Optical memory with twisted nematic liquid crystal (TNLC) devices

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Abstract

A design for obtaining memory in optical bistability with liquid crystals is reported. This design uses optical feedback on a twisted nematic liquid crystal (TNLC) through an optoelectronic system. A constant input light is the read-out and its value depends on the desired initial working point, usually at the bottom of the T(V) vs. V curve. Light levels depend on the feedback.

An input light pulse change the working point to the top of the transmission curve. When this pulse vanishes, the working point remains at the upper part of the curve. Hence a memory function is obtained. Minimum pulse width needed was 1msec. ON-OFF ratio was 100:3.

Introduction

During the past ten years, several proposals were made for a passive optical system which would exhibit bistability. Such system would be of interest for a large number of optical operations. Two types of this system has been considered: systems with intrinsic nonlinearity and systems with hybrid nonlinearity. The first type is based on the intrinsic properties of certain nonlinear media placed within a Fabry-Perot resonator. In the hybrid type, an electrical signal is derived from a detector which samples the light; this electrical signal is used to drive an element whose optical properties are a function of the applied voltage. In this work we will concentrate in this second type, the hybrid one.

By suitably adjusting the operating conditions of the hybrid device, a large variety of useful operating characteristics can be obtained. In this way optical memory, differential amplifiers, optical logic elements, optical triodes, optical limiters and clippers had been reported in the literature.[1,2,3,4] Moreover several kinds of nonlinear materials had been employed, most of them of the solid type, for example $LiNbO_3$.A few papers offer optical bistability with liquid crystals of the nematic type.[5,6] The advantages of this last material are the low voltage and power levels needed.

TNLCHOB devices

The TNLCHOB (twisted nematic liquid crystal hybrid optical bistable) device that we investigated as optical memory is essentialy of the same type that the one that we employed to obtain regenerative pulses[7] (Figure 1). The nonlinear material employed is a TNLC cell whose transmission T(V) as a function of applied voltage V is shown in Figure 2. This transmission characteristic is similar to the one had by other solid state materials which exhibit optical bistability.

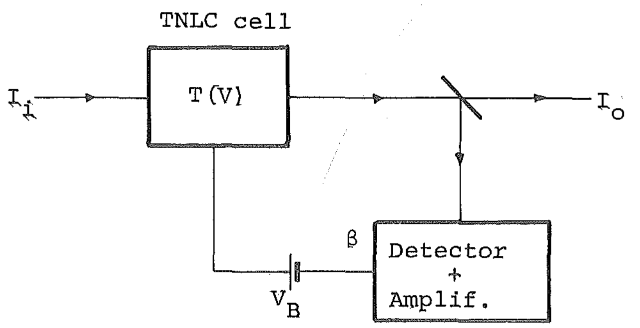

Fig. 1

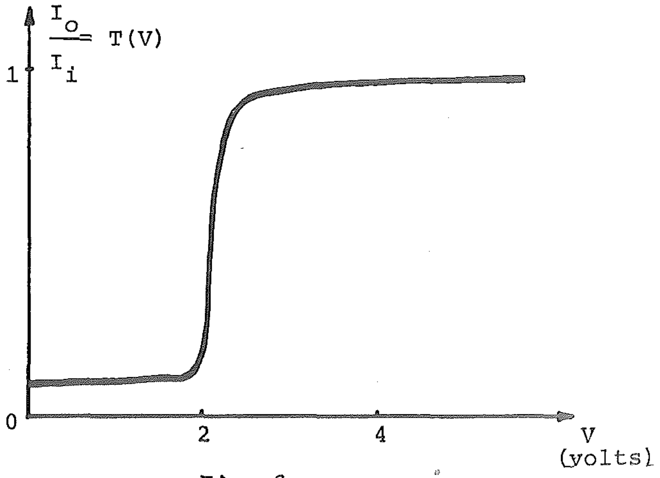

Fig. 2

In Figure 1, the input light I_i after crossing the TNLC cell is sampled by a photodetector and the resulting electrical signal is feedback to the TNLC cell. A biasing voltage V_B is added to control the operation point. As it is well-known from the literature the electrical signal applied to the TNLC cell is

$$V = V_B + \beta I_O \qquad (1)$$

where $I_O = T(V) I_i$

been T(V) the transmission characteristic given in Figure 2 and β the feedback amplification.

The electronic system employed during our experiments is shown in Figure 3. According to the above expressions, the operating point of the device is given by the intersection of the transmission curve T(V) versus V and the line given by Eq. (1). The slope of this line is given by $tg^{-1} \beta I_i$. An increase of either amplification factor β or the input light I_i enlarges the slope (respect to the T(V) axis) given by $\theta = tg^{-1} \beta I_i$.

