

Description

Technical Field

The invention relates to a liquid crystal display, which exhibits a nematic liquid crystal with positive dielectric anisotropy and twisted configuration, as well as a chiral additive and at least one polarizer. The support plates of the display cell exhibit orientation layers, at least one of which causes a tilt angle of more than 5° in the adjoining liquid crystal layer. The layer thickness of the liquid crystal is smaller than $10 \mu\text{m}$.

10 Prior Art

Such a display is known from J. Appl. Phys. 53, Dec. 1982, 8599-8606 (corresponding to GB-A 2,087,583). The liquid crystal in the known display is twisted through 360° and the tilt angle is 35° . As a result of the high degree of twist, a bistability effect is achieved, in such a manner that for a holding voltage which is applied two differently twisted liquid crystal configurations exist. The switch over from one configuration to the other takes place by briefly increasing or decreasing the holding voltage. The variation of the optical properties is made visible by means of crossed polarizers, using the Schadt-Helfrich effect (Appl. Phys. Lett. 18 (1971) 127), i.e. the orientation directions of the orientation layers are either parallel or perpendicular to the vibration direction of the polarizers, and the product of the liquid crystal layer thickness d and the birefringence Δn is large compared with the wavelength of the light. The chiral doping is selected so that a ratio of the layer thickness d to the pitch p of the twist of approximately 0.98 is obtained. The principal interest lies in the range 0.95 to 1.10. Above 1.15 the bistability disappears, and below 0.95 the switching times become too long. The layer thickness d is $15 \mu\text{m}$. The measurements described in the publication go as far as $d/p = 0.9$. A value of $d/p = 0.750$ is also mentioned, and considerations are indicated concerning a cell with $d = 7 \mu\text{m}$.

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The known display is driven in such a manner that writing takes place linewise. Since it must constantly be refreshed, only a few lines can be written. This means that the degree of multiplexing is low and a large dot matrix display cannot be produced.

In US-A-4,143,947 a liquid crystal display is described, in which the decay time after an electrical activation is to be reduced. The liquid crystal exhibits a twisted configuration, which is caused by orientation layers rotated through 90° relative to one another at the cell plates. A chiral doping is provided, in such a manner that a natural pitch p between d and $4d$ (d = layer thickness) is obtained. This gives rise to twist angles of 90° or 270° . The dielectric anisotropy is positive, and the variation of the optical properties on application of an electric voltage is made visible by means of the Schadt-Helfrich effect. The liquid crystal layer thickness is $12.5 \mu\text{m}$.

The described display exhibits no advantages, with respect to multiplexibility, as compared with the conventional liquid crystal displays of the Schadt-Helfrich type. Accordingly, it has, in particular, a relatively flat characteristic and a strong dependence upon the angle of sight. Accordingly, it is also not suitable for large displays with a high information density.

Finally, JP-A-57-133,438 discloses a liquid crystal display, which exhibits a twist angle of 270° . The optical variations on application of an electric voltage are made visible by means of the "guest host effect" (Heilmeyer et al. in "Molecular Crystals and Liquid Crystals" 1969, pp. 293-304 or Appl. Phys. Lett. 1 Aug. 1968, 91, 92), i.e. the liquid crystal is doped with a dichroic dye, and the cell is provided with an entrance polarizer, the vibration direction of which is parallel to the orientation layer.

This known display is also unsuitable for high degrees of multiplexing, inter alia on account of an excessively low contrast.

Presentation of the invention

The object of the invention is to provide a liquid crystal display which can be driven in accordance with a conventional multiplexing process (preferably according to
5 IEEE Trans. El. Dev. ED-21, 1974, pp. 146-155) with a high degree of multiplexing and exhibits a large sight angle range at high contrast.

- With a display of the initially described type, this is achieved primarily by the following elements:
- 10 - The absolute value of the twist Φ of the liquid crystal is equal to or greater than 180° and less than 360° .
 - The doping with the chiral additive is such that $d/p = 0.50 \dots 0.95$.
 - The direction of vibration of at least the front
15 polarizer forms an angle with the direction of orientation of the front orientation layer such that, depending on the applied operating voltage, the originally linearly polarized light becomes elliptically polarized to different extents because of the twist Φ and the birefringence Δn of
20 the liquid crystal, and the contrast of the display is optimized.
 - The display is switched over by the direct transition from a first to a second operating voltage, in a manner which is conventional for multiplex drives, and these two
25 operating voltages are outside any bistability range.
 - Spacers are distributed over the viewing area of the display.
 - The invention is based, in the first instance, on the finding that the bistability effect described in the above
30 discussed publication is constricted with respect to its voltage range by a reduction of the twist Φ associated with a suitable reduction also of the ratio d/p and of the tilt angle, in such a manner that a very high degree of multiplexing can be achieved with drive voltages outside this
35 range.

