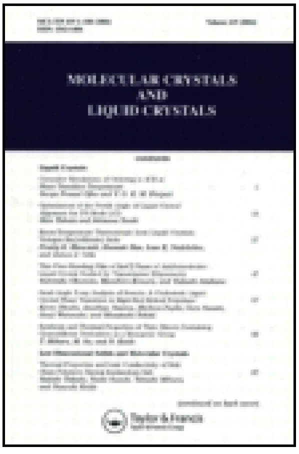

Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

Voltage Controlled Optical Bistability in a Twisted Nematic Liquid Crystal Cell Between Crossed Polarizers

F. Bloisi [a] , P. Terrecuso [a] & L. Vicari [a]

[a] Istituto Nazionale per la Fisica della Materia Dipartimento, di Scienze Fisiche Università di Napoli "Federico II" Piazzale V. Tecchio, 80 I, 80125, Napoli, Italy

Version of record first published: 24 Sep 2006.

Mol. Cryst. Liq. Cryst., 1996, Vol. 290, pp. 11–19
Reprints available directly from the publisher
Photocopying permitted by license only

VOLTAGE CONTROLLED OPTICAL BISTABILITY IN A TWISTED NEMATIC LIQUID CRYSTAL CELL BETWEEN CROSSED POLARIZERS.

F. BLOISI, P. TERRECUSO, L. VICARI
Istituto Nazionale per la Fisica della Materia
Dipartimento di Scienze Fisiche
Università di Napoli "Federico II"
Piazzale V.Tecchio, 80
I 80125 Napoli (Italy)

Abstract

We report experimental results about the bistability effect given by the light induced creation of an isotropic hole in a 90° twisted nematic liquid crystal cell between two crossed polarizers. The twisted structure acts as a polarization rotator so that the device is initially transparent, but becomes opaque if the twisted structure is broken, due to liquid crystal nematic-isotropic phase transition. The effect can be electrically driven controlling the nematic director configuration inside the cell.

1 Introduction

Thermally induced optical bistability has been studied in a number of active or passive devices[1, 2, 3, 4]. Recently we have shown that this effect can be observed for a liquid crystal in a twisted nematic configuration[5, 6, 7]. Twisted nematic liquid crystal displays[8, 9] are made by a twisted nematic liquid crystal placed between two crossed polarizers. A couple of crossed polarizers is opaque but the adiabatic following of the light wave travelling along the twisted structure[10] makes the device transparent for linearly polarized (or semi transparent for unpolarized) impinging light. On heating the sample, when the nematic-isotropic phase transition of the liquid crystal occurs, the device goes back to the usual behavior, i.e. it switches from a transparent ("ON") to an opaque ("OFF") state. We have theoretically predicted

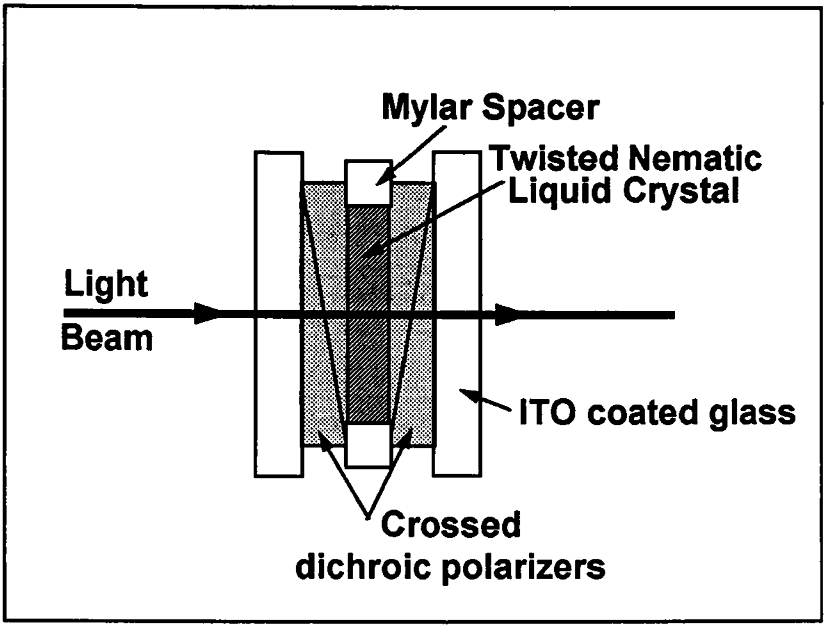

Figure 1: Twisted nematic liquid crystal cell between crossed dichroic polarizers.

