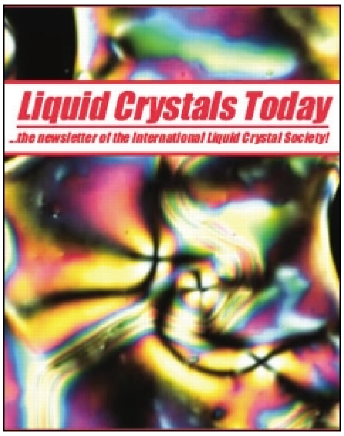

Liquid Crystals Today
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713681230

In-Plane Switching: A Novel Electro-optic Effect

G. Baur[a]; R. Kiefer[a]; H. Klausmann[a]; F. Windscheid[a]
[a] Ins titut Angewandre Fes tkorperphysik, Freiburg, Germany

To cite this Article Baur, G. , Kiefer, R. , Klausmann, H. and Windscheid, F.(1995) 'In-Plane Switching: A Novel Electro-optic Effect', Liquid Crystals Today, 5: 3, 12 — 13
To link to this Article: DOI: 10.1080/13583149508047615
URL: http://dx.doi.org/10.1080/13583149508047615

In-Plane Switching: A Novel Electro-optic Effect

G. Baur, R. Kiefer, H. Klausmann, F. Windscheid

Institut Angewandte Festkorperphysik, Freiburg, Germany

Introduction

Limited viewing angle range and angle dependent contrast are still serious problems for direct multiplex addressed LC-displays based on conventional electro-optic effects such as TN, STN and ECB. Active matrix addressed LC-displays (AMLCDs) based on the TN-effect show a distinctly improved performance but the image quality is still not sufficient to meet the requirements for TV or HDTV pictures.

In conventional untwisted or twisted nematic cells the director profile is significantly asymmetric with respect to the substrate normal if an electric field is applied. This results in a strong asymmetry of the transmission characteristics. This asymmetry increases with decreasing electric field hence being more pronounced if grey levels are addressed.

In the meantime refinements of the TN-effect have been suggested and implemented to achieve an improved image quality of AMLCDs [1,2]. A completely different approach based on a new electro-optic effect has been proposed and presented by the Freiburg LC Group [3]. In this effect, referred to as in-plane switching (IPS) [3], the asymmetry of the director profile is avoided by applying the electric field parallel to the plane of the substrate. This can be performed by using interdigitated electrodes [4].

Two different initial configurations have been suggested as shown in figure 1. In the off-state, either a 90°-twisted structure or an untwisted homogeneous structure can be used [3,5,6].

Starting with a 90° twisted structure, as shown in figure 1*a*, the off-state is identical to the off-state of a conventional TN-cell whose light blocking behaviour is insufficient. If an in-plane electric field is applied by stripe electrodes, the director $\mathbf{n}_{low}$ is rotated by electric torques inducing a homogeneous structure.

In contrast to this, an initially untwisted homogeneous structure (see figure 1*b*) shows an excellent light blocking behaviour even for large viewing angles. A twist up to 90° can be induced via an in-plane electric field. Due to the fact that an electric field component normal to the substrate plane cannot be completely avoided, materials with a negative dielectric anisotropy $\Delta\varepsilon$ are preferable.

The in-plane switching field effect shows a transmission versus voltage curve as required for grey scale addressing by an active matrix. The viewing angle characteristic is completely symmetric even in the grey level range. Results obtained by computer model calculations were confirmed by our experiments.