Furthermore, the invention is based on the idea of making visible the optical variations of the display by utilizing the birefringence of the liquid crystal, in that,

by the particular orientation of the entrance polarizer, elliptically polarized light is generated, which, after its passage through the liquid crystal, exhibits a differing state of polarization depending upon the operating voltage applied, which state of polarization can then be detected particularly sensitively. Since the state of polarization is based on the interference of the two light waves generated on entrance, the spacers distributed over the viewing surface must ensure a very constant layer thickness of the liquid crystal.

Displays according to the invention exhibit very steep characteristics, and it is possible to achieve very high rates of multiplexing at high contrast and a large viewing angle range as well as rapid switching times. Accordingly, they are outstandingly suitable for large dot matrix displays.

Brief Description of the Drawings

The invention is explained in greater detail hereinbelow with the aid of embodiments represented in drawings. In the drawings:

Figure 1 shows a cross section of a liquid crystal display according to the invention,

Figure 1a shows a section of a liquid crystal display according to the invention with internal reflector,

Figure 2 shows curves with the total twist angle Φ of the liquid crystal as a parameter in a diagram with the operating voltage U and the tilt angle θ in the middle of the display cell as variables,

Figure 3 shows contrast curves for a reflective display cell with two polarizers,

Figure 4 shows the schematic arrangement of the polarizers in a liquid crystal display according to Figure 1 for a first mode of operation (yellow mode),

Figure 5 shows an arrangement corresponding to Figure 4 for a second mode of operation (blue mode),

Figure 6 shows the measured contrast ratio CR as a function of the polarizer orientation in an arrangement according to Figure 4,

Figure 7 shows the results corresponding to Figure 6 for an arrangement according to Figure 5,

Figure 8 shows the computed curves of constant contrast ratio as a function of the polarizer orientation and the product $\Delta n \times d$ for an arrangement with one polarizer and one reflector,

Figure 9 shows the curves corresponding to Figure 8 for an arrangement according to Figure 5, and

Figure 10 shows the curves corresponding to Figure 8 for an arrangement according to Figure 4.

Routes for carrying out the invention

The liquid crystal display shown in Figure 1 consists of two glass support plates 1 and 2 which form a cell with a border 3. The border 3, as usual, consists of an epoxy cement which contains glass fibre spacers 4. Additional spacers 4 are randomly distributed between the support plates 1 and 2 over the entire viewing area of the display. A nematic liquid crystal 5 with positive dielectric anisotropy containing a chiral additive is filled into the cell. The inner surfaces of each support plate 1 and 2 have parallel strips of In_2O_3 electrode layers 6 and 7, whereby the direction of the strips on the one support plate 1 is perpendicular to the direction of the strips on the other support plate 2. In this manner, a dot matrix display is formed. But other electrode shapes are also possible, such as, e.g., the known seven-segment arrangement. Orientation layers 8 and 9 are applied over the electrode layers 6 and 7 and over the spaces between these electrode layers. A sheet-type linear polarizer 10 is bonded to the outside of the front support plate 1. For transmissive operation a linear polarizer 11 is also bonded to the outside of the rear support plate 2. For reflective operation, a diffusely scattering, metallic, external reflector 12 is placed behind this polarizer 11 (indicated by the dashed line in Figure 1). Such a reflector is known, e.g. from CH-B-618,018. The polarizer 11, however, can also be left out. By this means the brightness is improved but the contrast is lowered.

In Figure 1a, the situation is shown when, instead of an external reflector 12, an internal reflector 13 is used, as is known, e.g. from EP-B-060,380. As the section shows, this reflector is placed between the electrode layer 7 and the orientation layer 9. Otherwise, except for the polarizer 11, the same elements are present as in Figure 1.