and experimentally proven[5, 7] a giant nonlinear optical effect (bistability) if the dichroic polarizers are in thermal contact with the sample, so that heating is due to light absorption by the rear polarizer. If a low frequency electric field is applied in the direction orthogonal to the cell, the nematic liquid crystal configuration changes from twisted to homeotropic. Light polarization rotation, and therefore light absorbed by rear polarizator, is affected by the applied electric field. In this paper we present the first experimental results on such a voltage controlled thermooptical bistable device.

2 Thermooptical bistability

The sample configuration is shown in Fig.1: the liquid crystal is placed between two dichroic polarizers previously rubbed to induce planar alignment parallel to the direction of their maximum transmission and the sample is surrounded by two conducting glass plates. Liquid crystal is initially in the nematic phase and has a 90° twisted configuration. The device is initially transparent ("ON" state). When the intensity of the impinging light is sufficiently high, an isotropic hole is created in the cell due to the heating of the polarizer produced by the light absorption. Liquid

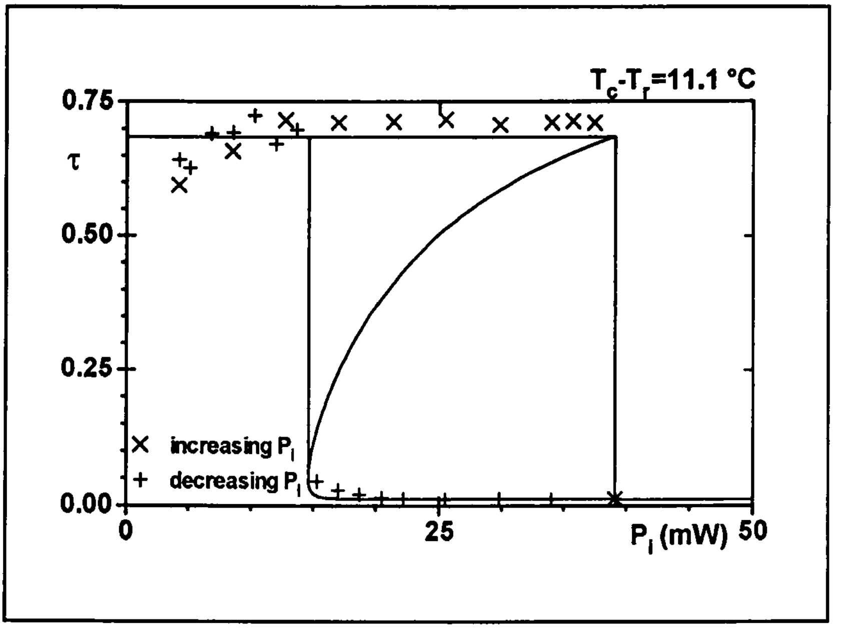

Figure 2: Light transmittance vs. impinging power for a 10μm thick cell obtained with two dichroic polarizers (by Polaroid) filled with K15 (by BDH).

crystal light transmittance has different values in the nematic and in the isotropic phases, however this is a secondary effect, since the liquid crystal is in thermal contact with the polarizers. In fact, if the device is hold in free air, the thermal exchange coefficient between the device middle plane and its external surfaces is several order of magnitude higher than the exchange coefficient between the device and its surroundings. As a consequence the temperature profile can be considered constant along the light propagation direction[11]. Hence power absorbed by the polarizers results in the same thermal effects as if it had been absorbed by the liquid crystal itself. Light absorption in the front polarizer depends on the polarization state of the impinging light, and therefore has a linear behavior. Since light polarization is rotated by the cell in the nematic area while it is unaffected by the isotropic hole, the light absorbed by the rear polarizer depends on the hole diameter which, in turn, is determined by light absorption itself. We have studied this nonlinear effect in a previous paper[7] discussing the case of the TEM_{00} mode of an Ar^+ laser impinging on the cell at normal incidence. The mathematical model we introduced there was able to explain the observed optical bistability. We do not give mathematical details here. In Fig.2 we see the comparison between experimental (crosses) and theoret-

