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THIN FILM PC-EL TYPE ELECTRIC AND OPTICAL SIGNAL DELAYING SYSTEMS

Z. PORADA
Institute of Engineering and Electronics, Technical University, Warszawska 24, 31-155 Kraków (Poland)
E. SCHABOWSKA-OSIOWSKA
Institute of Electronics, Academy of Mining and Metallurgy, Al.Mickiewicza 30, 30-159 Kraków (Poland)

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1. INTRODUCTION

The rapid development of optoelectronics and more widespread utilization in technology of various types of optoelectronic systems has resulted in an increase in interest in thin film PC-EL type systems. They are increasingly being used as logic circuits, as amplifiers of weak light signals, and can be used to delay electric and optical signals. The electric and optical signal delay lines find application in various types of industrial telecommunication systems.

In the presented work, the dependence of the delay times of electric pulse signals and optical signals in the form of rectangular light pulses on the parameters of PC-EL system was investigated. Characteristics obtained were compared with the curves calculated from a proposed mathematical model.

2. THEORETICAL CONSIDERATION

A diagram of electric signal delaying system is shown in Fig. 1. In such a system, the input signal is the voltage U_{inp} supplying the element EL_1, and the output signal is the current I_{out} through the element PC.

The switching on of the voltage U_{inp} will cause the emission of light from the element EL_1 of luminance B_1, which can be described[1] by the relation:

$$B_1(t) = B_{01} \exp(-\gamma_1 t) \exp[b_1/(|U_{inp}|)^{1/2}] \tag{1}$$

where B_{01}, γ_1 and b_1 are the parameters, constant for given electroluminescent cell EL_1.

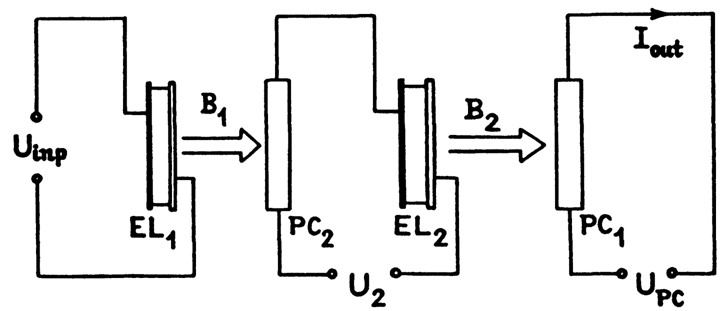

FIGURE 1 PC-EL type electric signal delaying system.

The light with luminance B_1 will then illuminate the element PC_2, causing an increase of its conductance G_{PC2}, which can be described[2] by following equation:

$$\frac{d}{dt} G_{PC2} = a_2\beta_1B_1 - \frac{G_{PC2} - G_{02}}{\tau_2} \qquad (2)$$

where G_{02} is the "dark" conductance of non-illuminated element PC_2, τ_2 is the photoconductivity rise time for this element, a_2 is a parameter, constant for given element PC_2, and β_1 is the unidirectional optical coupling coefficient of the element EL_1 with the element PC_2.

The increase of the conductance G_{PC2} will cause an increase of the voltage on the element EL_2, so that it will emit the light of luminance B_2, which can be described with a formula similar as in the case of luminance B_1:

$$B_2(t) = B_{02} \exp(-\gamma_2 t) \exp[-b_2/(|U_{EL2}|)^{1/2}] \qquad (3)$$

where the voltage U_{EL2} on the element EL_2 is given by the formula:

$$C_{EL2} \frac{d}{dt} U_{EL2} + U_{EL2}(G_{EL2} + G_{PC2}) = G_{PC2}U_2 \qquad (4)$$

where B_{02}, γ_2, and b_2 are parameters of electroluminescent cell EL_2, C_{EL2} is its capacity, G_{EL2} is its leakage conductance, and U_2 is the voltage supplying the PC_2-EL_2 system.

The light emitted by the element EL_2 illuminates the photoconducting element PC_1, causing an increase of its conductance G_{PC1} and thereby an increase in the output current I_{out}. The course of this current vs. time $I_{out}(t)$ can be expressed by the formula:

$$I_{out}(t) = G_{PC1}(t)U_1 \qquad (5)$$

where the conductance $G_{PC1}(t)$ is described by the eqution:

$$\frac{d}{dt} G_{PC1} = a_1\beta_2B_2 - \frac{G_{PC1} - G_{01}}{\tau_1} \qquad (6)$$

