



(51) International Patent Classification:

G02F 1/1335 (2006.01) **F21V 8/00** (2006.01)
G02B 6/00 (2006.01) **G02F 1/1345** (2006.01)

(21) International Application Number:

PCT/EP2009/053057

(22) International Filing Date:

16 March 2009 (16.03.2009)

(25) Filing Language:

English

(26) Publication Language:

English

(71) Applicant (for all designated States except US):
HEWLETT-PACKARD DEVELOPMENT COMPANY, L.P. [US/US]; 11445 Compaq Center Drive West, Houston, Texas 77070 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **RUDIN, John Christopher** [GB/GB]; Hewlett-Packard Limited, Long Down Avenue, Stoke Gifford, Bristol Avon BS34 8QZ (GB). **KITSON, Stephen** [GB/GB]; Hewlett-Packard Limited, Long Down Avenue, Stoke Gifford, Bristol BS34 8QZ (GB).

(74) Agent: **MARSH, David**; Long Down Avenue, Stoke Gifford, Bristol Bristol BS34 8QZ (GB).

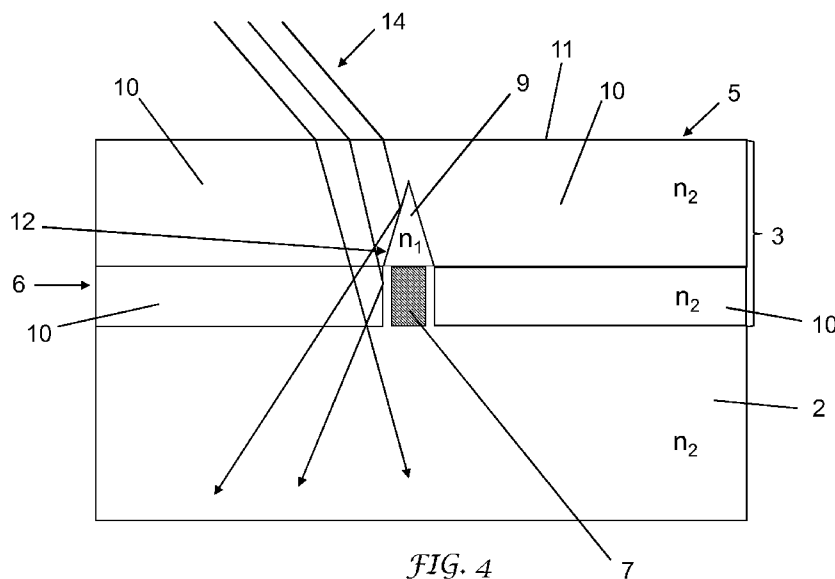
(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: OPTICAL STRUCTURE



(57) Abstract: An optical structure (3) contains a feature (7) comprising a narrow conductor or fluid channel and a light guide (9) for guiding or reflecting incident light (14) around the feature (7). The optical structure (3) may be included in a display device (1).

OPTICAL STRUCTURE

The present invention relates to an optical structure containing a narrow conductor or fluid channel, notably to a display device incorporating such an optical structure.

5

BACKGROUND

Electro-optic display devices typically comprise one or more layers of an electro-optic material 2 sandwiched between a first substrate 3 and a second substrate 4 (Fig. 1). Electrodes are used to apply an electric field or induce a current across the electro-optic material to cause a change in an optical property of the material. Examples of electro-optic materials include liquid crystals and electrophoretic mixtures.

15 It is desirable to improve the optical efficiency of display devices. This is particularly true for reflective displays based on a 'stacked' architecture where colour selection is effected by electrical addressing of layers of Cyan, Yellow, Magenta and optionally Black (or scattering) pixels (Fig. 1). In the simplest case light 14 entering the front of the display 1 has to travel through addressing
20 electrode structures on both opposed substrates 3,4 before being reflected back through the same six electrode structures again. Any losses in each electrode structure are thereby raised to the power of 12. (e.g. a 2% loss in each layer represents an overall loss of 22%). Addressing structures are essential in all types of display structures; for vertically addressed electro-optic (EO) systems (Fig. 2a),
25 e.g. Guest-Host dyed LC, the electrode 8 needs to be transparent and cover the viewed area. For horizontally addressed EO effects (Fig. 2b) e.g. in-plane electrophoretic, there may be a number of electrode traces 7 placed across the pixel area. In all cases to effect a large area display the impedance of the conductors should be moderately low; consequently metal traces 7 (or a
30 combination of metal trace 7 and conductive transparent material 8 such as PEDOT:PSS or ITO) are required. These metal traces, or busbars, 7 are opaque. Typically a highly conductive trace will be in the order of 5 μm wide by 5 μm deep, within a display of moderate resolution (e.g. 150ppi) this represents a 3% loss at

- 2 -

each layer for just a single conductive trace.