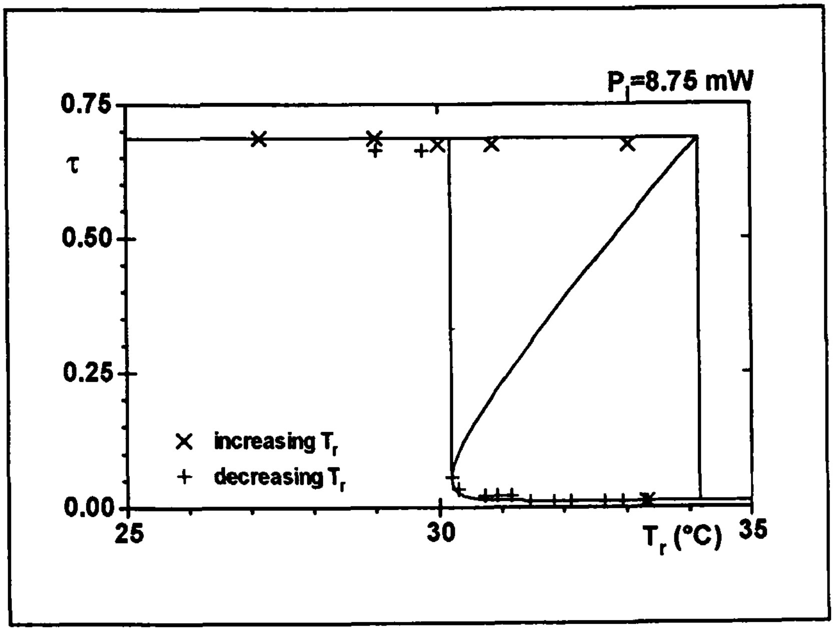

Figure 3: Light transmittance vs. temperature for a $10\mu m$ thick cell obtained with two dichroic polarizers (by Polaroid) filled with K15 (by BDH).

ical results (solid line) for a $10\mu m$ thick cell obtained with two plastic polarizers (by Polaroid) filled with liquid crystal K15 (by BDH). Overall cell transmittance is shown versus input power. Increasing the input power, at a certain value P_{OFF}, the liquid crystal's temperature becomes higher than the critical temperature for the N-I transition and an isotropic droplet appears. As explained above, the isotropic hole generation increases light absorption: the consequent temperature rise causes the enlargement of the isotropic hole. This process ceases only when the sample is completely darkened. On decreasing the input power the temperature decreases slowly because in this situation the sample is absorbing the input power almost completely. However at a certain value $P_{ON} < P_{OFF}$, the liquid crystal switches back to the nematic phase and the sample returns to the original "ON" state.

If the impinging light intensity is kept constant the device shows bistability versus temperature (Fig.3) offering the opportunity of it being used as a temperature sensor. If the temperature is below the nematic isotropic transition temperature T_c the liquid crystal is in the nematic phase and sample is transparent. On increasing temperature to a certain value T_{OFF} the sample becomes isotropic and therefore opaque. On lowering the temperature the sample remains isotropic until

