SELF-BEATING INSTABILITIES IN BISTABLE DEVICES

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INTRODUCTION

Since the observation of optical bistability by Gibbs et al.[1], optical bistability has been the field where researchers from many fields have found a common place to work. More recently, when Ikeda and co-workers[2-3] discussed the effect of a delayed feedback on instability of a ring cavity containing a non linear dielectric medium, and pointed out that the transmitted light from the ring cavity can be periodic or chaotic in time under a certain condition, optical bistable devices have shown new possibilities to be applied in many different fields. The novel phenomenon has been predicted to be observed in the hybrid optical device[3] and has been confirmed by Gibbs et al.[4]. Moreover, as we have shown[5], a similar effect can be obtained when liquid crystal cells are employed as non linear element.

In this paper sumarize the empirical and theoretical results that have been obtained by us. The electrooptic light intensity modulator has been a nematic liquid crystal cell with twisted configuration. A He-Ne laser beam, 5 mW of power, was incident to the device. Some of the here reported results were presented previously by us. As it will be shown, if certain conditions are achieved, a sustained oscillatory optical output can be obtained. Moreover, a selfbeating phenomena is achieved both, theoretical and empirically.

EXPERIMENTAL

The experimental configuration is the conventional one employed in hybrid optical bistable systems and it is shown, schematically, in Fig.1.

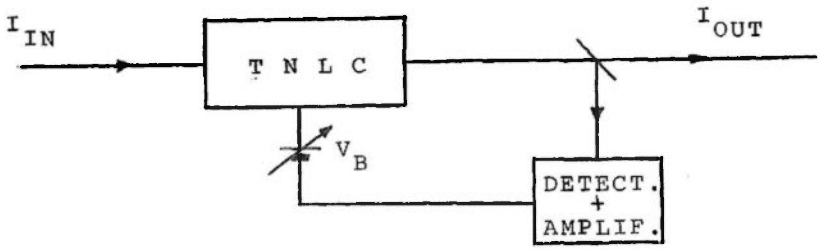


Fig. 1. Hybrid optical bistable system.

The main point concerning this arrangement is the electrooptic light intensity modulator, in our case, a twisted nematic liquid crystal cell. When this cell is orthogonal to the incident laser beam, its transmission curve, as a function of the cell applied voltage, is the one shown in Fig. 2, for 0°. In this case, polarizes are crossed. But when the cell is forming two aagles, Fig. 3, with the input beam direction, this transmission no longer verifies.

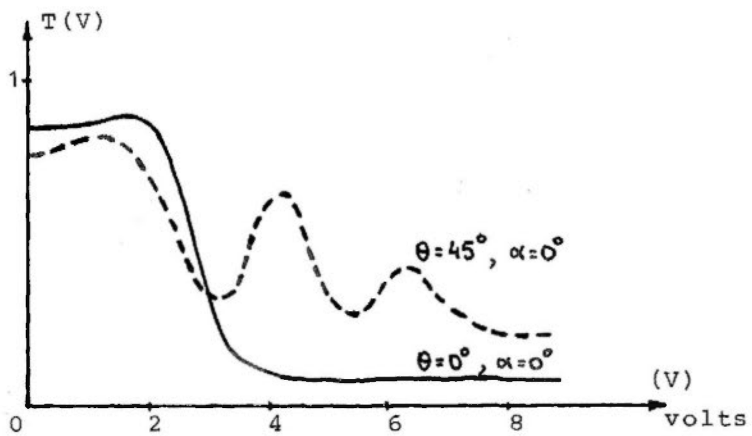


Fig. 2. Optical transmission versus voltage in T.N. cells with crossed polarizers.

The experimental results give the appearance of several maxima and minima. A theoretical study is being under progress and it will published elsewhere. For $\theta = 45°$ and $\alpha = 0°$ the new transmission curve is shown in Fig. 2. This curve has been obtained for the static case. When the applied voltage is varying with time, its shape changes to a more complex form.

With the above considerations, the final set up is shown in Fig. 4.

