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(54) IMPROVEMENTS IN OR RELATING TO OPTICAL DISPLAY ARRANGEMENTS

(71) We, SIEMENS AKTIENGESELLSCHAFT, a German Company of Berlin and Munich, German Federal Republic, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed to be partciularly described in and by the following statement:—

The present invention relates to an optical display arrangement for displaying a bright image or images against a dark background, comprising a liquid crystal cell having a liquid crystal layer at least one zone of which can be switched between at least two optically different states sandwiched between two carrier plates having a predetermined wall orientation, and with a light trap in the form of a fluorescent body which is made of a material having a refractive index greater than 1 and which is provided with a light emergence window disposed behind the or each switchable zone of the liquid crystal layer considered in the direction of observation.

The use of such a fluorescent body in an optical display device has already been proposed, for example, in our co-pending Application No. 50393/76 (Serial No. 1 564 211). It gives a particularly brilliant display since the fluorescent body traps incident ambient light by fluorescent dispersion and subsequent total reflection within the body and finally re-emits it with increased intensity through its emergence window or windows. In this case, the amplification of the brilliance is essentially given by the ratio of the light-collecting to the light-emitting areas of the fluorescent body which usually has the form of a plate.

If the liquid crystal cell is arranged to operate on the basis of polarisation effects, the liquid crystal layer is usually placed between two linear polarisers. However, it is desirable to avoid the use of such polarisers wherever possible, since not only does their use involve persistent problems with regard to the assembly of the device and its durability in use, but they drastically reduce the intensity of light passing through both by filtering out light having one plane of oscillation and by the inevitable absorption of light during passage, and thus prevent the full exploitation of the improvement in contrast and enlargement of the reading angle which is made possible by the use of a fluorescent body.

It is an object of the present invention to provide an optical display arrangement using a fluorescent body in which the limitations produced by the use of polarisers are eliminated or at least reduced and in which a very bright image is produced that is also easily legible from oblique angles.

According to the invention, there is provided an optical display arrangement for displaying a bright image against a dark background, comprising a liquid cell having a layer of liquid crystal material enclosed between two carrier plates having a given wall orientation, said liquid crystal layer containing at least one pleochroic dye and having at least one zone which is independently switchable between different optical states, and a light trap in the form of a fluorescent body located behind said cell in the viewing direction, said flourescent body being made of a material having a refractive index greater than 1 and containing fluorescent particles, and said fluorecent body being provided with a light-emergence window or windows located behind the switchable zone or respective switchable zones of said liquid crystal layer. Preferably, the dye or dyes used have a spectral range of maximum absorption which subsequently coincides with the spectral range of maximum emission of the fluorescent particles present in the fluorescent body.

The addition of pleochroic dyes to liquid crystal materials to produce the "guest-host effect" has been known *per se* for a considerable time. The use of a pleochroic dye in a liquid crystal display having a fluorescent plate has also been described, but only in connection with displays having

specific additional features, such as an additional illumination means in our co-pending Application No. 17703/77 (Serial No. 1 566 516), or a light-emergence window which emits on a frequency-selective basis as described in German Offenlegeschrift No. 2,619,368.

The addition of the dye makes the use of at least one of the two polarisers that would otherwise be required, unnecessary. This elimination of at least one polariser is particularly advantageaus in the arrangement in accordance with the invention. If the display arrangement contains fewer parts which undesirably weaken the light intensity, a given image brilliance can be achieved with a more exactly dimensioned fluorescent body, an advantage which is particularly significant in the case of instruments of compact design, such as wristwatches, for example. It may be added that the elimination of the rear polariser (considered in the viewing direction) allows the fluorescent body and a light-dispersing layer when used, to be moved close to the liquid crystal layer and thus creates the conditions required for the cell to emit light received from the fluorescent body at high yield and with a wide aperture angle without appreciable parallax.

The contrast of the display is particularly marked if a dye is used that absorbs the fluorescent light in the liquid crystal cell in its inoperative state but allows light for the excitation of the fluorecscent particles to pass through unhindered in this state, but which is transparent at least to the fluorescent light when in its operative state. In this case, the fluorescent body can also absorb useful light for producing fluorescence at its face which is covered by the cell.

The same effect can be obtained without the use of a dye which is frequency-matched to the fluorescent particles, if the following measures are taken. In the inoperative state, the liquid crystal layer is arranged to absorb the excitation light for the fluorescent particles and the fluorescent light to only a low degree, whilst in the operative state it absorbs the fluorescent light to a high degree. At the same time, the individual zones of the liquid crystal layer are only switched to the operative state when they constitute the background to the image. Even when the cell is transparent in the inoperative state, the image background still remains almost black. In the first place, the part of the screen not used by the display elements is dark because only a very small proportion of the light trapped in the fluorescent body escapes again outside the emergence windows and the light energy behind the fluorescent body can be collected by an absorption film; the display elements not required for forming the image and switched accordingly are black because in these zones the liquid crystal cell is in its opaque state. Further information about liquid crystal light valves with complementary activation and a transparent inoperative state is given in our German Patent Application No. P.27 06 372.5.