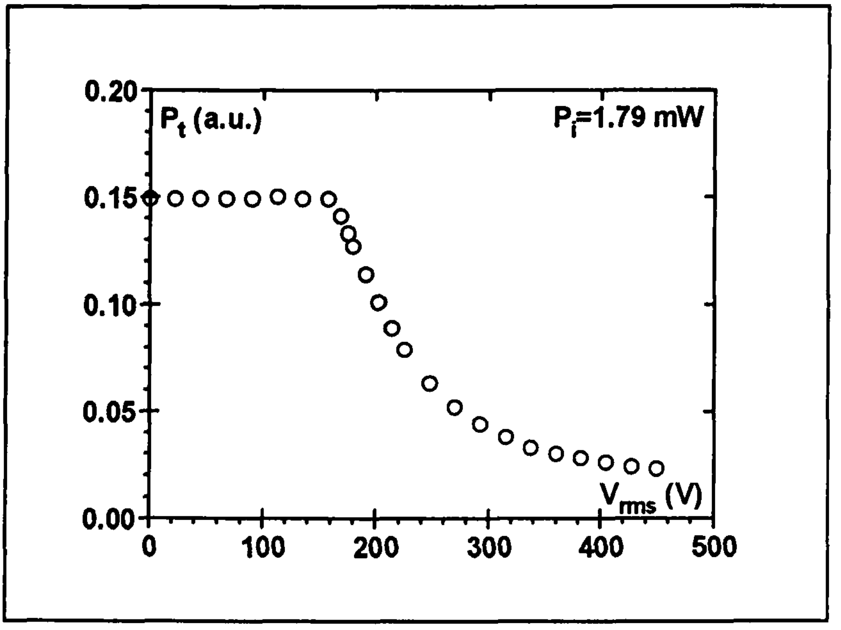

Figure 4: Typical behavior of the optical transmitted power vs. applied voltage for a twisted nematic liquid crystal between crossed dichroic polarizers.

a temperature $T_{ON} < T_{OFF}$ is reached, when it turns to the nematic phase and its transmittance rises again.

3 Experiment and discussion

If an electric field is applied to the twisted liquid crystal cell it changes the orientation of the liquid crystal molecules in the nematic phase, affecting the light polarization rotation and therefore the sample transmittance. In Fig.4 we report the transmitted optical power versus the applied field, measured using a low power ($P_i = 1.78\,mW$) beam to ensure that the whole liquid crystal is in the nematic phase. This effect gives the possibility to change the bistability gap by varying the voltage applied to the cell. The sample is obtained by placing the liquid crystal (K15 by BDH, $T_c = 35.5$ °C) between two dichroic polarizers (by Polaroid), 23 μm spaced, previously rubbed to induce planar alignment parallel to the direction of their maximum transmission. The sample is surrounded by two conducting (ITO-coated) glass plates, spaced 550 μm from each other. The experimental setup is sketched in Fig.5 : a linearly polarized Ar^+ laser beam (wavelength $\lambda = 514.5nm$) impinges orthogonally on the

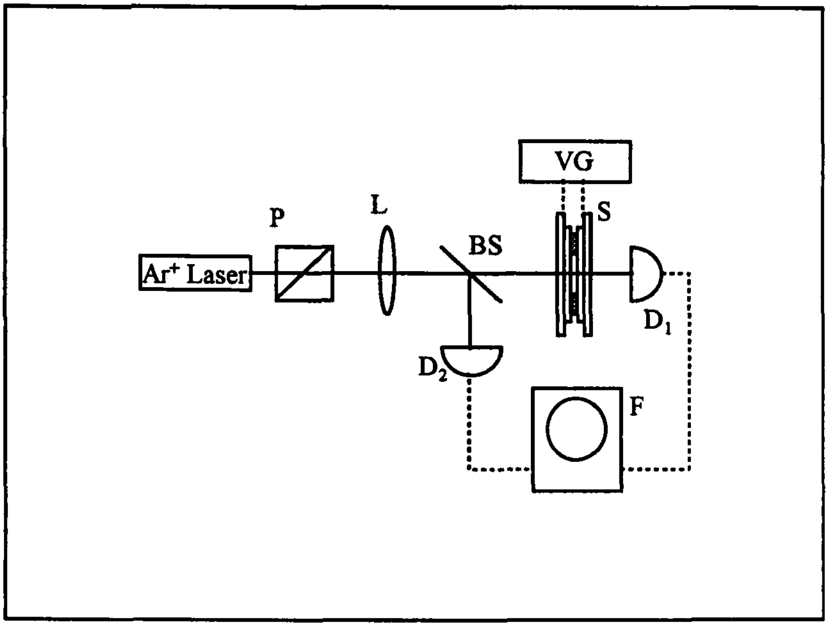

Figure 5: Experimental setup: P: polarizer; BS: beam splitter; D_1, D_2: photodiode detectors; VG: voltage generator; F: oscilloscope.

cell; a voltage generator VG is used to apply a $1KHz$ square wave voltage to the conducting glass plates; two photodiode detectors, D_1 and D_2, are used to measure the reference and the transmitted beam respectively. In the zone where the liquid crystal is in the isotropic phase, the sample transmittance is not affected by the electric field. On the contrary, where the liquid crystal is in the nematic phase, the presence of an electric field changes the molecular director orientation of the bulk from twisted to homeotropic, so that the transmittance is expected to be a function of the applied field. The isotropic hole radius depends on the absorbed power, and therefore is a function of both the impinging power and the applied voltage.