Figure 2 represents, for a typical liquid crystal, the theoretical relation between the tilt angle θ of the local optical axis (i.e. the director) of the liquid crystal in the middle of the cell and the applied operating voltage U. The angle θ is measured in relation to the support plate. The tilt angle of the liquid crystal on the support plates in both cases amounts to 28° . The parameter, the total twist angle Φ of the liquid crystal within the display cell, runs through the values 210° (curve I), 240° (curve II), 270° (curve III), 300° (curve IV), 330° (curve V) and 360° (curve VI). At a specific layer thickness d of the liquid crystal, the pitch p is so chosen that the d/p ratio is described by the following formula:

$$d/p = \Phi/360^\circ . \quad (1)$$

This guarantees that the twisted state of the liquid crystal layer is stable and not twisted by an additional $\pm 180^\circ$ and that no optical disturbances occur in the display. The values of 210° , 240° , 270° , 300° , 330° and 360° therefore correspond to a d/p ratio of 0.58, 0.67, 0.75, 0.91 and 1.0. The pitch p is defined in accordance to common usage as the characteristic amount of twist produced in the undisturbed nematic liquid crystal by the addition of the chiral additive. The pitch p is counted as positive system with right-handed twist and negative in a system with left-handed twist.

It is essential to the invention that the magnitude of the ratio of layer thickness d to pitch p of the liquid crystal be in the range of 0.50 to 0.95, preferably between 0.65 and 0.85. The pitch p is adjusted by adding a specific

weight percentage of a chiral additive to the nematic liquid crystal. The weight percentage depends on the type of liquid crystal and chiral additive and on the layer thickness d . Furthermore, it is important that at least one of the orientation layers 8 or 9 aligns the adjoining liquid crystal molecules with a tilt angle greater than 5° , preferably with about 10° to 40° . In this connection, care is to be taken that the alignment of the orientation layers 8 and 9 agrees with the natural rotation sense of the liquid crystal 5 doped with the chiral additive. Furthermore, the layer thickness d has to be less than $10\text{ }\mu\text{m}$ and the total twist angle within the display cell has to be in the range between 180° and 360° , preferably between 240° and 300° . As a result, it is ensured that the characteristic of the display, i.e. the transmission curve as a function of applied operating voltage, is sufficiently steep and the range of the bistable behaviour is so narrowed that addressing can take place according to the usual multiplexing process (cf., e.g., IEEE Trans. EL Dev., Vol. ED-21, No. 2, February 1974, pages 146 - 155) with operating voltages outside this range. It was found that within this range the switching times are at least a hundred times longer than outside this range. The characteristic of the display has a shape similar to the curves in Figure 2, except that the negative slope of the curve (here curves III to VI) should be replaced by a bistable region (hysteresis loop).

Another important point is that the product of birefringence Δn and layer thickness d of the liquid crystal lies within the range $0.6\text{ }\mu\text{m}$ to $1.4\text{ }\mu\text{m}$, preferably between $0.8\text{ }\mu\text{m}$ and $1.2\text{ }\mu\text{m}$.

The operation of the liquid crystal display according to the invention in transmission can now be explained as follows: the light linearly polarized by the linear polarizer 10 penetrates the support plate 1 and strikes the liquid crystal aligned on the orientation layer 8 at an angle. Because of the total twist and the birefringent properties of the liquid crystal, the originally

Linearly polarized light is elliptically polarized, i.e. variably polarized, depending upon the applied operating voltage. The orientation direction of the orientation layer 9 and the direction of vibration of the rear linear polarizer 11 also form a certain angle. The term orientation direction used here is understood to be the projection of the local optical axis of the liquid crystal immediately adjacent to the orientation layer onto the plane of the orientation layer. The direction of vibration is understood to refer to the vibration direction of the electric field vector. The elliptically polarized light leaving the liquid crystal is absorbed in the rear polarizer 11, either almost completely or hardly at all, depending upon whether the principal axis of the elliptically polarized light is perpendicular or parallel to the direction of vibration of the polarizer 11. An optimum contrast is achieved by suitable choice of the abovementioned angles between the orientation layers 8 and 9 and the polarizers 10 and 11. These angles have a magnitude lying between 20° and 70° , preferably between 30° and 60° , with the rotation sense being either clockwise or counter-clockwise. The clockwise sense is defined with respect to the incident direction of the light and the angle is defined with respect to the orientation direction of the orientation layer.

In the reflective mode of operation, the operating principle is essentially the same as in the transmissive mode. In particular, the optimum contrast in a system with only one polarizer 10 is determined by suitable choice of the angle between the direction of vibration of the front linear polarizer 10 and the orientation direction of the first orientation layer 8.

Because the abovementioned angles between the directions of vibration of the polarizers 10, 11 and the orientation directions of the orientation layers 8, 9 play an essential role for the attainment of an optimum contrast ratio CR, the way in which these angles are counted will be more precisely explained by means of the schematic arrangements in Figures 4 and 5.

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Figures 4 and 5 show an exploded, perspective representation of the arrangement of the polarizers 10 and 11, the orientation layers 8 and 9 as well as the liquid crystal 5 located between the orientation layers. The total twist angle Φ of the liquid crystal is made clear by a chain of liquid crystal molecules which are schematically represented by small rectangular platelets. Support plates, border and possible reflectors have been left out for the sake of clarity.