The metal surface can however reflect light, which mitigates the absorption to some degree; however this can have the effect of increasing the reflectivity of the dark state and reduce the overall contrast ratio of the display system.

Similarly, in electrophoretic or electrowetting displays, the fluid channels may absorb incident light and reduce the display's contrast ratio.

10 Aspects of the present invention are specified in the independent claims. Preferred features are specified in the dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be further described, by way of example only, with reference to the following drawings, in which:

5

Figure 1 is a schematic view of a prior art display device having stacked colour pixel layers;

Figures 2a and 2b are schematic views of prior art display devices;

10

Figure 3 is a schematic sectional view of part of the device of Figure 1;

Figures 4 and 5 are schematic sectional views of parts of display devices in accordance with embodiments of the present invention; and

15

Figure 6 is a graph modelling optical gain as a function of wedge angle for an optical structure in accordance with an aspect of the invention.

DETAILED DESCRIPTION

20

Figure 3 shows part of a prior art display device 1. The device comprises a first display substrate 3 which includes a typical 'busbar' or 'narrowline' metallic structure 7. The display substrate 3 comprises a cell wall 5, typically of a glass or plastics material, bonded to a resin material 6 in which the busbar 7 is located.

25

The substrate 3 may be formed by a transfer technique such as described in US 2006/0082710 or US 2007/0099095, the contents of both of which are incorporated herein by reference in their entirety. The first substrate 3 is spaced apart from a second substrate (not shown) with a layer 2 of an electro-optic material sandwiched between. The materials are selected such that the refractive

30

indices of the cell wall 5, the resin layer 6, the layer 2 of electro-optic material, and the second substrate have substantially the same value (n_2). Some incident light 14 is reflected or scattered from the upper surface of the busbar 7; likewise on the return journey, light is reflected from the metal and suffers further losses before

being reflected back out of the stack.

The device shown in Figure 4 has a similar structure but in one embodiment with a first region 9 of material with a lower refractive index (n_1) close to the busbar 7, while a second region 10, farther from the busbar 7 has a higher refractive index (n_2). In this embodiment, the optical structure is the substrate 3, which contains a feature 7 which is a narrow conductor in the form of the busbar. The first region 9 functions as a light guide or modulator for reflecting or refracting incident light 14 around the feature 7.

The transition from the first region 9 to the second region 10 can be a step change in the local refractive index (n) as shown, or a gradual (gradient) index (GRIN) system, such as is used in a SELFOC lens. However the net effect is for the material of the first region 9 to provide a waveguide structure to guide the light 14 around the narrow line 7 thereby reducing back-reflection and back-scatter from the busbar 7. In the illustration of Figure 4, a practical solution with light guiding on one side only is shown - this would give a improvement in layer opacity. Typical values for n_2 are in the range 1.48 to 1.55, and typical values for n_1 are in the range 1.30-1.35 or less. In an alternative embodiment, the first region 9 functions as a reflective 'wedge' ie, a triangular section extruded for the length of the busbar 7.

Both arrangements (lower refractive index or reflective wedge) work well for normal incidence collimated light, and substantially all of the light which would have impinged on the busbar 7 is transmitted at useful angles if the wedge angle is moderately low. For 'real' incident light, with a practical range of angular distribution, we have modelled the optical gain of such a wedge as a function of the wedge angle. The results of the modelling are shown in Figure 6. Low angles show a marked improvement, and overall the modelling shows about a 30% advantage would be achievable. As used herein, angles are specified with reference to external (in air/vacuum) angles of incidence relative to the normal of the top surface, ie normal incidence is perpendicular to the surface and is defined as 0° . Grazing incidence is about 89° .

At higher external angles of incidence, a wedge 9 of higher refractive index reduces the optical cross section of the busbar 7, so a preferred material is one which has a birefringence in the right direction. Thus, in a preferred embodiment, light at a low incident angle experiences a low refractive index, while light at a high incident angle experiences a high refractive index. Such varied refractive index may be achieved, for example, by using a suitably aligned liquid crystal polymer material.

The first substrate 3 has a first planar surface 11 on the side opposed to the layer 2 of electro-optic material. To facilitate light guiding and/or reflection of light away from the busbar 7, the first region 9 has a surface 12 at least a part of which is preferably at an angle between 5° and 40° to the normal of the first planar surface 11, notably between 5° and 10° .

The opaque busbar 7 itself provides a convenient means for the fabrication of such waveguide structures 9. In one example, a polymer of low refractive index is electrodeposited onto the conductive trace prior to lamination and separation using a technique similar to those outlined in US 2006/0082710 and US 2007/0099095.