The observed bistable behavior of the transmittance versus the impinging power is shown in absence of applied voltage (Fig. 6)and for two different values of the applied electric field (Figs. 7 and 8). It can be easily seen that the application of an electric field substantially reduces the bistability gap. We cannot offer now a full mathematical description of this phenomenon since a solution of the light propagation in the distorted twisted nematic cell under these conditions is not still available. Further work is in progress to give a more quantitative description of the nonlinear effect that we have presented here.

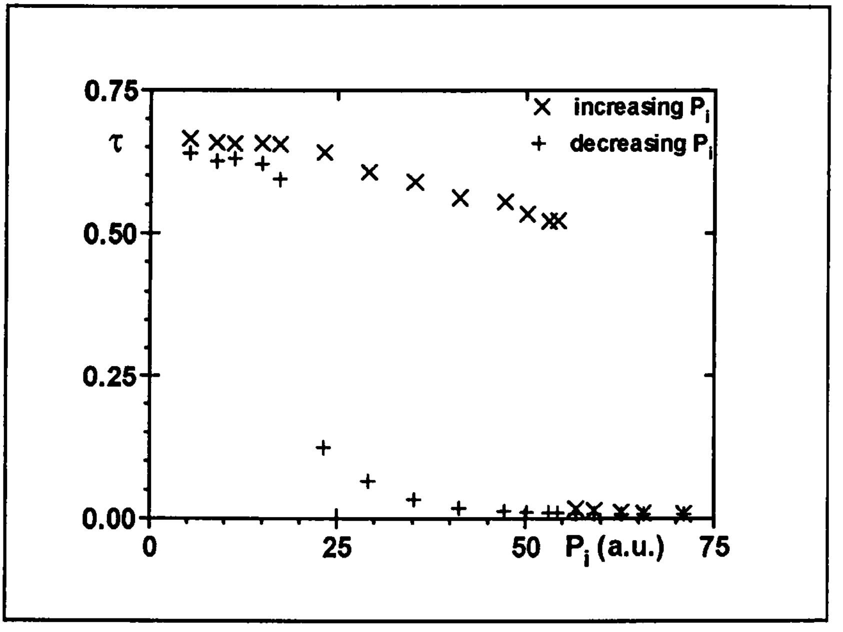

Figure 6: Sample transmittance vs. impinging power at $T = 35.3°C$. No external field.

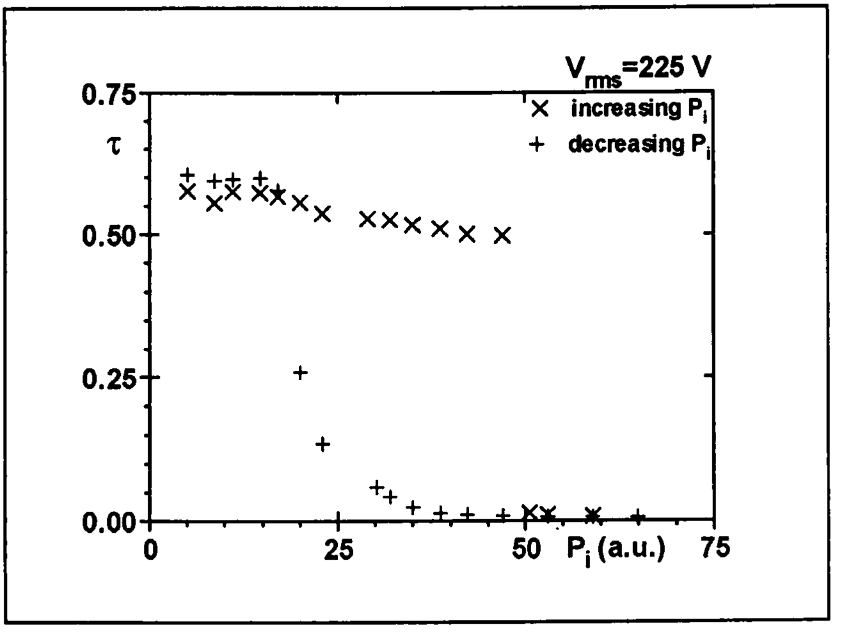

Figure 7: Sample transmittance vs. impinging power at $T = 35.3°C$. Applied voltage: $\nu = 1\,kHz$, $V_{rms} = 225\,V$.