10 The elements of the cell are arranged along an axis of the cell pointing along the direction of the incident light. The directions of vibration of the polarizers 10 and 11 as well as the orientation directions of the orientation layers 8 and 9 are also indicated by solid arrows which lie
15 in the corresponding planes perpendicular to the said axis of the cell.

This directed axis (incident direction of the light) defines a right-handed system in which the occurring angles are counted as positive in the clockwise sense and as negative in the counter-clockwise sense. In the cases of Fig-
20 ures 4 and 5 the liquid crystal molecules drawn in by way of example, form a left-handed screw which has a twist angle Φ of -270° going out from the front orientation layer 8.

25 The vibration directions of the polarizers 10 and 11 are rotated from the orientation directions of the orientation layers 8 and 9, represented by the dashed lines in the polarizer planes, by angles β and γ . In the arrangement shown in Figure 4 both angles β and γ are
30 positive. In the arrangement shown in Figure 5 only β is positive, whereas γ is negative. In the following, the angle specifications always refer to the rules laid down in Figures 4 and 5.

The invention has proven to be useful in a reflective display cell with a layer thickness d of $7.6 \mu\text{m}$ and a
35 total twist angle Φ of the liquid crystal of -270° . The d/p ratio in this case is -0.75 . The first orientation layer 8 is produced by oblique vacuum deposition of SiO at

an angle of 5° to the plate plane and aligns the adjoining liquid crystal molecules in such a manner that the tilt angle between the local optical axis of the liquid crystal at the orientation layer and the projection of this optical axis on the plate plane, i.e. the orientation direction, amounts to 28° . The direction of vibration of the front polarizer 10 and the orientation direction of the orientation layer 8 form an angle of about 30° . The second orientation layer 9 is a rubbed polymer layer which gives a tilt angle of 1° . However, an orientation layer similar to the first one is also possible. The liquid crystal 5 consists of the nematic mixture ZLI-1840 from the firm of Merck, FRG, and 2.05 per cent by weight of the chiral additive cholesteryl nonanoate. This liquid crystal has a positive dielectric anisotropy of +12.2 and a birefringence of 0.15. The temperature range extends from 258 K to 363 K, and the viscosity is $1.18 \times 10^{-4} \text{ m}^2/\text{s}$ at 273 K and $3.1 \times 10^{-3} \text{ m}^2/\text{s}$ at 293 K.

With this display cell, 96 lines can be addressed using the usual multiplexing processes. The operating voltages are 1.90 V for the non-driven state (dark) and 2.10 V for the driven state (bright). In the bright state, the display is completely achromatic, in the dark state it is deep blue. If, additionally, an optical retardation plate, such as, e.g., a $\lambda/4$ plate, is used between the front linear polarizer 10 and the front support plate 1, the colour of the display can be correspondingly changed. It has an excellent range of viewing angles independent of the direction of the illumination. The on and off switching times of the display are 0.4 s at 296 K.

Another especially preferred embodiment of the invention consists of a reflective display cell with a 0.7 mm thick support plate 1 and a 0.5 mm thick support plate 2. The layer thickness d is 6.5 μm . This display cell is provided with a front polarizer 10, a rear polarizer 11 and an external reflector 12. Both orientation layers 8 and 9 are produced by oblique vacuum deposition of SiO_2 at an angle of 5° to the plate plane. These layers orient the

neighbouring liquid crystal molecules in such a manner that the optical axis of the liquid crystal forms a tilt angle of 28° with respect to the plate plane. The orientation layers 8 and 9 are arranged so that the total twist angle Φ makes a left-handed spiral of -250° . As the liquid crystal 5, the nematic mixture ZLI-1840 with a chiral additive of 2.56 per cent by weight of cholesteryl nonanoate is filled into the cell. The birefringence Δn of ZLI-1840 is 0.15, so that the product $\Delta n \times d = 0.975 \mu\text{m}$. The angle β between the vibration direction of the front linear polarizer 10 and the orientation direction of the associated orientation layer 8 and the angle γ between the vibration direction of the rear linear polarizer 11 and the orientation direction of the associated orientation layer 9 are $\pm 45^\circ$. Contrast curves are given in Figure 3 for the case that both angles are $+45^\circ$ or -45° (curve A), and for the case that one angle is $+45^\circ$ and the other angle is -45° , or vice versa, (curve B). The abscissa indicates, in this case, the applied voltage U in volts and the ordinate indicates the brightness of the display in arbitrary units. In the first case (curve A) a bright yellow display in the non-select state and a black display in the select state are obtained. This case corresponds to the arrangement shown in Figure 4 where both angles β and γ are chosen to have the same sign, positive or negative (yellow mode). In the second case (curve B) a deep violet display in the non-select state and a bright display in the select state are obtained. This case corresponds to the arrangement shown in Figure 5 where the angles β and γ are chosen to have opposite signs (blue mode). The measurements were carried out in normally incident light using a Tektronix Model J 6523 photometer. This photometer takes into account the spectral sensitivity function of the human eye. The voltage was swept at a rate of 30 mV/s. The measured contrast ratios at a degree of multiplexing of 100:1 are as follows:

curve A $V_s = 1.580 \text{ V}$

$V_{ns} = 1.429 \text{ V}$

contrast ratio = 19.8

curve B $V_S = 1.609 \text{ V}$
 $V_{NS} = 1.456 \text{ V}$ contrast ratio = 11.8

5 The voltages V_S and V_{NS} are the usual select and non-select addressing voltages as given in the article appearing in IEEE Trans. El. Dev. that was already mentioned. The ratio V_S/V_{NS} is then 1.106 for a degree of multiplexing of 100:1.

10 In using two polarizers having angles β and γ relative to the orientation directions according to Figures 4 and 5, general conditions have now been found which should be fulfilled for an optimized contrast ratio CR. These conditions can be described as follows:

15 (2) $\beta + \gamma = \pm 90^\circ$ (Figure 4)

or

20 (3) $\beta + \gamma = 0^\circ$ (Figure 5)

In both cases the range of angles is limited so that $20^\circ \leq |\beta| \leq 70^\circ$ and $20^\circ \leq |\gamma| \leq 70^\circ$ is valid.

When condition (2) is fulfilled (e.g. $\beta = \gamma = \pm 45^\circ$) then a bright yellow display in the non-select state (yellow mode) is obtained (curve A in Figure 3). If, on the other hand, condition (3) is fulfilled, then a deep violet display in the non-select state (blue mode) is obtained (curve B in Figure 3).

30 That the conditions (2) and (3) are not sufficient conditions for an optimum contrast ratio can be seen from the curves in Figures 6 and 7. These curves show the measured contrast ratio CR as a function of the angle β under the conditions (2) or (3) for a cell with two linear polarizers in the transmissive mode of operation.

35 A liquid crystal mixture consisting of 95.6% ZLI-2392 (Merck), 2.5% S 811 (Merck) and 1.9% CB 15 (BDH) was used for these measurements. The twist angle was -270°C ,

the tilt angle 24° , the layer thickness $6,3 \mu\text{m}$ and the birefringence was Δn 0.15.

The results illustrated in Fig. 6 are for the yellow mode ($\beta + \gamma \approx +90^\circ$) and those in Fig. 7 correspond to the blue mode ($\beta + \gamma \approx 0^\circ$). It is recognized that the angle β lies around 32° for a maximum contrast ratio CR of about 22:1 in the yellow mode, clearly deviating from 0° .

In the blue mode (Figure 7) the maximum contrast ratio CR of about 6.5:1 is clearly lower. Here also β is about 38° , lying in an unexpected angle range.

The surprising values for the angle β associated with the optimum contrast ratio CR are confirmed by subsequent theoretical computations. These results are illustrated in Figures 8 - 10 as lines with constant contrast ratio as a function of the product of the layer thickness d and the birefringence Δn as well as the angle β .

For the computations a multiplex ratio of 100:1, a layer thickness of $d = 6.2 \mu\text{m}$, an ordinary refractive index n_o of 1.5, liquid crystal elastic constant ratios of $k_{33}/k_{22} = 2.5$ and $k_{33}/k_{11} = 1.5$, a ratio for the dielectric constants of $(\epsilon_{11} - \epsilon_{\perp})/\epsilon_{\perp} = 2.5$, a twist angle of $\phi = -270^\circ$ and a ratio of layer thickness to pitch of $d/p = 0.75$ are assumed.

Figure 8 makes it clear that, in the case of a cell operating in the reflective mode with one polarizer, a maximum contrast ratio CR of about 3.6:1 is only then achieved if the angle β is about 20° and $\Delta n \times d$ is approximately $1.13 \mu\text{m}$. For this case a tilt angle of 28° was assumed.

In the display cell with two polarizers operating in reflective mode in the blue mode (Fig. 9) corresponding values of $\beta \approx 45^\circ$ and $\Delta n \times d \approx 0.78 \mu\text{m}$ are obtained.

