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University of California, Berkeley, California

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Electroluminescence occurs widely and is often attributed to transitions involving impurity levels in solids.¹ The observation of this phenomenon in electrooptic light modulators (EOLM) composed of KDP (KH_2PO_4) and KD^*P (KD_2PO_4) was unanticipated because the excellent optical properties of these materials has led us to assume naively that they were largely free of impurities.²

The characteristics of the electroluminescence are presented in Figs. 1 through 3. Figure 1 illustrates the time dependence of the phenomenon; each half cycle of the exciting voltage produces a pulse of radiation from the EOLM. The peak intensity of the luminescence varies with the magnitude and frequency of the applied field, as shown in Fig. 2.³ The intensity of the light varies as the inverse square of the distance between crystal and photomultiplier. Lastly, the wavelength of the emission has been roughly localized with interference filters, and the peak of intensity is at approximately 3270 Å, as is shown in Fig. 3.

Electroluminescence has not been observed previously in modulators composed of KDP for a number of reasons; some of the more obvious are: the use of lower excitation frequencies and voltages; lower sensitivity of the photomultipliers in the ultraviolet; larger separation of the crystal and detector; and higher levels of the light of interest, which tend to mask the phenomenon.

There are two other possibilities. First, the electroluminescence may occur only with the particular EOLM's investigated. This seems unlikely as we have observed the phenomenon in three modulators, each of a different construction (see Table I). Secondly, other workers could have attributed the electroluminescence to arcing or corona.

Our principal interest in these devices is their use as polarization modulators in circular dichrographs,⁴ where the light generated in the modulators may constitute an intolerable source of noise, especially when the source-light intensity is low, as it often is in the ultraviolet. The degradation of the signal-to-noise ratio in the limit of low incident flux is easily determined. For shot-noise-limited optical measurements (no electroluminescence) we have

$$N \propto \phi^{1/2},$$

$$S \propto \phi,$$

and

$$(S/N) \propto \phi^{1/2},$$

where ϕ is the light flux passing through the system and incident on the photomultiplier.

If we let ϕ_e be the flux of the electroluminescence, then for measurements in the presence of ϕ_e

$$N \propto (\phi + \phi_e)^{1/2},$$

$$S \propto \phi,$$

and

$$(S/N)_e \propto \phi / (\phi + \phi_e)^{1/2}.$$

As a measure of the S/N degradation we may write

$$R = \frac{(S/N)_e}{(S/N)_0} = \left(\frac{\phi}{\phi + \phi_e} \right)^{1/2}.$$

For low levels of ϕ , the effect of ϕ_e becomes greater, and in the limit of low incident flux

$$\lim_{\phi \rightarrow 0} R = \lim_{\phi \rightarrow 0} \left(\frac{\phi}{\phi + \phi_e} \right)^{1/2} = \lim_{\phi \rightarrow 0} \left(\frac{\phi}{\phi_e} \right)^{1/2}.$$

As can be inferred from the preceding paragraphs, our immediate purpose is to minimize or totally exclude the electroluminescence.

By contrast, however, the exponential relationship between emitted flux and excitation voltage, coupled with the high breakdown voltage of these materials, implies that light intensities several orders of magnitude greater than reported here may be expected. Were this to occur with high efficiency, laser operation might be possible. Such a development would be of interest because of the short wavelength of the luminescence.

Footnote and References

*Work performed under the auspices of the U.S. Atomic Energy Commission.

1. H. F. Ivey, Electroluminescence and Related Effects, in Supplement 1 to Advances in Electronics and Electron Physics, L. Marton, Ed. (Academic Press, New York, N. Y., 1963).
2. Subsequent to these observations, Dr. A. Carlson of the Clevite Corporation informed us that a number of impurities are intentionally introduced into the starting materials to facilitate the growth of large crystals along selected axes.
3. The data for this figure was obtained by measurements on crystal "B" (see Table I). The field strength can be determined from the equation $E = V/t$.
4. H. W. Babcock, Astrophys. J. 118, 387 (1953).

Table I

Listing of electrode type, crystal material, and crystal thickness (t) for three electrooptic light modulators which exhibit electroluminescence

Crystal Material	Electrode Type	
	Indium Ring	Gold Grid
Potassium Dideuterium Phosphate	EOLM "A" t = 2 mm	EOLM "B" t = 1.6 mm
Potassium Dihydrogen Phosphate	EOLM "C" t = 25 mm	

Figure Legends

Figure 1. Oscilloscope records of electroluminescence intensity (upper trace) and EOLM exciting voltage (lower trace). Frequency of exciting voltage is 500 Hertz.

Figure 2. Dependence of electroluminescence intensity on magnitude (upper graph) and frequency (lower graph) of EOLM exciting voltage.

Figure 3. Wavelength dependence of electroluminescence intensity.

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Figure 1. Oscilloscope records of electroluminescence intensity (upper trace) and EOLM exciting voltage (lower trace). Frequency of exciting voltage is 500 Hertz.

Figure 2. Dependence of electroluminescence intensity on magnitude (upper graph) and frequency (lower graph) of EOLM exciting voltage.

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Figure 3. Wavelength dependence of electroluminescence intensity.

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