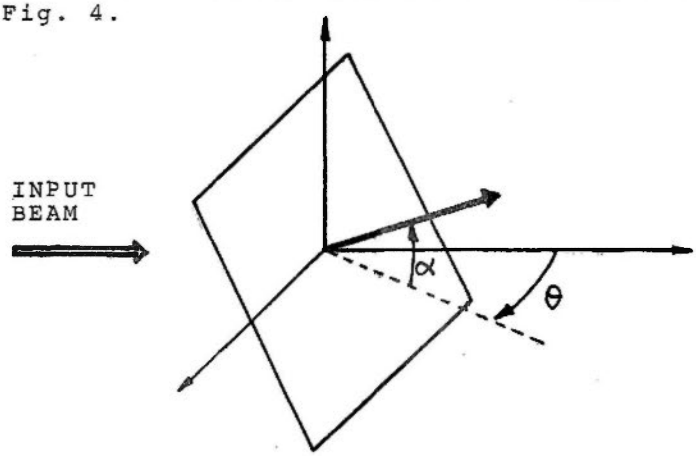


Fig. 3. Orientation of the TNLC cell.

The light, after crossing the liquid crystal cell and a crossed polarizer, impinges on a phototransistor, in our case a TIL 78, working as a current source. The obtained current is afunction of the output intensity level. Feedback is obtained through the variable resistor R. Its value gives the feedback coefficient. This electrooptical system is equivalent, from an alectronic standard point of view, to the circuit shown in Fig.5.a, where C stands for the liquid crystal cell capacitance. This circuit, because the phototransistor is operating as a current source, is equivalent to the one shown in Fig. 5.b. Moreover, by Norton and Thevenin theorems , its electrical equivalent is shown in Fig. 5.c. This circuit has been the basis of our study.

THEORETICAL MODEL

Several are the considerations involving the circuit of Fig. 5.c. Everyone of them gives a certain contribution to the total behaviour of the system. Moreover , some are responsible for the peculiar results obtained by us.

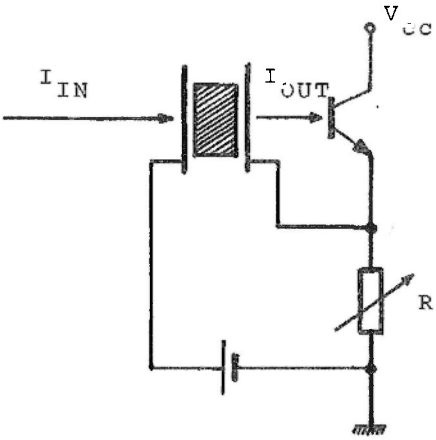


Fig. 4. Experimental setup.

The first consideration is the one concerning the time constant, T_1, for the photodetector. Because its apperance, the equation governing the variation of voltage V_o at Fig. 5.c is

$$V_o + T_1 \frac{dV_o}{dt} = \beta \, I_{OUT} \qquad (1)$$

where β is the feedback coefficient.

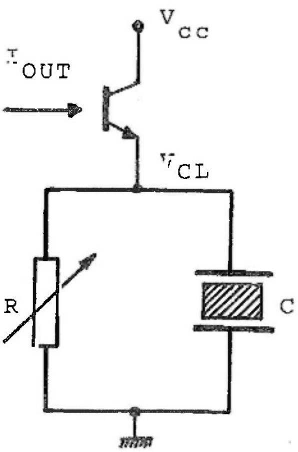


Fig.5.a
Experimental circuit

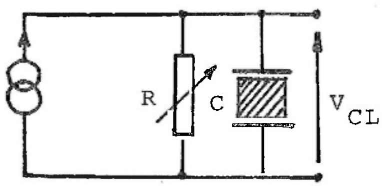


Fig.5.b.Norton circuit

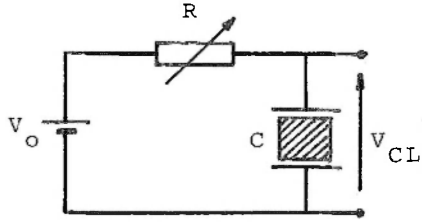


Fig.5.c. Thevenin circuit

Together with the above time constant, is the one associated with R and C components. If we call it, T_2, we will have

$$V_{CL} + T_2 \frac{dV_{CL}}{dt} = V_o \qquad (2)$$

where V_{CL} stands for the effective voltage applied to the liquid crystal cell. C is due to the capacitive effect due to the cell. Moreover, this cell has associated with it capacitive and resistive effects, both giving the value for T_2.

