MAGNETO-OPTICAL DEFLECTOR WITH NEMATIC LIQUID CRYSTALS

by

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Abstract

In this paper we report a new metod for optical switching based on the magneto-optical properties of liquid crystal materials. In order to improve previous response times, we used a wedge structure.

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 Nematic Licristal Fase V. The geometrical configuration is the twisted one in a wedge structure. This configuration has potential applications where hight modulation frequency is required. This property is based, mainly, on the very small separation between electrodes near the vertex. The highest deflection frequency obtained in this case has been 8 kHz (around).

Optical behaviour of the wedge structures

As we have shown previously[1,2,3], 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, as we have proved, is based 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. This fact comes from the molecular anisotropy of the liquid crystals, that for the case of magnetic fields is always positive. These two rays, one the ordinary and the other the extraordinary one, will have an angle between then that will be 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 value of the magnetic anisotropy, if we are working with magnetic fields. An study of these angles has been reported by us previously[4] and it will published elsewhere.

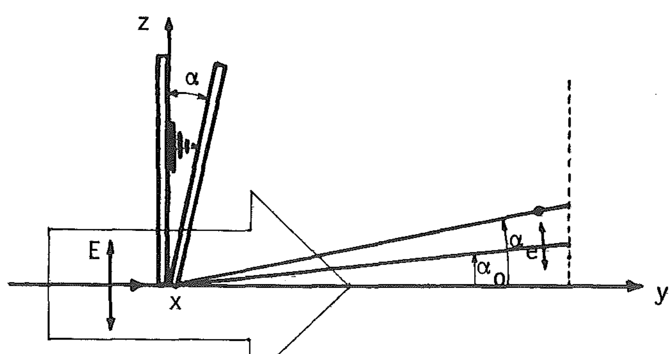

FIG. 1

In the case that we are with a twisted molecular configuration, as it is our case in this paper, the two possible exit rays, ordinary and extraordinary, will form an angle given by

$$\Delta\alpha \simeq \alpha\ (n_e - n_o) \qquad (1)$$

where we have taken, as it is always here, the wedge angle, α, very small. n_o and n_e are the ordinary and extraordinary indexes.

Magneto-optical behaviour of wedge structures

As we have pointed out before, two rays appear when an optical beam crosses a wedge structure, if the input beam is unpolarized. But if the input ray have a certain polarization, the situation is different. If we don't have any magnetic field applied to the cell, the input light is polarized parallel to the z axis and the twisted configuration inside the cell has the characteristics shown in Fig. 1, a single ray, orthogonally polarized with respect to the initial one, will go out. Its angle, with respect to the input beam, is given by

$$\alpha_e = \alpha\,(n_e - 1) \qquad (2)$$

as before, for small values of the wedge angle, α.

If a certain magnetic field is applied to the cell, with the direction shown in Fig. 1, the molecules will be affected by such a field. Because their positive magnetic anisotropy, the molecules will reorient their directors along the field direction. In this situation, the light will not rotate its polarization, as in the previous case did, but will keep the same one as the input one. Moreover, the exit angle will be different and the value will be given by

$$\alpha_o = \alpha\,(n_o - 1) \qquad (3)$$

As it can be seen, the difference is the angle given by (1).

An important fact can be obtained from the above considerations. This fact is the possibility of obtaining one of two rays from the application or not of a magnetic field. Moreover, this situation will appear for any kind of liquid crystal used. If an electric field should be applied to this cell, the situation would be very different deppending on the nematic liquid crystal used. As we have shown previously, if the liquid crystal is one with positive dielectric anisotropy, we would have the same behaviour as with the magnetic field. But if the liquid crystal is one with negative dielectric anisotropy, we would have a more complicated behaviour. Because of the electrohydrodynamic instabilities, the liquid crystal will give rise to a very complex set of diffraction rays after crossing the cell. And this set of rays will not be useful for deflection or switching. It can have some other applications that will be published by us shortly. As a consequence, a great number of nematic liquid crystals are no valid for electro-optical deflection and in this way, nematics as popular as the MBBA, cannot be employed. Moreover, other molecular configurations in the cell, as the one we have published[3], can offer interesting possibilities as pure modulators, but not as deflectors.

Going back to the magneto-optical behaviour, it is possible to show that there is a certain thrshold magnetic field given by

$$H_{th} = \frac{\pi}{\alpha\, r}\sqrt{\frac{3\,K}{4\,\chi_a}} \qquad (4)$$

this threshold value is different for the other molecular configurations. This value is just valid for the twisted configuration. As can be seen from (4), this threshold depends on the value of the separation between walls, r, taken. In our case, this value was around 0.27 mm. This value was taken from several considerations coming from the wish of obtaining a high value for the cut-off frequency, from the physical aspects corresponding to the existence or not of twisted structures for very small distances between walls and from the physical dimensions of the electromagnet used. For the liquid crystal used, Nematic Licristal Fase 5, and by substitution of its physical constants, a value of 6500 gauss is obtained. From these values, higher magnetic fields will reorient the molecules according to a law represented in Fig. 2 As can be seen, there is an analogical behaviour between the threshold field up to a value of 12500 gauss, the highest magnetic field given by our electromagnet. This behaviour is, again, different from the obtained, with this configuration, for electric field. With electric fields, as we have shown, the behaviour is digital. This is another advantage of working with magnetic fields.

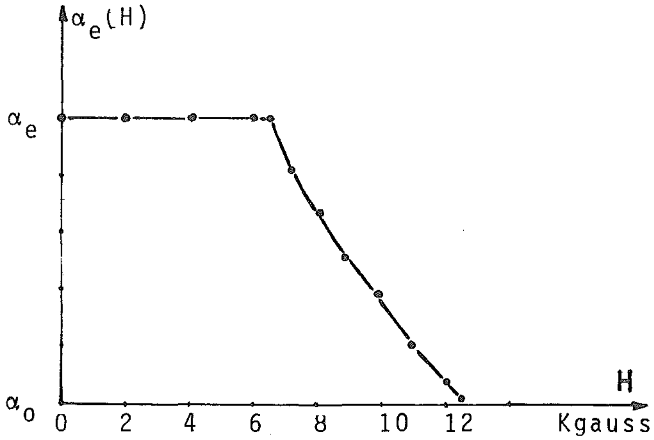

FIG. 2

The wedge angle in our case was 2°± .5. The temperature was room temperature. If a better time response is required, the temperature should be increased to a value near the critical point of L.C. used. This fact comes from the decreasing in the viscosity with temperature. But $n_e - n_o$ get smaller values, decreasing, in consequence, the value of the difference angle.

The light used was from a 5 mwatt He-Ne laser with a diameter beam of .1 (after collimation).

The highest frequency obtained was 7600 Hz.

Acknowledgments

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