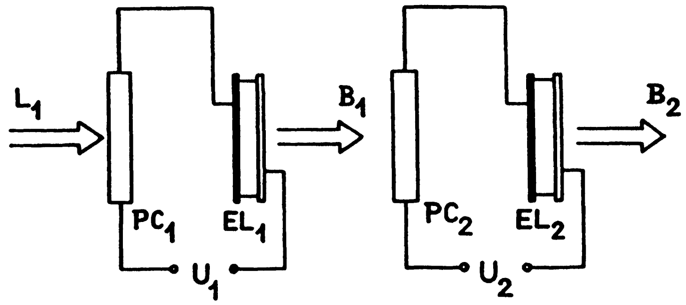

FIGURE 2 Diagram of an optical signal delaying PC-EL system.

where G_{01} is the "dark" conductance of non-illuminated element PC_1, τ_1 is the photoconductivity rise time for this element, a_1 is a parameter, constant for given element PC_1, β_2 is the unidirectional optical coupling coefficient of the element EL_2 with the element PC_1, and U_1 is the voltage supplying the circuit with the element PC_1.

The solution of the set of equations (1)–(6) allows one to calculate the delay time τ_2 of the output signal I_{out} in relation to the input signal U_{inp}.

In Fig. 2, the diagram of an optical signal delaying PC-EL system is shown. In the circuit under consideration, the input signal is a light pulse illuminating PC_1 element, the illumination of which is L_1, and the output signal is the light emitted by the element EL_2, the luminance of which is B_2.

The illumination of the element PC_1 causes an increase in the conductance G_{PC1} of this element, the result of which the voltage on the element EL_1 will increase so that the electroluminescent cell EL_1 will emit the light of luminance B_1. This luminance can be described by the expression (1), where $U_{inp} = U_{EL1}$. The voltage U_{EL1} is given by the formula:

$$C_{EL1} \frac{d}{dt} U_{EL1} + U_{EL1}(G_{EL1} + G_{PC1}) = G_{PC1}U_1 \tag{7}$$

where C_{EL1} are, respectively, the capacity and the leakage conductance of the element EL_1, U_1 is the voltage supplying the PC_1-EL_1 circuit, and the conductance G_{PC1} is described by the formula:

$$\frac{d}{dt} G_{PC1} = a_1L_1 - \frac{G_{PC1} - G_{01}}{\tau_1} \tag{8}$$

where a_1 is a parameter, constant for the element PC_1, τ_1 is the photoconductivity rise time for this element, and G_{01} is the "dark" conductance of non-illuminated element PC_1.

As can be seen on Fig. 3, the element EL_1 is optically coupled with the element PC_2 and, thereby, the illumination of the element PC_2 will be $L_2 = \beta B_1$, where β is the unidirectional optical coupling coefficient. Thus, the output signal in the

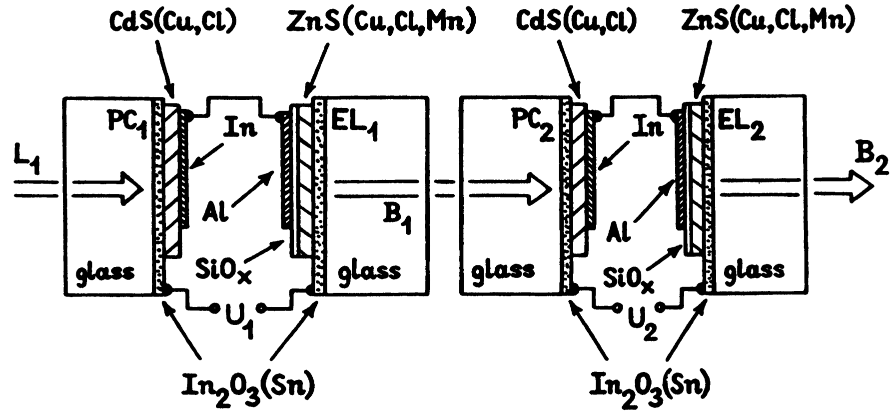

FIGURE 3 Thin film PC-EL type optical signal delaying circuit.

form of luminance B_2 of the light emitted by the element EL_2 can be described using the dependence:

$$B_2(t) = B_{02} \exp(-\gamma_2 t) \exp[-b_2/(|U_{EL2}|)^{1/2}] \tag{9}$$

where the voltage U_{EL2} is described by the formula:

$$C_{EL1} \frac{d}{dt} U_{EL2} + U_{EL2}(G_{EL2} + G_{PC}) = G_{PC2}U_2 \tag{10}$$

and the conductance G_{PC2} of the element PC_2 is given by the equation:

$$\frac{d}{dt} G_{PC2} = a_2\beta B_1 - \frac{G_{PC2} - G_{02}}{\tau_2} \tag{11}$$

where B_{02}, γ_2, and b_2 are parameters, constant for given element EL_2, C_{EL2} is the electric capacity of this element, G_{EL2} is its leakage conductance, a_2 is a parameter, constant for the element PC_2, G_{02} is the "dark" conductance of non-illuminated element PC_2, and U_2 is the voltage supplying the PC_2-EL_2 circuit.