The resulting fabrication is effectively self-patterned from the busbar line itself. A method of manufacturing the optical structure 3 may comprise using the feature 7 as a mask to pattern a region of a resist layer corresponding to the desired shape of the light guide 9, and developing the resist layer to etch away unwanted regions to leave the light guide 9 and feature 7 in a predetermined arrangement.

In the variant shown in Figure 5, a third region 13 is disposed between the first region 9 and the second region 10. The third region 13 has a higher refractive index n_3 than the first region 9 or the second region 10. Light 14 is guided within the high index core structure 13 so as to pass around the busbar 7.

In each embodiment, the busbar 7 is illustrated as an electrode. It will be understood that the busbar may be electrically connected to a transparent electrode structure such as ITO or the like, where appropriate and in a manner

known in the art *per se*.

It would also be possible to shape the busbar 7 to form part of the efficient optical system (e.g. by making it with a cross section which is diamond-shaped, elliptical, or semi-elliptical, with highly reflective sides in combination with a light guiding layer).

The main advantage of the present invention is that the light is substantially only guided around and not reflected back or absorbed by the metallic structure. By using a transfer fabrication method, the optical guide structures 9,13 may be self-aligned to the conductive traces 7.

The articles 'a' and 'an' are used herein to mean 'at least one' unless the context otherwise requires.

CLAIMS

1. An optical structure containing a feature comprising a narrow conductor or fluid channel and a light guide for reflecting or refracting incident light around the feature.
5
2. An optical structure according to claim 1, wherein the light guide is a waveguide structure which is birefringent and constructed so that light at lower angles of incidence will encounter a lower refractive index and light at higher angles of incidence will encounter a higher refractive index.
10
3. An optical structure according to claim 1 or claim 2, wherein the light guide is a waveguide structure which has a first region of lower refractive index (n_1) close to the feature and a second region of higher refractive index (n_2) farther from the feature.
15
4. An optical structure according to claim 3, wherein the first region is shaped so as to cause at least some light when incident through the first substrate, to be reflected and/or guided so as not to impinge on the feature.
20
5. A display device including an optical structure according to any preceding claim, wherein the feature is an opaque conductive busbar.
6. A display device according to claim 5, comprising a layer of an electro-optic material sandwiched between a first substrate and a second substrate, the first substrate being translucent and including the opaque busbar.
25
7. A display device according to claim 6, wherein the first substrate has a first planar surface on the side opposed to the layer of electro-optic material, and the first region has a surface at least a part of which is at an angle between 5° and 40° to the normal to said first planar surface.
30

8. A display device according to claim 7, wherein said angle is between 5° and 10° .

9. A display device according to any of claims 5-8, further comprising a third region adjacent to the first region, the third region having a refractive index (n_3) which is higher than the refractive index (n_1) of the first region.

10 A display device according to claim 9, wherein the third region is disposed between the first region and the second region.

11. A display device according to any of claims 5-10, wherein the busbar has at least one reflective surface and is shaped so as to promote internal reflection and/or light guiding of light incident through a face of the first substrate opposed to the layer of electro-optic material.

12. A substrate for a display device as specified in claim 5, the substrate being translucent and including an opaque busbar; wherein the substrate is provided with a light guide for reflecting or refracting incident light around the busbar.

13. A display device comprising a layer of an electro-optic material sandwiched between a first substrate and a second substrate, the first substrate being translucent and including an opaque busbar; wherein the first substrate has at least two regions of different refractive index, whereby at least some light incident through a face of the first substrate opposed to the layer of electro-optic material which, if all regions of the first substrate had the same refractive index, would impinge on the busbar, will be reflected and/or refracted so as not to impinge on the busbar.

14. A method of manufacturing an optical structure as specified in claim 1, comprising using the feature as a mask to pattern a region of a photoresist layer corresponding to the desired shape of the light guide, and developing the resist layer to remove unwanted regions to leave the light guide and feature in a predetermined arrangement.

15. A method according to claim 14, wherein the photoresist is a negative material, and the step of removing unwanted regions comprises removing photoresist from unexposed regions; the method further comprising filling regions
- 5 where material has been removed with a material of lower refractive index.