In the associated yellow mode (Fig. 10), finally, these values amount to $\beta \approx 32.5^\circ$ and $\Delta n \times d \approx 0.84 \mu\text{m}$. In the last two cases mentioned the tilt angle was assumed to be 20° .

The theoretically computed optimum contrast ratios of 50 and 150 lie clearly higher than the measured values



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because the computations assumed operation in the reflective mode which gives a better contrast ratio than in the transmissive mode because of the double use of the polarizers.

5 As a whole this invention makes possible a highly multiplexible, high contrast and fast liquid crystal display having a wide range of viewing angles, which in addition can be manufactured using the proven technology of the conventional TN (Twisted Nematic cells).



Patent Claims

1. Multiplexible liquid crystal display having
 - two plane-parallel support plates (1, 2) which form a cell with a border (3),
 - a nematic liquid crystal (5) filled into the cell, with positive dielectric anisotropy and a chiral additive,
 - electrode layers (6, 7) on the inner surfaces of the support plates (1, 2),
 - orientation layers (8, 9) overlying said electrode layers, between which the liquid crystal (5) is arranged in twisted configuration with an axis of twist at right angles to the plate plane, at least one of the said orientation layers aligning the adjoining liquid crystal molecules in such a manner that the local optical axis of the liquid crystal at this one orientation layer has a tilt angle of more than 5° with respect to the plate plane,
 - at least one polarizer (10) arranged so that the light passes a polarizer at least twice between entry and exit, and a layer thickness (d) of the liquid crystal (5) of less than $10\text{ }\mu\text{m}$, characterized in that
 - the absolute value of the twist (Φ) of the liquid crystal (5) in the cell from one orientation layer to another is greater than or equal to 180° and less than 360° ,
 - the absolute value of the ratio of layer thickness (d) to pitch (p) of the liquid crystal (5) is greater than or equal to 0.50 and less than or equal to 0.95,
 - the direction of vibration of at least the front polarizer (10) forms an angle with the direction of orientation of the front orientation layer (8) such that, depending on the applied operating voltage, the originally linearly polarized light becomes elliptically polarized to different extents because of the twist (Φ) and the birefringence (Δn) of the liquid crystal (5), and the contrast of the display is optimized,
 - the display is switched over by the direct transition from a first to a second operating voltage, and these two operating voltages are outside any bistability range of the display, and



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- spacers (4) are distributed over the viewing area of the display.

2. Liquid crystal display according to Claim 1, characterized in that the product of birefringence (Δn) and layer thickness (d) is between $0.60 \mu\text{m}$ and $1.40 \mu\text{m}$, preferably between $0.80 \mu\text{m}$ and $1.20 \mu\text{m}$.

3. Liquid crystal display according to Claim 2, characterized in that the absolute value of the twist of the liquid crystal (5) in the cell is between 240° and 300° , preferably about 270° .

4. Liquid crystal display according to Claim 3, characterized in that the dielectric anisotropy of the liquid crystal (5) is greater than or equal to 5.

5. Liquid crystal display according to Claim 1, characterized in that the tilt angle at the other orientation layer is less than 5° .

6. Liquid crystal display according to any of Claims 1 to 5, characterized in that only one front polarizer (10), and on the rear support plate (2), a metallic diffusely reflecting reflector (12, 13) are provided, and the direction of vibration of the front polarizer (10) forms a certain angle, for example about 30° , with the direction of orientation of the front orientation layer (8).

7. Liquid crystal display according to any one of Claims 1 to 5, characterized in that two polarizers (10, 11) are provided, and both the direction of vibration of the front polarizer (10) with the direction of orientation of the front orientation layer (8), and the direction of vibration of the rear polarizer (11) with the direction of orientation of the rear orientation layer (9), form a certain angle (β , γ).

8. Liquid crystal display according to Claim 6 or 7, characterized in that the absolute values of the angles (β , γ) between the direction of vibration of the linear polarizer (10, 11) and the direction of orientation of the associated orientation layer (8, 9) are greater than 20° .

9. Liquid crystal display according to Claim 6 or 7, characterized in that the absolute values of the angles



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(β , γ) are each between 20° and 70° , preferably between 30° and 60° .

10. Liquid crystal display according to Claim 7 or 8, characterized in that a metallic, diffusely reflecting reflector (12) is provided behind the rear polarizer (11).

11. Liquid crystal display according to any one of Claims 7 to 9, characterized in that the sum of the first angle (β) and the second (γ) is either about $\pm 90^\circ$ or about 0° , the angles being counted as positive in the clockwise sense in the direction of the incident light.