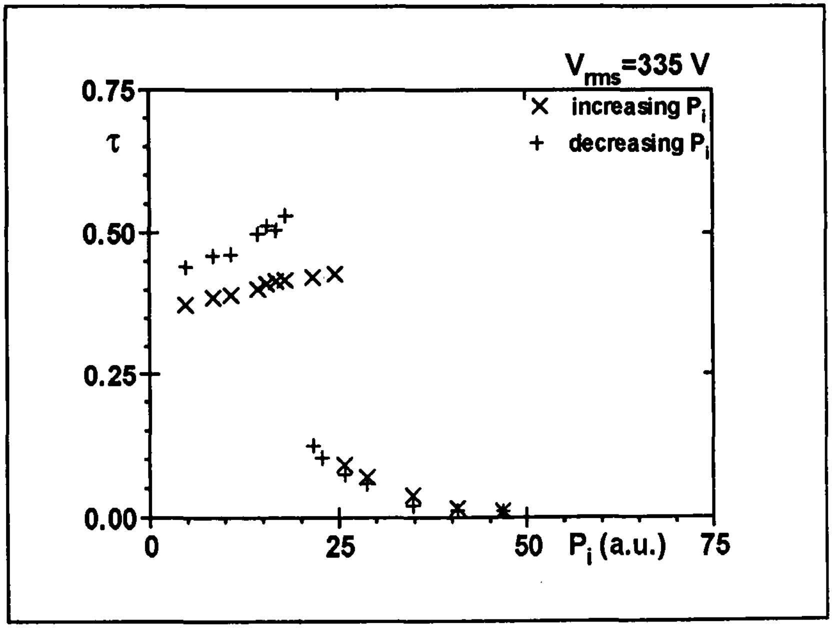

Figure 8: Sample transmittance vs. impinging power at $T = 35.3°C$. Applied voltage: $\nu = 1\,kHz$, $V_{rms} = 335\,V$.

References

1. I. Janossy, M. R. Taghizadeh and E. Araham, in Optical Bistability III, edited by H. M. Gibbs, P. Mandel, N. Peyghambarian and S. D. Smith (Springer, Berlin, 1986), p. 160.

2. I. C. Khoo, P. Y. Yan, T. H. Liu, S. Shepard and J. Y. Hou, Phys. Rev. A, 29, 2756 (1984).

3. I. C. Khoo, J. Y. Hou, T. H. Liu, P. Y. Yan, R. R. Michael and G. M. Finn, J. Opt. Soc. Am. B, 4, 886 (1987).

4. Y. R. Shen, in Optical Bistability III, edited by H. M. Gibbs, P. Mandel, N. Peyghambarian and S. D. Smith (Springer, Berlin, 1986), p. 148.

5. L. Vicari, F. Bloisi and F. Simoni, Mol. Cryst. Liq. Cryst., 207, 251 (1991).

6. L. Vicari, F. Bloisi and F. Simoni, Opt. Commun., 80, 388 (1991).

7. L. Vicari, F. Bloisi and F. Simoni, Appl. Phys. B, 53, 314 (1991).

8. R. J. Gagnon, J. Opt. Soc. Am., 71, 348 (1981).

9. D. W. Berreman, J. Opt. Soc. Am., 63, 1374 (1973).

10. P. Allia, C. Oldano and L. Trossi, in Physics of liquid crystalline materials, edited by I. C. Khoo and F. Simoni (Gordon and Breach, New York, 1991), pp.337-363.

11. F. Bloisi, L. Vicari, P. Cavaliere and S. Martellucci, Nuovo Cimento, 10, 1199 (1988).