Finally, a third time constant, τ, appears. It is the time needed by the molecules to reorientate according to the electric field inside the cell. This time constant is, certainly, not a constant. Its value depends on the voltage value and on its derivative with time. The first dependence is the strongest and it will be main source for our model. The equation will be

$$V_{ef} + \tau \frac{dV_{ef}}{dt} = V_{CL} \qquad (3)$$

From these three equations we can obtain

$$V + \frac{dV}{dt}\left[\tau + (T_1+T_2)\left(1+\frac{d\tau}{dt}\right) + T_1T_2 \frac{d^2\tau}{dt^2}\right] +$$

$$+ \frac{d^2V}{dt^2}\left[\tau(T_1 + T_2) + T_1T_2 \left(1+2\frac{d\tau}{dt}\right)\right] +$$

$$+ \frac{d^3V}{dt^3}\left[\tau T_1T_2\right] = \beta I_{IN} T (V + V_B) \qquad (4)$$

where $V \equiv V_{ef}$ and $T(V+V_B)$ stands for the transmission function. For $\tau \neq \tau(t)$ this equation simplifies to the one previously reported by us[6]. A further aproach to solve equation (4), is to consider $T_1 \simeq 0$. This aproximation is valid because T_1 is around two orders of magnitude smaller than either T_2 and τ. Equation (4) hence becomes

$$V + \left(T_2 + \tau + T_2 \frac{d\tau}{dt}\right)\frac{dV}{dt} + T_2\tau \frac{d^2V}{dt^2} =$$

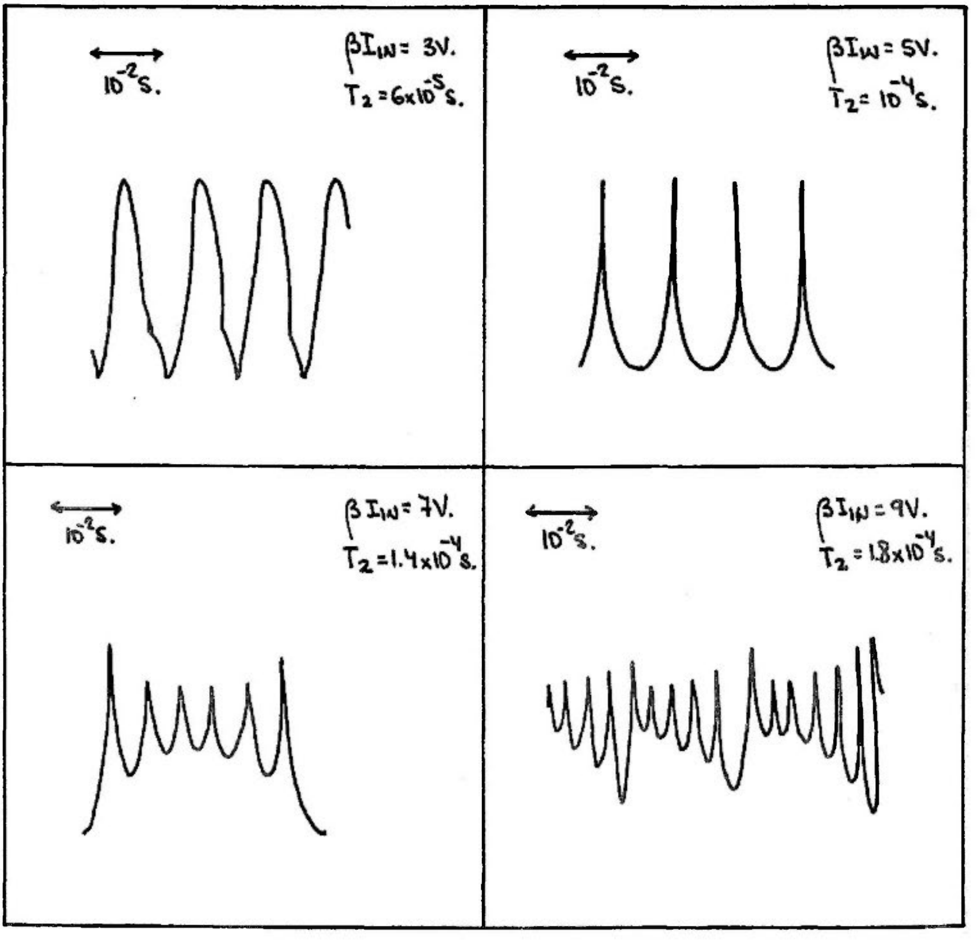
$$= \beta I_{IN} T (V + V_B) \qquad (5)$$

