and the light output, measured

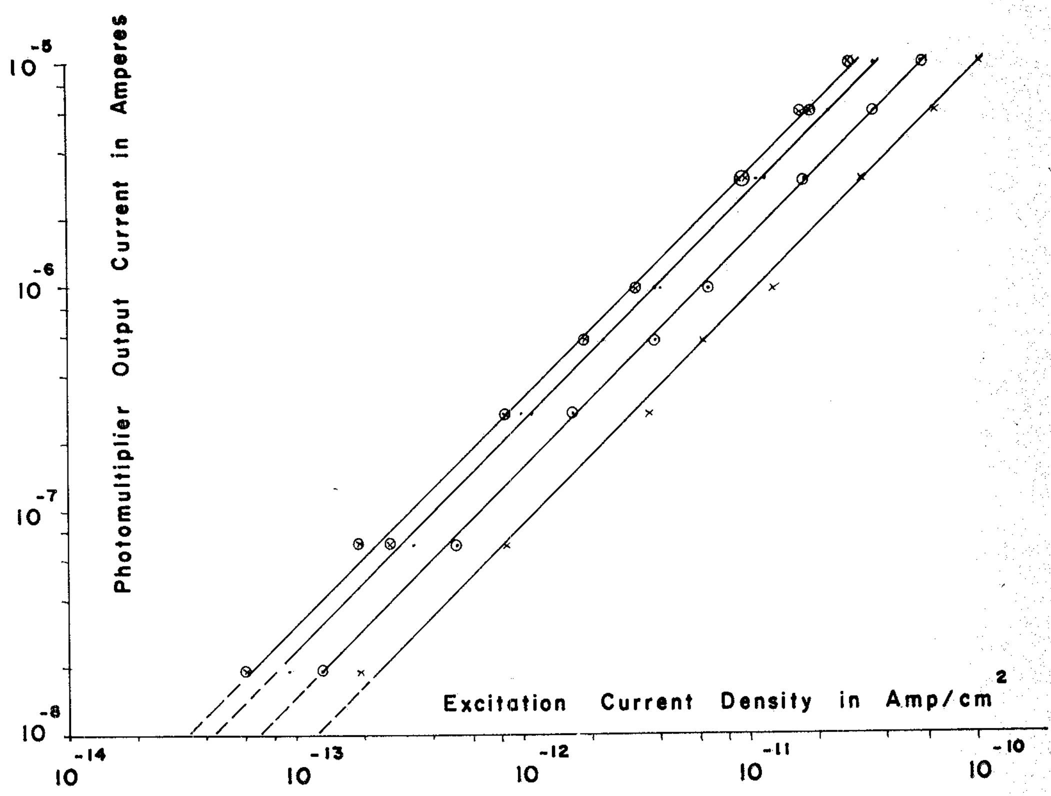


FIG. 3. Relationship between the light output from the phosphor screen and the excitation current density in the range 6×10^{-14}–4×10^{-11} A/cm². ×—at 10.0 kV; ⊙—at 12.5 kV; ●—at 15.0 kV; ⊗—at 17.5 kV.

by a photomultiplier, from the same ZnS:Ag phosphor screen operated at the same range of applied voltages.

The experimental results show a linear relationship between the light output and the excitation current density over the range 4×10^{-8}–6×10^{-14} A/cm². From these measurements it is concluded that the efficiency of ZnS:Ag phosphor remains constant through the above mentioned range, at least for the type of phosphor under investigation.

[1] H. W. Leverenz, *Luminescence of Solids* (Wiley, New York 1950), p. 351.
[2] G. W. Francis and R. G. Stoudenheimer, Rev. Sci. Instrum. **31**, 1246 (1960).