As printed

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Revendications

1. Elément d'affichage multiplexable à cristal liquide, comportant

- deux lames de base (1, 2) planes parallèles qui, avec un bourrelet (3), forment une cellule,
- un cristal liquide (5) nématique remplissant la cellule, présentant une anisotropie diélectrique positive et un additif chiral,

- des couches-électrodes (6, 7) appliquées sur les faces intérieures des lames de base (1, 2),

- des couches d'orientation (8, 9) posées par-dessus, entre lesquelles se place le cristal liquide (5) dans une configuration torsadée avec un axe de torsion perpendiculaire au plan des lames, et dont au moins une couche aligne les molécules voisines dans le cristal liquide de telle façon que l'axe optique local du cristal liquide à cette couche d'orientation forme un angle d'inclinaison de plus de 5° avec le plan des lames,

- au moins un polariseur (10) agencé de telle façon que la lumière, entre l'entrée et la sortie, traverse au moins deux fois un polariseur, et

- une épaisseur de couche (d) du cristal liquide (5) de moins de $10\text{ }\mu\text{m}$, caractérisé en ce que

- la torsion (Φ) du cristal liquide (5) à l'intérieur de la cellule, d'une couche d'orientation à l'autre couche d'orientation, a une valeur absolue supérieure ou égale à 180° et inférieure à 360° ,

- le rapport entre l'épaisseur de couche (d) et le pas (p) du cristal liquide (5) a une valeur absolue supérieure ou égale à 0,50 et inférieure ou égale à 0,95,

- la direction d'oscillation au moins du polariseur antérieur (10) forme avec la direction d'orientation de la couche d'orientation (8) antérieure un angle tel que la lumière qui, initialement, est polarisée linéairement acquiert, du fait de la torsion (Φ) et de la biréfringence (Δn) du cristal liquide (5), une polarisation elliptique différente selon la tension de service appliquée et que le contraste de l'élément d'affichage est optimisé,

- la commutation de l'élément d'affichage est effectuée par le passage direct d'une première à une seconde tension de service, et que ces deux tensions de service sont situées hors d'un quelconque domaine de bistabilité de l'élément d'affichage, et

- des séparateurs (4) sont répartis sur la surface visible de l'élément d'affichage.

2. Elément d'affichage à cristal liquide suivant la revendication 1, caractérisé en ce que le produit de la biréfringence (Δn) et de l'épaisseur de couche (d) est compris entre $0,60\text{ }\mu\text{m}$ et $1,40\text{ }\mu\text{m}$, et de préférence entre $0,80\text{ }\mu\text{m}$ et $1,20\text{ }\mu\text{m}$.



3. Élément d'affichage à cristal liquide suivant la revendication 2, caractérisé en ce que la torsion du cristal liquide (5) à l'intérieur de la cellule a une valeur absolue comprise entre 240° et 300° , et de préférence voisine d'environ 270° .

4. Élément d'affichage à cristal liquide suivant la revendication 3, caractérisé en ce que l'anisotropie diélectrique du cristal liquide (5) est supérieure ou égale à 5.

5. Élément d'affichage à cristal liquide suivant la revendication 1, caractérisée en ce que l'angle d'inclinaison sur l'autre couche d'orientation est inférieur à 5° .

6. Élément d'affichage à cristal liquide suivant une quelconque des revendications 1 à 5, caractérisé en ce qu'il n'est prévu qu'un seul polariseur antérieur (10), et un réflecteur (12, 13) métallique à réflexion diffuse situé sur la lame des base (2) postérieure, et en ce que la direction d'oscillation du polariseur antérieur (10) forme avec la direction d'orientation de la couche d'orientation antérieure (8) un angle déterminé, p.ex. d'environ 30° .

7. Élément d'affichage à cristal liquide suivant une quelconque des revendications 1 à 5, caractérisé en ce qu'il est prévu deux polariseurs (10, 11) et qu'aussi bien la direction d'oscillation du polariseur antérieur (10) que la direction d'oscillation du polariseur postérieur (11) forment, respectivement avec la direction d'orientation de la couche d'orientation (8) antérieure ou avec la direction d'orientation de la couche d'orientation (9) postérieure, un angle déterminé (β , γ).

8. Élément d'affichage à cristal liquide suivant la revendication 6 ou 7, caractérisé en ce que les valeurs absolues des angles (β , γ), entre la direction d'oscillation du polariseur linéaire (10, 11) et la direction d'orientation de la couche d'orientation (8, 9) correspondante sont supérieures à 20° .