Whenever there are several intersections for a given slope of the intersecting line, then it is possible to construct a multistable optical device. The device will exhibit a hysteresis similar to that observed with the nonlinear resonators discussed in previous works. The behaviour of this system is shown in Figure 4, where the corresponding working points (A,B,...) are determined by the different slopes

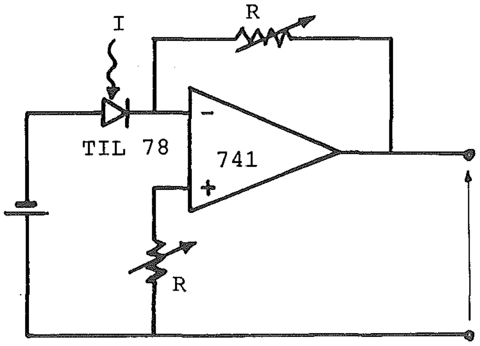

Fig. 3

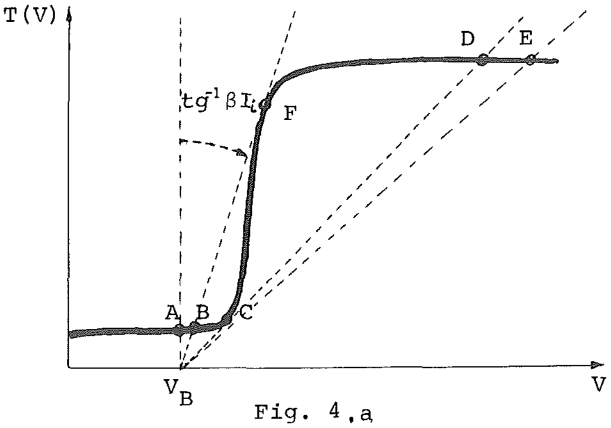

Fig. 4.a

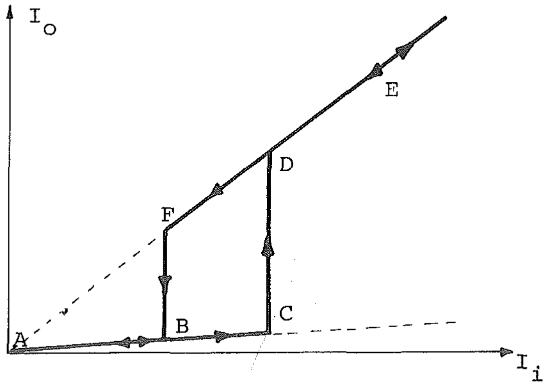

Fig. 4.b

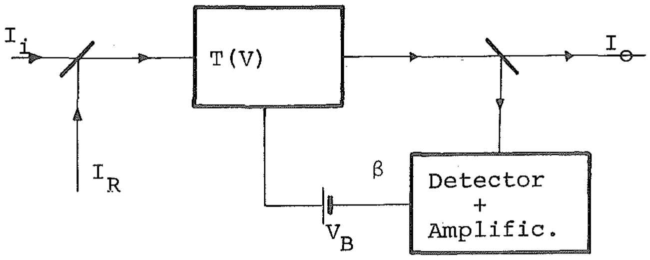

Fig.5

Optical memory operation

From the facts above considered, optical memory operation can be obtained. The difference of our structure with respect to the previous one is the presence of a read-out light I_R (Figure 5). Both input signals, I_R and I_i, are recombined by a beam-splitter. When no input light is present, the input read-out beam gives the working point labelled A in Figure 6. This point correspond to a position on the lower level of the TNLC cell transmission curve. When an input light pulse appears at the system, a new working point B is achieved. The system has been switched to the higher transmission state. If this input pulse vanishes, the only light crossing the TNLC cell will be the read-out. But because the transmission curve characteristic, the new stable point will be C instead A as it was before. Hence optical memory has been obtained. The system will remain at the upper position while the read-out input beam be present.