Numerical solutions of this equation, for different values of T_2 and β, are shown in Figs. 6-9. The variation with time of τ, has been taken as

$\tau \simeq \frac{K}{(V-V_{th})^2}$ when voltage is rising, with V_{th} = V of threshold, and

$\tau \simeq K = 10^{-2}$ s. when voltage is going to zero.

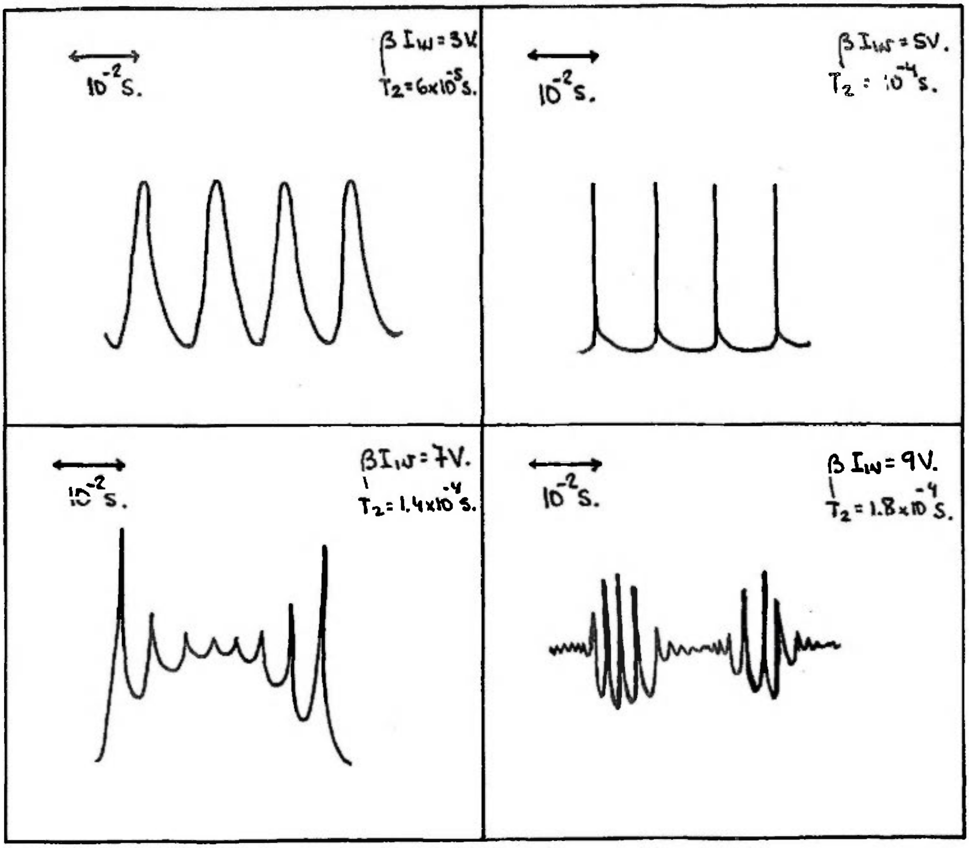
The corresponding values for T_2 and $\beta\ I_{IN}$ are given in Figs. 6-9.



Figs. 6, 7, 8 y 9. Numerical results.

EXPERIMENTAL RESULTS

The main experimental results are shown in Figs. 10 13. Their different waveforms correspond as before to different values for both $\beta\ I_{IN}$ and T_2. As it can be seen, a good agreement with the empirical results obtained from our theoretical model is obtained for the lowest values. This agreement is not so good for higher values. In particular, for $\beta\ I_{IN}$ = 9 volts the discrepancy is evident. The difference is due, according to our calculations, to the simplification had from equation (4) to equation (5). Moreover, in the present model the value for C, liquid crystal cell capacitance, has been taken as a constant, but its value depend on V.



Figs. 10, 11, 12 y 13. Experimental results.

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