Digital light beam deflector with liquid crystals

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Abstract

In this communication we report a new method for deflecting a laser beam with liquid crystals cells. In order to improve previous response times of these cells, we use a wedge structure with twisted orientation.

Introduction

A simple digital light beam deflector has been developed by us with liquid crystal materials of the nematic type. The liquid crystal used has been MBBA + PEBAB, whose dielectric anysotropy is positive. The geometrical configuration is the twisted one in a wedge structure. This configuration has potential applications where hight deflection or modulation frequency is required. This property is based mainly on the very small separation between electrodes near the vertex. The highest deflecting frequency obtained has been 12.5 kHz.

Optical behaviour of the wedge structures

As we have shown previously [1,2], an structure with a wedge shape can overcome the limitations of a sandwich cell when a deflecting or a modulating application is required. This fact is based, mainly, on the possible separation of an unpolarized light beam into two rays after crossing such a cell. These two emerging rays will have orthogonal polarizations because the molecular anisotropy. One of then is the ordinary ray and the other one is the extraordinary ray. These two rays will have an angle between then dependent on the internal configuration of the molecules. In some cases, this angle will be zero but in some others it will have a value dependent on the wedge angle and on the dielectric anisotropy. An exhaustive estudy of these angles has been reported by us elsewhere[1,2].

In the case of a twisted structure, the ray after crossing the wedge, as shown in Fig. 1, will be split into two rays, ordinary and extraordinary, forming angles α_o and α_e

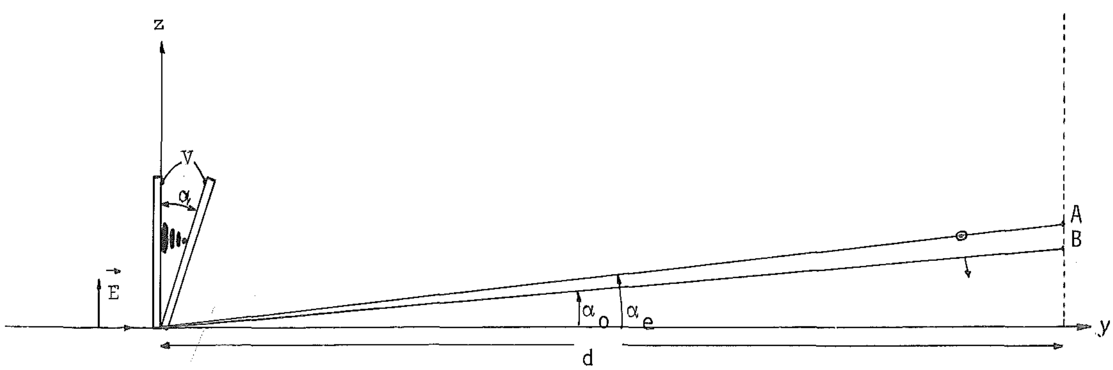

Fig. 1

with the y direction, whose values are:

$$\alpha_o = \sin^{-1} (n_o \sin \alpha) - \alpha \qquad (1)$$

$$\alpha_e = \sin^{-1} (n_o \sin(n_e \alpha / n_o)) - \alpha \qquad (2)$$

n_o and n_e are the ordinary and extraordinary refraction indeces. The angle difference is:

$$\Delta\alpha = \sin^{-1}(n_o \sin(n_e\alpha/n_o)) - \sin^{-1}(n_o \sin\alpha) \quad (3)$$

that for small values of α (wedge angle), which is our case, becomes:

$$\Delta\alpha \simeq \alpha\,(n_e - n_o) = \alpha\,\Delta n \quad (4)$$

Electrooptical behaviour of the wedge structure

Two possible situations can now appear, when an electric field is applied, depending on the dielectric anisotropy sign. If it is negative, electrohydrodynamic instabilities will be present, as it is well known from the literature [3,4], for the case of a sandwich cell. These instabilities are much more complex in the wedge structure case. As we have found, for voltages higher than the corresponding to the Williams omains region, a new kind of structure is present. The details of this structure will be published by us elsewhere. These new domains appear for frequencies up to 10 kHz. If a light beam crosses through a cell having these domains, the diffraction pattern is composed by two set of lines. The first one is the typical diffraction pattern corresponding to the Williams domains. The second one is composed by a set of points, in lines parallel to the first one. This second structure is analogous to the diffraction figure of a grill. The emerging spots are intensity modulated up to frequencies near 10 Hz. For higher frequencies this domains are stable. According to this situation, the liquid crystal with negative anisotropy is not usefull for digital light beam deflectors, because the resulting spots are static in time.

With respect to the liquid crystals with positive anisotropy, the situation is very different. We do not have in this case the previous electrohydrodynamic instabilities. When a pulsed voltage is applied to the cell, with internal $Sn\,O_2$ electrodes, the behaviour is different. When the voltage is zero, the imput light is polarized parallel to the x axis and the frontal face of the twist has its direction of rubbing along the same axis, a single ray, orthogonally polarized with respect to the initial one, comes out. His angle with the imput beam is given by

$$\alpha_e = \alpha\,(n_e - 1) \quad (5)$$

for small values of the wedge angle, α.

If a certain voltage is applied to the cell, his internal molecules will change their orientation. The light ray will adopt another exit angle given by

$$\alpha_o = \alpha\,(n_o - 1) \quad (6)$$

This ray will be different from the previous on by an amount given by

$$\Delta\alpha = \alpha_e - \alpha_o = \alpha\,\Delta n \quad (7)$$

This expression is similar to (4). This ray has the same polarization than the incident one.

The electrical behaviour of this cell is shown in Fig. 2. For voltages higher than 5 volts. the ray will adopt the α_o angle. For voltages smaller than 2.5 volts the angle will be α_e. The ray will have an analogical behaviour between these two values. This fact can give rise to some other applications. Moreover, we have presented [5] another wedge configuration where this analogical region is wider.

From the above considerations, if a pulsed voltage of peak value higher than 6 volts is applied to the cell we can have a digital light modulator. This behaviour has been verified at our Laboratory with a mixture of MBBA and PEBAB. The higher frequency obtained was 12.5 kHz. We did not observed any kind of overshoot. We think this absence is due to the wedge configuration. This fact deserves a posteriour study. We used a 5 mwatt He-Ne laser as light source and we have employed a silicon solar cell photodetector. The temperature was 23°C.

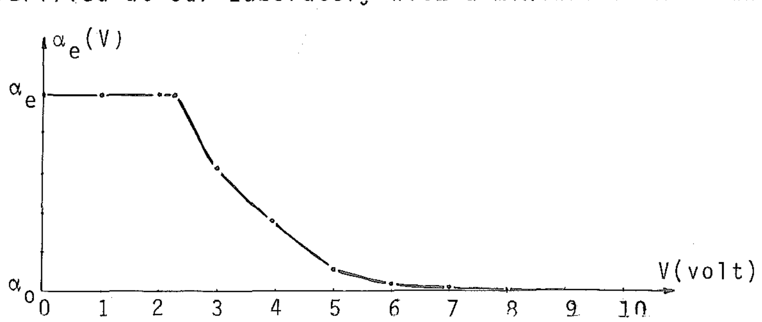

Fig. 2

We point out the fact that incresing the temperature decreases the viscosity but, at the same time, Δn becomes smaller. As a consequence the difference angle will be smaller and its applications more difficult to progress favourably. There is a balance for the optimun temperature to work with that has to be studied if this device is to be put in working conditions.

Acknowledgments

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