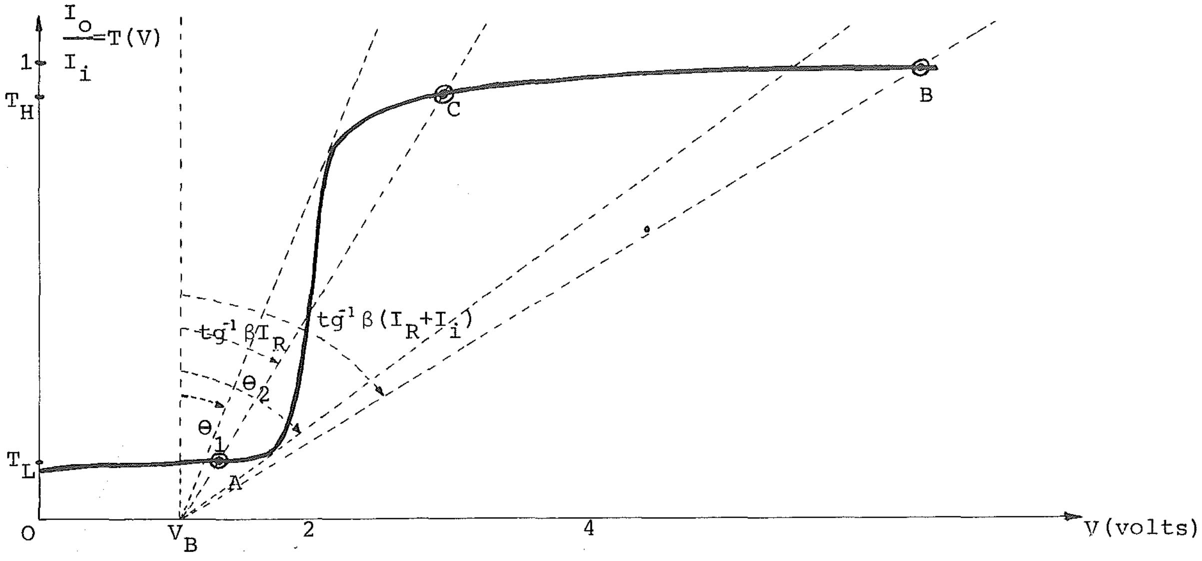

Fig. 6

For a given V_B the product βI_R has to have a value such that the line given by Eq.(1) intersects the transmission curve at three points. This is the situation indicated in Fig. 6 for the line which crosses the points A and C. As a consequence V_B can not have a value higher than 2 volts in our case. Moreover when just the read-out input light is present the slope corresponding to it describing line has to be larger than θ_1 and smaller than θ_2. When the input light pulse is present it slope has to be larger than θ_2. The optical behaviour of this system is shown in Figure 7 . Two requirements are needed with respect to the input light pulse. The first one is that it has to last at least a time Δt larger than the material time response δt. In our case this pulse width is around 1 msec. The corresponding output signal is shown in Figure 8. The second one concerns to the minimum input light needed to achieve optical memory. According to Figure 7, a certain threshold has to be overcome. For a fixed read-out, this threshold can be varied by changing the electronic amplification β. The ON:OFF ratio observed for the device was 100:3 with the electronic shown in Figure 3. The intensity levels needed were around 0.1 mwatts. In conclusion we have

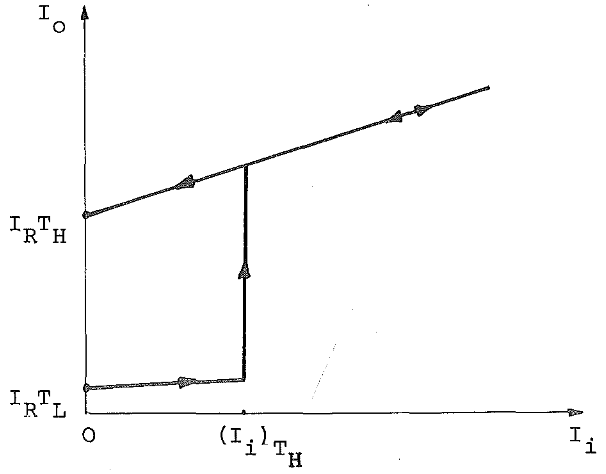

Fig. 7

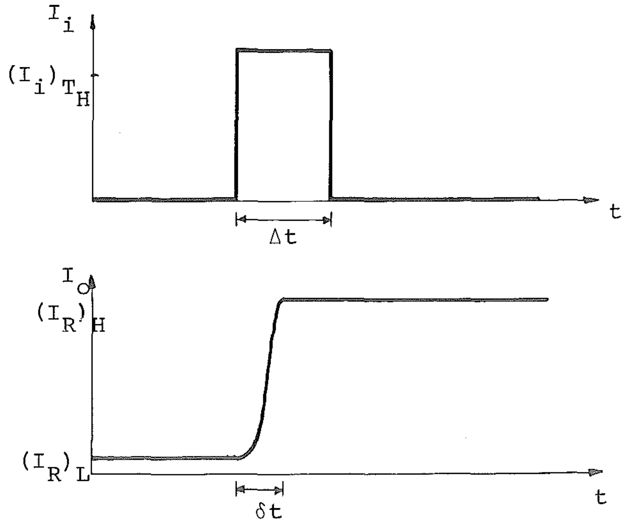

Fig. 8

obtained optical memory operation in TNLC cells, with dim light levels.

Acknowledgments

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