9. Élément d'affichage à cristal liquide suivant la revendication 6 ou 7, caractérisé en ce que les valeurs absolues des angles (β , γ) sont toujours comprises entre 20° et 70° , et de préférence entre 30° et 60° .

10. Élément d'affichage à cristal liquide suivant la revendication 7 ou 8, caractérisé en ce qu'il est prévu un réflecteur (12) métallique, à réflexion diffuse, derrière le polariseur postérieur (11).

11. Élément d'affichage à cristal liquide suivant une quelconque des revendications 7 à 9, caractérisé en ce que la somme du premier angle (β) et du second angle (γ) est égale soit à environ $\pm 90^\circ$ soit à environ 0° , les angles étant considérés comme positifs dans le sens horaire suivant la direction de la lumière incidente.

Claims

1. Multiplexible liquid crystal display having
- two plane-parallel support plates (1, 2) which form a cell with a border (3),
 - a nematic liquid crystal (5) filled into the cell, with positive dielectric anisotropy and a chiral additive,
 - electrode layers (6, 7) on the inner surfaces of the support plates (1, 2),

- orientation layers (8, 9) overlying said electrode layers, between which the liquid crystal (5) is arranged in twisted configuration with an axis of twist at right angles to the plane of the plates, at least one of the said orientation layers aligning the adjoining liquid crystal molecules in such a way that the local optical axis of the liquid crystal at this orientation layer has a tilt angle of more than 5° with respect to the plane of the plate,

- at least one polarizer (10) arranged so that the light passes a polarizer at least twice between entry and exit, and

- a layer thickness (d) of the liquid crystal (5) of less than $10 \mu\text{m}$, characterized in that

- the absolute value of the twist (ϕ) of the liquid crystal (5) in the cell from one orientation layer to another is greater than or equal to 180° and less than 360° ,

- the absolute value of the ratio of layer thickness (d) to pitch (p) of the liquid crystal (5) is greater than or equal to 0.50 and less than or equal to 0.95,

- the direction of vibration of at least the front polarizer (10) forms an angle with the direction for orientation of the front orientation layer (8) such that, depending on the applied operating voltage, the originally linearly polarized light becomes elliptically polarized to different extents because of the twist (ϕ) and the birefringence (Δn) of the liquid crystal (5), and the contrast of the display is optimized,

- the display is switched over by the direct transition from a first to a second operating voltage, and these two voltages are outside any bistability range of the display, and

- spacers (4) are distributed over the area of the layer of the display.

2. Liquid crystal display according to claim 1, characterized in that the product of birefringence (Δn) and layer thickness (d) is between $0.60 \mu\text{m}$, and $1.40 \mu\text{m}$ preferably between $0.80 \mu\text{m}$ and $1.20 \mu\text{m}$.

3. Liquid crystal display according to claim 2, characterized in that the absolute value of the twist angle of the liquid crystal (5) in the cell is between 240° and 300° , preferably about 270° .

4. Liquid crystal display according to claim 3, characterized in that the dielectric anisotropy of the liquid crystal (5) is greater than or equal to 5.

5. Liquid crystal display according to claim 1, characterized in that the tilt angle at the other orientation layer is less than 5° .

6. Liquid crystal display according to any of claims 1 to 5, characterized in that only one front polarizer (10) and, on the rear base plate (2), a metallic diffusely reflecting reflector (12, 13) are provided, and the direction of vibration of the front polarizer (10) forms a certain angle, for example about 30° , with the direction of orientation of the front orientation layer (8).

7. Liquid crystal display according to any of claims 1 to 5, characterized in that two polarizers (10, 11) are provided, and both the angle between the direction of vibration of the front polarizer (10) and the direction of orientation of the



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front orientation layer (8), and that between the direction of vibration of the rear polarizer (11) and the direction of orientation of the rear orientation layer (9), have a certain value (β , γ).

8. Liquid crystal display according to claims 6 or 7, characterized in that the absolute values of the angles (β , γ) between the direction of vibration of the linear polarizer (10, 11) and the direction of orientation of the associated orientation layer (8, 9) are greater than 20° .

9. Liquid crystal display according to claims 6 or 7, characterized in that the absolute values of

the angles (β , γ) are each between 20° and 70° , preferably between 30° and 60° .

10. Liquid crystal display according to claims 7 or 8, characterized in that a metallic, diffusely reflecting reflector (12) is provided behind the rear polarizer (11).

11. Liquid crystal display according to any of claims 7 to 9, characterized in that the sum of the first angle (β) and the second angle (γ) is either about $\pm 90^\circ$ or about 0° , the angles being counted as positive in the clockwise sense in the direction of the incident light.