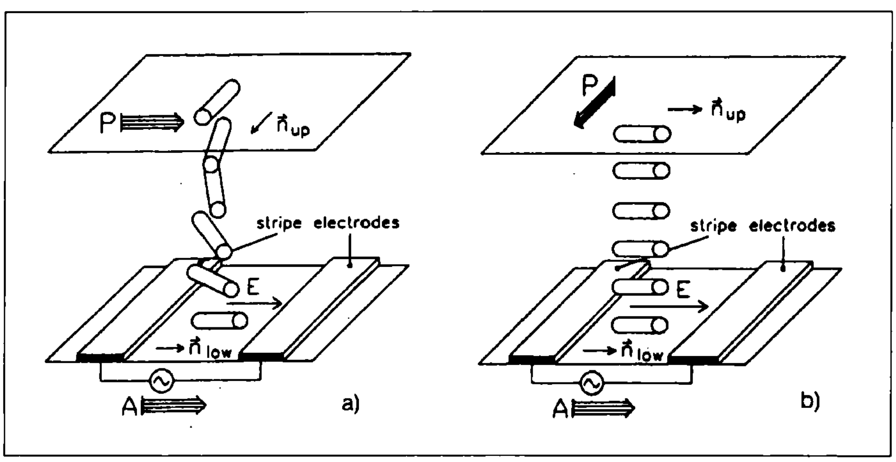

Figure 1: Electric field effects for in-plane switching of nematic LCs.
(a) 90°-twisted structure in the off-state and $\Delta\varepsilon < 0$. Polarizer is set parallel to the analyser and perpendicular to the director $\mathbf{n}_{up}$ on the upper substrate plate.
(b) Untwisted, homogeneous planar structure in the off-state and $\Delta\varepsilon < 0$. The polarizer is set perpendicular to the director $\mathbf{n}_{up}$ but the analyser is crossed.

In earlier publications response times of about 150 ms have been reported. The target was to meet the AMLCD specifications of about 30 ms.

Experimental

Test cells with the following specifications have been fabricated:

- The parallel stripe shaped finger electrodes are located on just one of the two substrate plates.
- The opaque electrodes which are composed of chromium are 5 μm wide and are separated by a distance of 10 μm.
- No electrode is required for the upper glass plate.
- Alignment: Polyimide PIX 1400
- Pretilt: 3.5°
- LC-Material: MLC 2011 (Merck), $\Delta\varepsilon < 0$

Results

For a more detailed analysis of the switching properties of the IPS-effect, the model suggested in figure 1(*b*) has to be refined. As the molecules at the substrate surface are strongly anchored, the horizontal electric field induces a double twisted structure as schematically sketched out in figure 2. The screw sense of twist in the upper and lower part of the cell are opposite and the transmitted light is mainly affected by the twisted structure in the upper part of the cell.

If p_T is the pitch of the twist in the upper part of the cell and p_{RT} the pitch of the reverse twist in the lower part of the cell, the ratio p_{RT}/p_T depends on the actual electric field distribution along the substrate normal which is not exactly known. Figure 3 shows the transmitted intensity versus $d\Delta\mathbf{n}/\lambda$ calculated for a LC-structure according to Figure 2 assuming a pitch ratio p_{RT}/p_T of 0 %, 5 %, 10 % and 20 % respectively. From these curves one recognizes that at low values of $d\Delta\mathbf{n}/\lambda$ (corresponding to the 1st. minimum of the TN-cell) high ratios of p_{RT}/p_T up to 20 % are tolerable but the influence of the reverse twist increases with larger $d\Delta\mathbf{n}/\lambda$.

The viewing angle characteristic of such a cell is calculated by using a computer program supplied by D.W. Berreman. It is assumed that the director switching occurs in a thin layer near the substrate surface.

In figure 4 the viewing angle characteristic of a cell corresponding to configuration 1*b* is compared with a conventional TN-cell matched to the first minimum. It is obvious that the cell operated in the in-plane switching mode shows considerably reduced asymmetry in the viewing angle characteristic, even in the grey level range.

A detailed theoretical analysis indicates that the relaxation time increases quadratically with LC-layer thickness as for conventionally switched TN-cells. This relationship has been verified experimentally.

By using 2–4 μm thick cells which are operated in the first minimum of the Gooch–Tarry curve (see figure 3) we have been successful in reducing the response times of the In-Plane-Switching IPS-Effect to less than 30 ms rendering this effect promising for the application in AMLCDs [7,8].

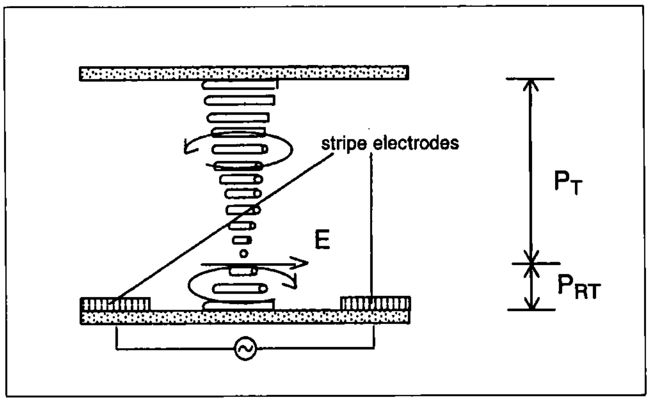

Figure 2: In-plane switching effect of nematic LCs for the initially homogeneous planar structure in the off-state with $\Delta\varepsilon < 0$ according to figure 1*b*. If an electric field is applied a double twisted structure is induced as schematically shown.