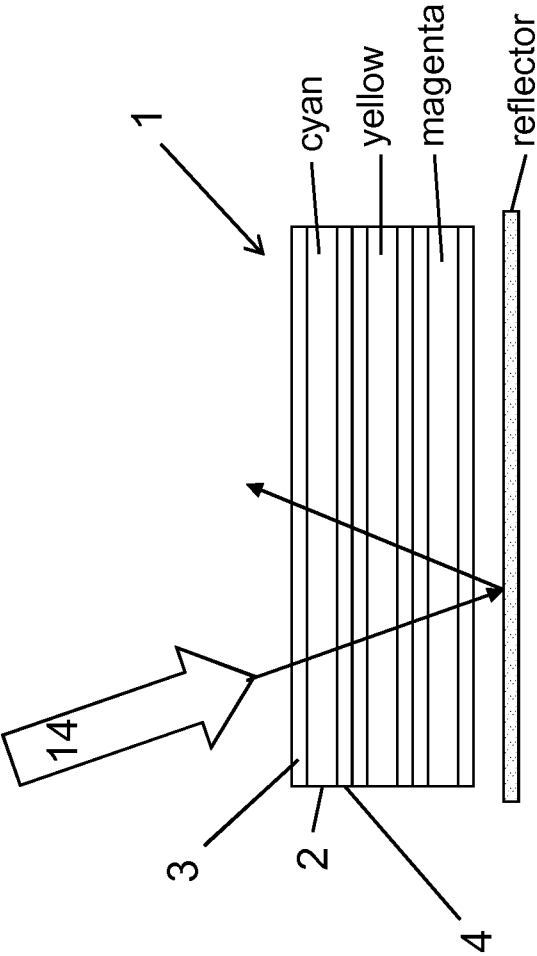


FIG. 1 (PRIOR ART)

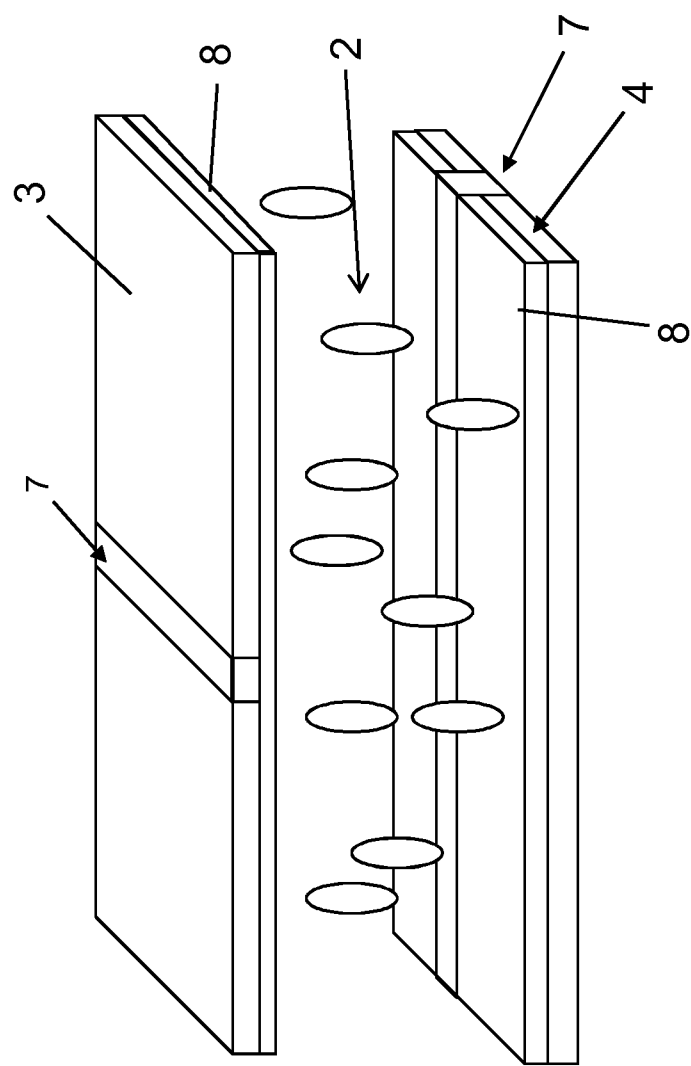


FIG. 2a (PRIOR ART)