After solving the set of equations (7)–(11) the delay time τ_{op} of output signal B_2 in relation to input signal L_1 can be determined.

3. RESULTS OF EXPERIMENTAL INVESTIGATION

The circuit PC-EL delaying the optical signal (Fig. 3) was composed of two photoconducting elements, PC_1 and PC_2, and two electroluminescent cells, EL_1 and EL_2.

In the elements PC, the photoconducting layer was made of copper- and chlorine-doped cadmium sulphide, the transparent electrode was a tin-doped indium oxide layer, and the second electrode an indium layer[3].

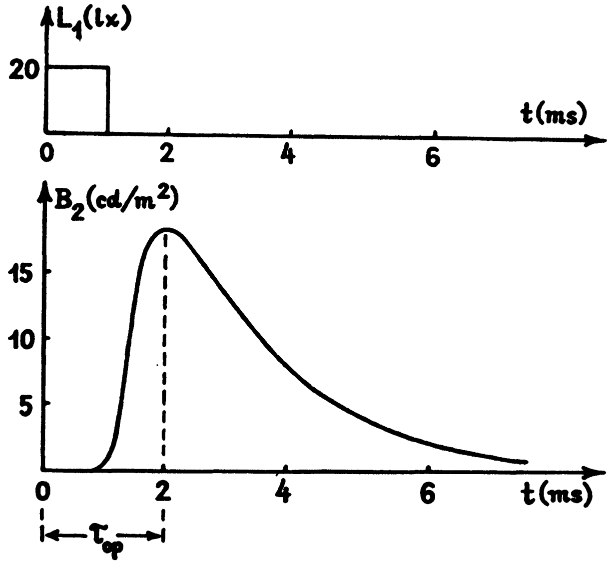

FIGURE 4 The dependence of luminance B_2 and illumination L_1 on time for the delaying circuit PC-EL supplied with equal sinusoidal voltages $U_1 = U_2 = 420$ V of the frequency f = 70 Hz.

In the elements EL, the electroluminescent layer was copper-, chlorine- and manganese-doped zinc sulphide, the transparent electrode was a tin-doped indium oxide layer, and the second electrode was an aluminium layer[4].

In the circuit under consideration, the dependence of luminance B_2 on time, as well as the dependence of the illumination L_1 on time, for the delaying circuit PC-EL supplied with equal sinusoidal voltages U_1 and U_2 ($f_1 = f_2 = f$) of the frequency f = 70 Hz (Fig. 4) were investigated.

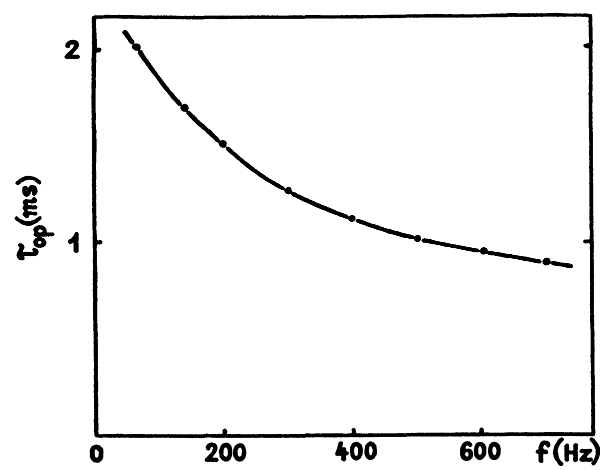

FIGURE 5 The dependence of the delay time τ_{op} on the frequency of the voltage supplying the PC-EL circuit.