The invention will now be further explained with reference to the drawing which is a schematic side-sectional view of one embodiment of the invention.

The drawing shows an optical display arrangement with a liquid crystal cell for use as a single-digit numerical display. The display arrangement comprises a linear polariser 1, a front carrier plate 2, a rear carrier plate 3, a fluorescent plate 4 and an absorption film 5, these elements being disposed one behind another in the order specified in the direction in which the display is to be viewed. On their opposed inner faces, two carrier plates 2 and 3 are provided with respective conductive coatings, the rear plate with an overall coating forming an unbroken rear electrode 6 and the front plate with a coating forming a segmented front electrode having electrode segments 7. Between the two plates, there is located a spacing frame 8 arranged to hermetically seal a chamber defined by the frame and the two carrier plates and which is filled with a liquid crystal layer 9. The fluorescent plate 4 is provided with a plurality of light-emergence windows, a respective window being disposed behind each of the electrode segments 7 in the direction of observation. Each of the windows comprises an indentation 10 in the rear face of the plate and a scattering element 11 located on the front face of the plate and consisting, for example, of a pigment layer or a roughened area on the face of the plate. In the case under consideration, the scattering elements are made of a luminous material that can be excited by tritium and are each covered with a tritium layer 12. The geometry used, with a scattering plane very close behind the liquid crystal layer, makes possible an extremely wide angle of observation free from parallax.

In one form of liquid crystal display system in which, as previously described, a dye is used which is not frequency-matched to the fluorescent particles of the plate 4, the liquid crystal layer 7 is nematic, has a dielectric constant with negative anisotropy and contains a very small amount of a pleochroic dye. The dye molecules have the property of absorbing light which oscillates in a direction parallel to the longitudinal axis of the molecule axis but allowing light with a plane of oscillation at

right-angles to the longitudinal axis to pass unimpeded. The dye does not need to absorb over the entire visible light range; it is sufficient for its range of maximum absorption to approximately coincide with the range of maximum emission of the fluorescent particles in the plate 4.

As a result of suitable wall orientation, the liquid crystal material and the dye dissolved therein, exhibits a uniformly tilted homotropic texture in the inoperative state. The direction of tilt is parallel to the direction of polarisation (i.e. the axis of polarisation) of the linear polariser 1; the angle of tilt is small, being only a few degrees.

In its inoperative state, the liquid crystal cell is transparent so that light which is weakened only by a passage through a single polariser can pass into the fluorescent plate from the front face thereof. If a sufficiently high voltage is now applied to one of the eletcrode segments, the liquid crystal molecules and thus the dye molecules also present in the area covered by this segment take up a uniformly homogeneous orientation with a bias parallel to the axis of polarisation. The cell thus absorbs in the operative state.

The activating means (not shown) is such that only the electrode segments 7 not required to form the image to be displayed are activated. The result is a very bright image on a dark background.

If the direction of tilt of the liquid crystal layer is not uniform in the inoperative state but is twisted through 90° at the carrier plate remote from the polariser, the molecules of the layer would change to a homogeneous texture with a 90° twist about the normal to the palte in the operative state. With such an orientation determined by the direction of tilt, the dye molecules absorb to a particularly high degree.

Instead of using a liquid crystal cell which is transparent in the inoperative state and is opaque when activated, one could of course use a type of cell which is opaque to light in the unactivated state and allows light to pass in the activated state, and which makes use of the first method of obtaining a display with marked contrast previously referred to. In this case, it is sufficient if the liquid crystal layer absorbs the light for exciting the fluorescent material at a low level in the inoperative state, whilst absorbing the fluorescent light at a high level, and absorbs at least the fluorescent light at a low level in the operative state. Such a light valve, which is not switched in a complementary manner can be relatively simply constructed in the following manner.

In contrast to the embodiments hitherto described, the liquid crystal layer in this case has a dielectric constant with a positive anisotropy, and a uniform homogeneous orientation in the inoperative state with a bias at least approximately parallel to the polariser axis, and assumes an essentially homotropic texture in the operative state. In the inoperative state, the cell absorbs to a somewhat higher degree if the liquid crystal is fixed, not in a uniform homogeneous mode, but in a twisted homogeneous mode with a 90° twist and a bias parallel to the polariser axis at the interface adjacent the polariser.

The invention is not limited to the particular embodiments described. Thus, in particular, dyes or dye mixtures can be combined with components which basically absorb when their longitudinal molecule axes are parallel with the light propagation path. From the preceding description, it will be quite simple to establish with which particular liquid crystal materials, textures and activation methods, such "inversely" reacting dyes can be rationally combined.