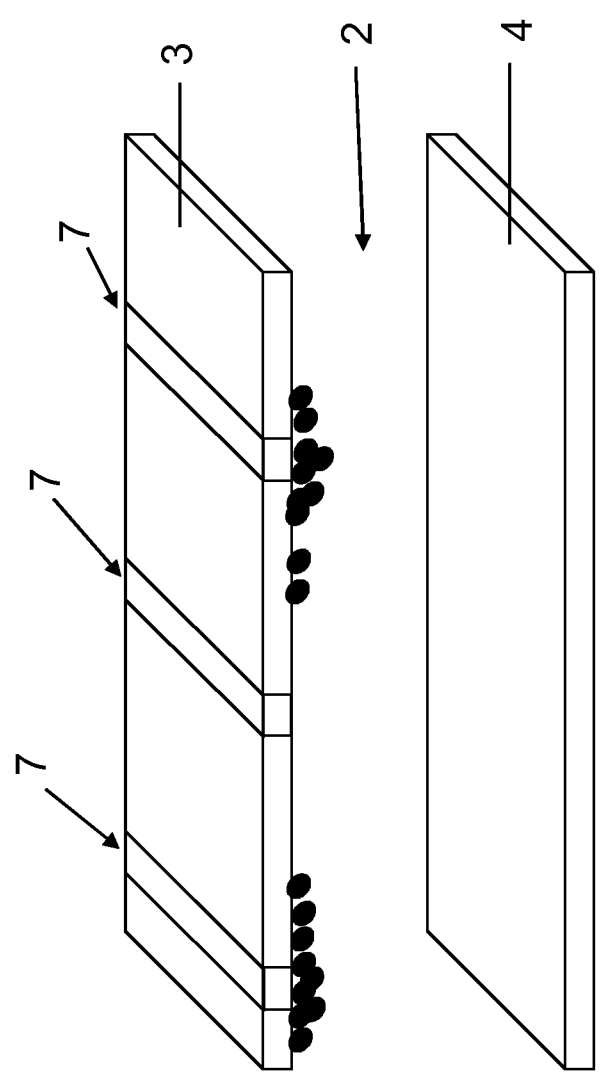


FIG. 2b (PRIOR ART)

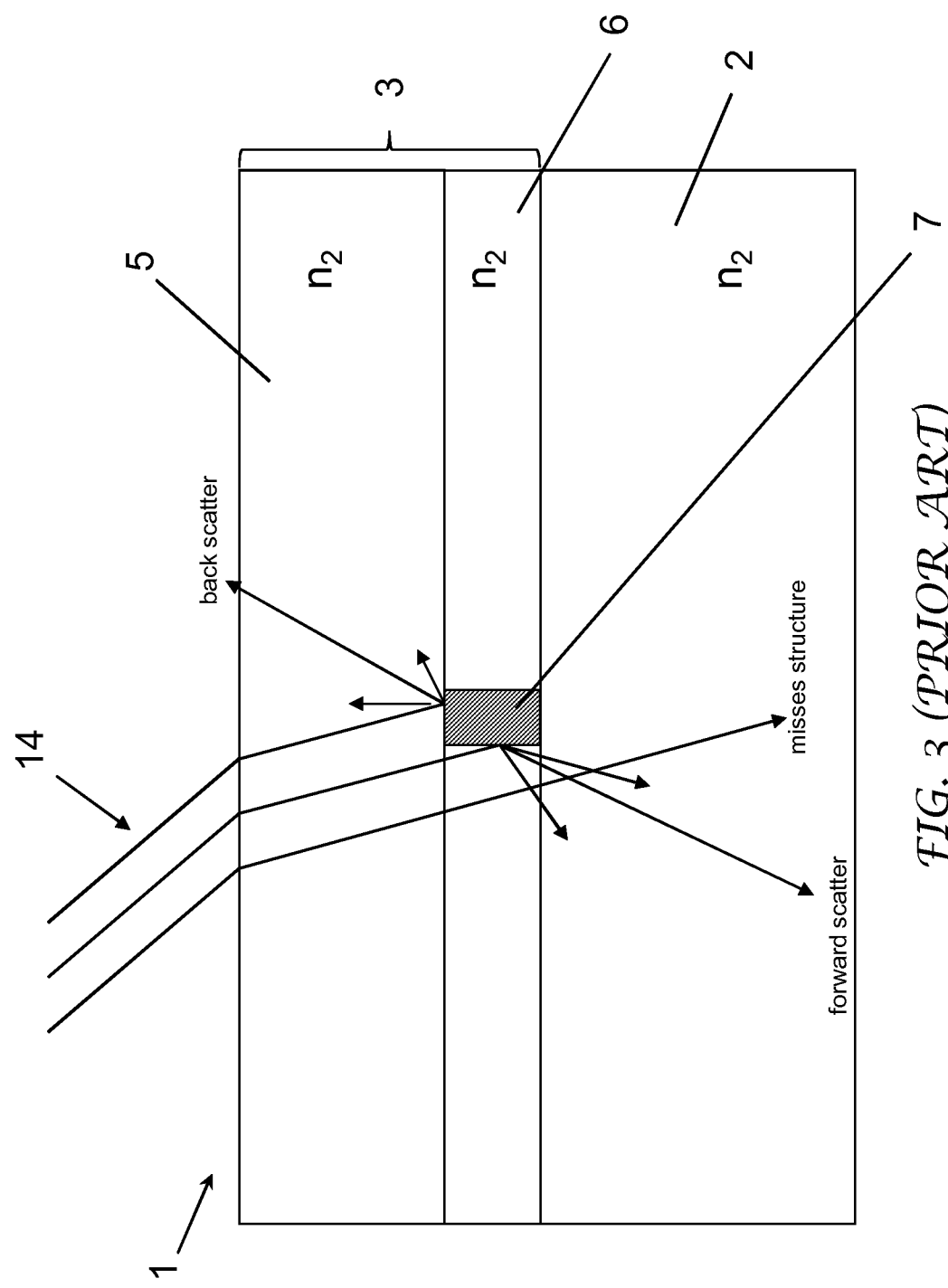


FIG. 3 (PRIOR ART)