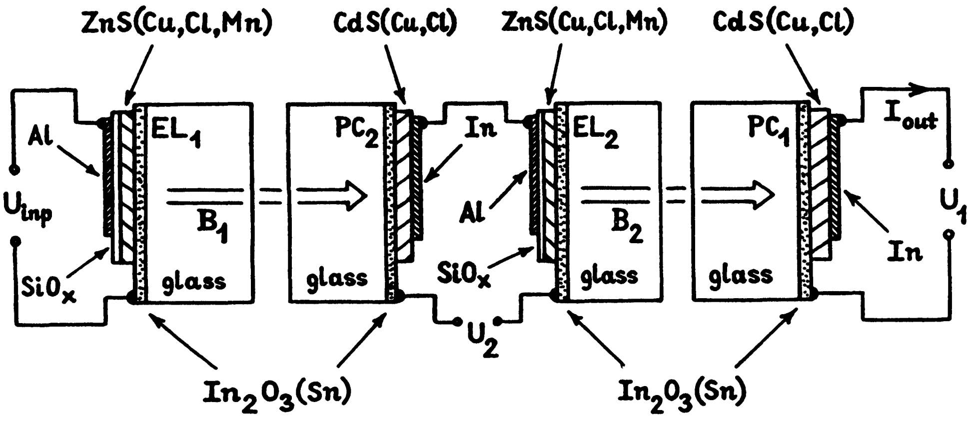

FIGURE 6 Thin film PC-EL type electric signal delaying circuit.

In Fig. 5, the dependence of the delay time τ_{op} on the frequency of the voltage supplying the PC-EL circuit ($f_1 = f_2 = f$) is presented. The electric signal delaying circuit is shown in Fig. 6. In the considered circuit, the dependence of the voltage U_{inp} and the current I_{out} on time was investigated (Fig. 7). In Fig. 8, the dependence of delay time τ_0 on the frequency of voltage supplying the PC_2-EL_2 circuit is presented.

4. CONCLUSIONS

Results from the analysis of proposed theoretical model indicate that the delay time of the optical signal τ_{op} depends, in the first place, on the photoconductivity

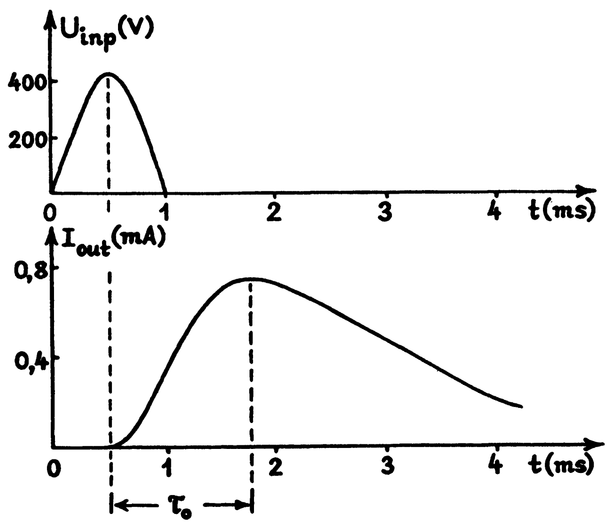

FIGURE 7 Time dependences of the input signal U_{inp} and of the output signal I_{out}; $f = 140$ Hz.

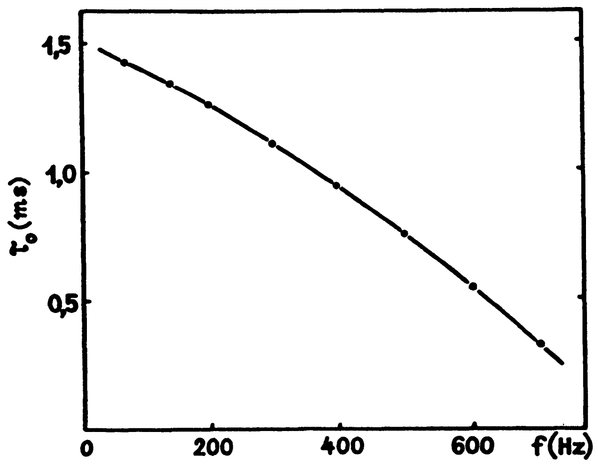

FIGURE 8 Dependence of delay time τ_0 on the frequency of supplying voltage U_2.

rise times τ_1 and τ_2, as well as on the frequency of supplying voltages U_1 and U_2; the value τ_{op} can be increased, in the circuit under consideration, by using a greater number of PC_1-EL_2 circuits.

The delay time of electric signal τ_0 depends also on the values of photoconductivity rise times τ_1 and τ_2, as well as on the frequency f of voltage U_2 supplying the PC_2-EL_2 circuit.

The PC-EL type electric signals delaying systems, as well as optical delaying system, have an additional advantage; namely, the connection of input circuits with output circuits in these systems is not galvanic, i.e., from the point of view of electric circuits they perform the function of a separator.

REFERENCES

1. Z. Porada and E. Schabowska, J. Luminescence, 21, 129 (1980).
2. P.S. Kireev, Semiconductor Physics, Mir, Moscow, 1978 (English translation).
3. Z. Porada and E. Schabowska-Osiowska, Active and Passive Elec. Comp., 13, 151 (1988).
4. Z. Porada and E. Schabowska, Vacuum, 33, 179 (1983).