Our co-pending Application No. 5775/78 (Serial No. 1 585 754) comprises an optical display arrangement for the representation of a bright image against a dark background, comprising a light valve having a medium having zones switchable between at least two different optical states; a fluorescent body which is made of a material having a refractive index greater than 1, contains fluorescent particles and is provided with a light outlet window or windows assigned to an image zone or respective image zones of said medium; and drive means for switching the medium between its optical states; wherein the zones of said medium are switchable between a rest state in which the medium permits the passage of light for exciting said fluorescent particles and of fluorescent light emitted by said body, and a switched-on state in which the medium is opaque to said fluorescent light; and wherein said drive means is arranged to form an image by switching to the switched-on state only those switchable zones of the medium which form part of the image background.

WHAT WE CLAIM IS:—

1. An optical display arrangement for displaying a bright image against a dark background, comprising a liquid crystal cell having a layer of liquid crystal material enclosed between two carrier plates having a given wall orientation, said liquid crystal layer containing at least one pleochroic dye and having at least one zone which is independently switchable between different optical states, and a light trap in the form of a fluorescent body located behind said cell in the viewing direction, said fluorescent body being made of a material having a refractive index greater than 1 and con-

taining fluorescent particles, and said fluorescent body being provided with a light-emergence window or windows located behind the switchable zone or respective switchable zones of said liquid crystal layer.

2. An arrangement as claimed in Claim 1, wherein the spectral range of maximum emission of said fluorescent particles substantially coincides with the spectral range of maximum absorption of said pleochroic dye or dyes.

3. An arrangement as claimed in Claim 1 or Claim 2, wherein said liquid crystal material absorbs light for excitation of said fluorescent particles to a low degree but absorbs the light emitted by the fluorescent particles to a high degree when in a first inoperative optical state, and absorbs the light-emitted by said fluorescent particles to a low degree when in a second operative optical state.

4. An arrangement as claimed in any one of Claims 1 to 3, wherein said zone or zones of said liquid crystal layer is or are switchable electrically, wherein a linear polariser is arranged in front of or behind a liquid crystal layer in the direction of viewing; and wherein said liquid crystal layer has a dielectric constant with positive anisotropy, is orientated in a uniform homogeneous manner in the unactivated optical state with a bias at least approximately parallel to the direction of polarisation of said linear polariser, and assumes an essentially homotropic texture when in the electrically activated optical state.

5. An arrangement as claimed in any one of Claims 1 to 3, wherein said zone or zones of said liquid crystal layer is or are switchable electrically, wherein a linear polariser is arranged in front of or behind said liquid crystal layer in the direction of viewing; and wherein said liquid crystal layer has a dielectric constant with positive anistropy, is orientated in a twisted homogeneous manner in the unactivated optical state with a bias twisted through 90° about the normal to the fluorescent body and parallel to the direction of polarisation of the linear polariser in the vicinity of the carrier plate adjacent to the polariser, and assumes an essentially homotropic texture when in the electrically activated optical state.

6. An arrangement as claimed in Claim 1 or Claim 2, wherein in a first unactivated optical state, said liquid crystal layer absorbs the light for the excitation of the fluorescent particles of said body and the light emitted by said fluorescent particles to a low degree, and in a second activated state, absorbs the light emitted by said fluorescent particles to a high degree; and wherein means for activating said zone or zones of said liquid crystal layer are provided such that, in use, the individual zone or zones of said liquid crystal layer are activated only when they form the image background.

7. An arrangement as claimed in Claim 6, wherein said zone or zones of said liquid crystal layer is or are switchable electrically; wherein a linear polariser is arranged in front of or behind the liquid crystal layer in the direction of viewing; and wherein the liquid crystal layer has a dielectric constant with negative anisotropy, is orientated in a uniformly tilted homotropic manner when in the unactivated optical state with a tilt parallel to the direction of polarisation of said linear polariser, and assumes an essentially uniformly homogeneous texture when in the activated optical state with a bias determined by the direction of tilt.

8. An arrangement as claimed in Claim 6, wherein said zone or zones of said liquid crystal layer is or are switchable electrically; and wherein a linear polariser is arranged in front of or behind the liquid crystal layer in the direction of viewing; wherein said liquid crystal layer has a dielectric constant with negative anisotropy, is orientated in a tilted homotropic manner when in the unactivated optical state with a tilt twisted through 90° about the normal to said fluorescent body and parallel to the direction of polarisation of said linear polariser in the vicinity of the carrier plate adjacent to said polariser, and assumes a twisted homogeneous orientation in the activated optical state with a bias determined by the direction of tilt.

9. An optical display arrangement substantially as hereinbefore described with reference to the drawing.

For the Applicants,
G. F. REDFERN & CO.,
Marlborough Lodge,
14 Farncombe Road,
Worthing,
West Sussex.

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1 SHEET *This drawing is a reproduction of the Original on a reduced scale*