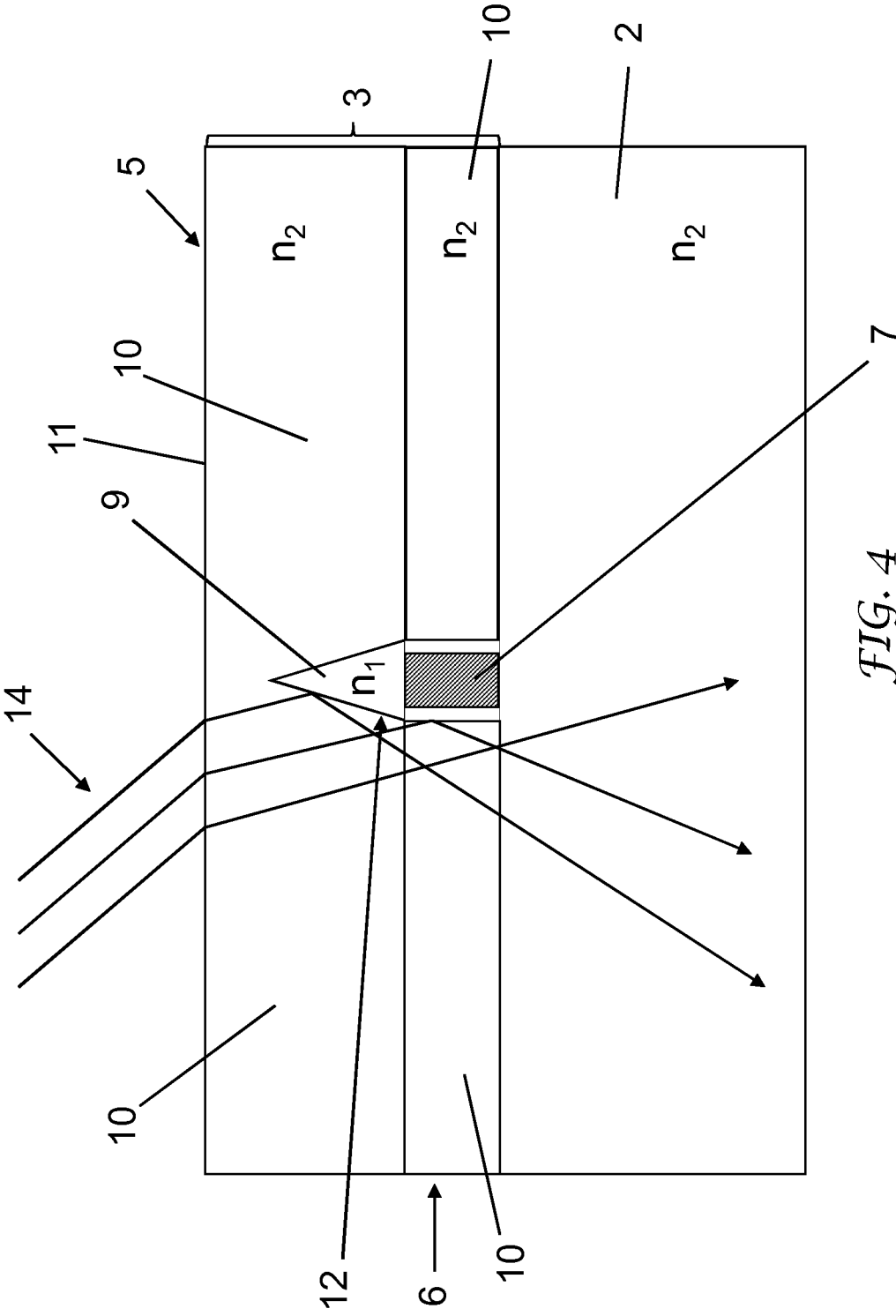


FIG. 4

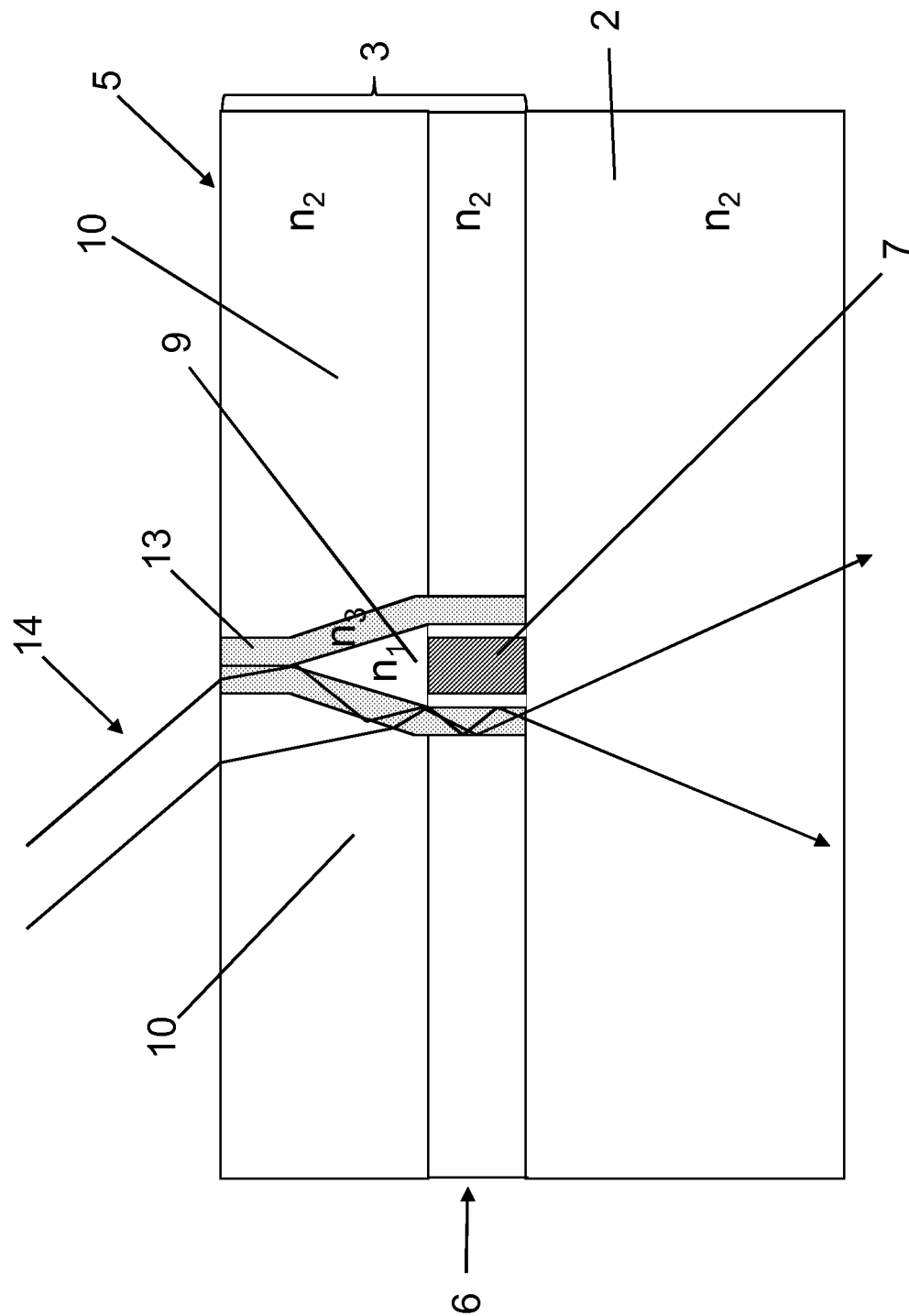


FIG. 5

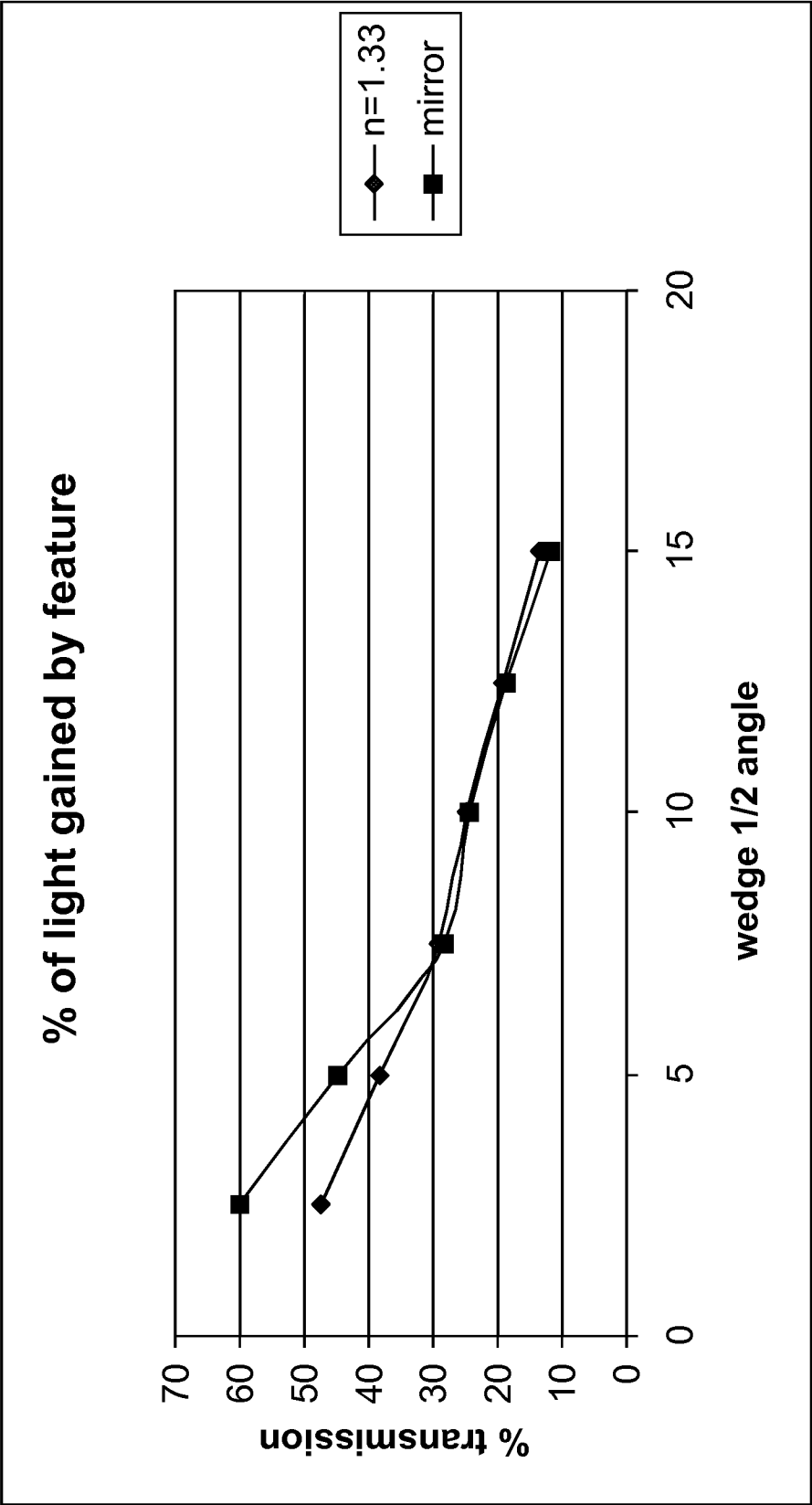


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2009/053057

A. CLASSIFICATION OF SUBJECT MATTER

INV. G02F1/1335 G02B6/00 F21V8/00
ADD. G02F1/1345

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G02B G02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	JP 05 100222 A (SHARP KK) 23 April 1993 (1993-04-23) the whole document -----	1, 3-10, 12-13 2
X Y A	JP 05 249450 A (NIPPON ELECTRIC CO) 28 September 1993 (1993-09-28) the whole document -----	1, 3-5, 7-10, 12 14-15 2
X A	DE 43 32 699 A1 (THOMSON BRANDT GMBH [DE]) 30 March 1995 (1995-03-30) the whole document -----	1, 3-5, 7-10, 12 2
X A	JP 01 167729 A (HITACHI LTD) 3 July 1989 (1989-07-03) abstract; figures 3-6 -----	1, 5-6, 11-12 2
	-/--	

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

A document defining the general state of the art which is not considered to be of particular relevance

E earlier document but published on or after the international filing date

L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

O document referring to an oral disclosure, use, exhibition or other means

P document published prior to the international filing date but later than the priority date claimed

T later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

X document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

Y document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

* & * document member of the same patent family

Date of the actual completion of the international search

2 December 2009

Date of mailing of the international search report

09/12/2009

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Kloppenburger, Martin

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2009/053057

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2001 356352 A (MATSUSHITA ELECTRIC IND CO LTD) 26 December 2001 (2001-12-26) abstract; figures 1-6 -----	14-15
A	US 2005/134769 A1 (MI XIANG-DONG [US]) 23 June 2005 (2005-06-23) abstract; figure 4A -----	2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2009/053057

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
JP 5100222	A	23-04-1993	NONE	
JP 5249450	A	28-09-1993	NONE	
DE 4332699	A1	30-03-1995	NONE	
JP 1167729	A	03-07-1989	NONE	
JP 2001356352	A	26-12-2001	NONE	
US 2005134769	A1	23-06-2005	WO 2005066669 A1	21-07-2005