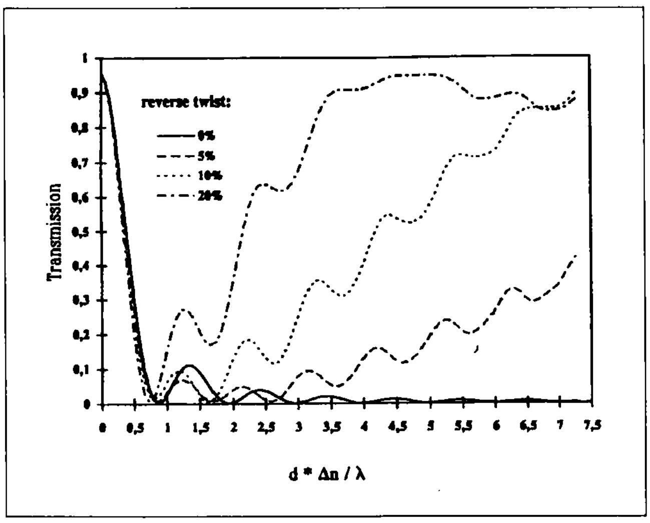

Figure 3: Gooch & Tarry curves i.e. transmission versus $d\Delta n/\lambda$ for a 90°-twisted LC-structure placed between parallel set polarizers for different ratios p_{RT}/p_T (0 %, 5 %, 10 %, 20 %), p_{RT} = helical pitch of the reverse twist near the lower substrate, p_T = helical pitch of the twist at the upper part of the cell.

References

[1] SARMA K.R., FRANKLIN H., JOHNSON M., FROST K. AND BERNOT A., 1989 SID *Digest*, p. 148
SUNATA T., INADA T., NAKAGAWA T., MATSUSHITA Y., UGAI Y. and AOKI S., 1991, *IDRC Conference Report*, p. 255

[2] KAMADA T., KOIKE Y., TSUYUHI S., TAKEDA A. and OKAMATO K., 1992, *Japan Display* '92, p. 886
YANG K.H., 1991, IDRC *Conference Report*, p. 68
TAKATORI K., SUMIYOSHI K., HIRAI Y. and KANEKO S., 1992, *Japan Display '92*, p. 591

[3] KIEFER R., WEBER B., WINDSCHEID F., and BAUR G., 1992, *Japan Display '92*, p. 547

[4] SOREF R.A., 1974, *Jour. Appl. Phys.* **45**, 5466; 1974, *Proceed. IEEE*, 1710.

[5] BAUR G., 22. Freiburger Arbeitstagung Flüssigkristalle, 31.3. - 2.4.1993

[6] BAUR, G., KAMM M., KIEFER R., KLAUSMANN H., WEBER B., WIEBER B., and WINSCHEID F., 1994, *Abstracts of the 15th International Liquid Crystal Conference*, Budapest, Hungary, p. 909

[7] OH-E, M., OHTA, M., KONDO, K., and OH-HARA, S., 1994, *Abstracts of the 15th International Liquid Crystal Conference*, Budapest, Hungary, p. 911.

[8] OHTA, M., OH-E, M., and KONDO, K., 1995, *Asia Display '95*, Hamamatsu, Japan, S30–2.

Figure 4: Transmission characteristic $f(\theta,\phi)$ calculated for a grey level state corresponding to 50% transmission for $\theta = 0°$, $\lambda = 550$ nm, $\mathbf{n}_0 = 1.5$, $\Delta\mathbf{n} = 0.0595$, $d = 8$ μm).
Left: the *conventional TN-effect* (1. Minimum, Pol/An 0°/0°)
Right: *in-plane switching-effect* according to figure 1*b* (Pol/An 0°/90°).