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(54) Title: MULTI-VIEW STEREOSCOPIC DISPLAY

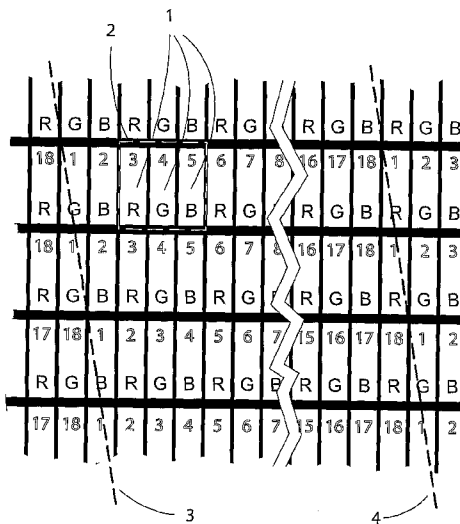


Fig 3

(57) Abstract: An auto-stereoscopic display which delivers a 3D sensation by coupling a lenticular lens to an LCD display, the lens axis inclined at an angle to the vertical of the display, with the output from each alternate row of pixels repeated on the row or rows immediately above each row, the auto-stereoscopic display delivering repeating sets of a multiple of nine views.



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MULTI-VIEW STEREOSCOPIC DISPLAY

FIELD OF INVENTION

This invention relates to auto-stereoscopic displays whereby a lenticular lens is
5 placed between a flat-panel display and an observer in order to generate a perceived
three-dimensional impression.

BACKGROUND

To increase the visual experience of a viewer observing two-dimensional images it
10 has been recognised that introducing a perceived third dimension is one successful
method. This effect has been used for advertising signage and visual promotional
campaigns. In the entertainment industry, a perceived three-dimensional viewing
was achieved for many years using coloured filter glasses and later by using shutter
glasses synchronised with a display that alternated between left and right eye views.

15

The advent of flat panel displays such as the liquid crystal (LCD) and plasma
varieties heralded the possibility of interposing an optical element between the
display and the viewer to present a different image to each eye of a viewer.

20 To achieve these different images, an image is split into a multitude of views
corresponding to different viewing angles. These views are spliced into an image
and an array of cylindrical lens focuses each view into different directions. The
angular separation between adjacent views is designed such that within a specified
viewing distance from a display, each eye of an observer receives light from a
25 different view. Various literature describes the principles and technology, for

example with US patent no. 6,064,424. The simplest arrangements only produce two views, while multi-view systems have typically between seven and nine views, with the sets of views repeating as an observer moves sideways. At the transition between the sets of views the image seen by an observer's eyes are unmatched and
5 the 3D effect is lost and the experience is uncomfortable.

Higher numbers of views provide an increased 3D experience as objects can be 'looked around' to a greater degree and also the number of transitions at which a set of views repeats is reduced. The resistance to increasing the number of views is the
10 loss of horizontal resolution and the disparity between horizontal and vertical resolutions.

Another relevant issue with displays featuring lenticular lens is the production of Moiré patterns. These are most pronounced when the axis of the lenticles passes
15 through the non-light emitting intersections between sub-pixels, and manifests itself by dark bands that pass across the screen as an observer moves sideways. Moiré patterns are very conspicuous with nine-view systems for which the lenticle axes pass diagonally through each sub-pixel from corner to opposite corner intersecting the maximum number of non-light emitting intersections.

20

Recent developments with LCD technology are producing high definition displays which exceed 2000 pixels in a horizontal direction, and approach 4000 pixels. Prior to the advent of these ultra-high definition displays, the highest commercially available definition was 1920 x 1080 pixels which limited the quantity of effective
25 views to a maximum of about nine, which coincides with the optimum configuration of a slanted lenticular lens whereby the resolution in the horizontal and vertical

directions is the same. Using the same or different slant angle and attempting to increase the quantity of views results in a mismatch between the resolutions in the two directions.

5 This invention is directed at a method of generating large quantities of view sets, notably 18, 27 or more, with equal horizontal and vertical resolutions, producing a greater 'look-around' effect and providing a display with fewer transitions between sets of views and also a display with reduced Moiré patterns. To appreciate the method it is beneficial to understand the current technology.

10

LCD and plasma screens feature light-emitting elements that comprise red, green and blue rectangular elements, grouped in triplet sets adjacent each other to form pixels. Typically the individual colour elements, known as sub-pixels, are rectangular with an aspect ratio of 3:1 with a long axis in the vertical direction.

15

In auto-stereoscopic situations, adjacent sub-pixels can represent a 'view', of which there can be as few as two, for a simple single-viewer display or as many as nine or more views which allow greater latitude in the position of a viewer. A lenticular lens serves to image different views into each eye of an observer and hence deliver the

20

illusion of depth to an image.

It is helpful to understand the technology with the aid of diagrams. Figure 1, with an enlarged portion, shows the plan view geometry for an LCD display 1 having a slanted lenticular lens 2 comprising columns of cylindrical lens 3 also known as
25 lenticles. Depending on the angle of view, different sub-pixels 4 will be seen, and at

an optimum viewing distance, adjacent sub-pixels will be seen by different eyes 5.
Ray paths are shown as dashed lines.

The schematic of a display as seen front-on is shown in Figure 2. It shows red, green
5 and blue sub-pixels 1, and the axis 4 of a lenticle is shown slanted in order to
intersect red, green and blue sub-pixels. In a nine-view system the lens axis is
inclined from the vertical by an angle of $\text{atan}(1/3)$ which is about 18.5 degrees, and
each lenticle spans 9 sub-pixels or 3 pixels.

10 The resolution in this optimised arrangement of 9 views is one third of an 'un-
lensed' display. For example a 1920 x 1080 pixel display in effect becomes a 640 x
360 pixel display. Whilst seemingly low, such resolution is nevertheless adequate
for most viewing applications.

15 It will be noted that in order to generate say 18 views, it could be achieved by
doubling the pitch of the lenticles, however this would not result in a reduction of
the vertical resolution which is also determined by the angle of the lenticular slant.
The horizontal resolution of a display delivering 18 views would be reduced by a
factor of 6. A display having a native 3840 pixels in the horizontal direction would
20 deliver the same horizontal resolution as a nine-view lens applied to a native 1920
pixel display.

One of the drawbacks of ultra high-resolution displays is the demands for file sizes
and data transfer rates when movie files are concerned. The present invention aims
25 to provide a 3D auto-stereoscopic display with more than ten views and having
equal resolution in the horizontal and vertical directions.

PRESENT INVENTION

The invention is said to reside in an auto-stereoscopic 3D display using a slanted lenticular lens coupled to a pixel-based display such as an LCD whereby it presents $9.n$ views where n is an integer greater than 1, characterised by the pixel output
5 being duplicated in adjacent row sets of n pixel rows and the lenticular lens having a slant angle of $\text{atan}(1/(3.n))$ and a horizontal pitch of near $3.n.p$ where p is the pixel width.

The invention may also be said to reside in an auto-stereoscopic display comprising
10 a lenticular lens sheet coupled to an LCD screen characterised by the lens having parallel cylindrical lenselets inclined near 9.5 degrees to vertical and having a horizontal pitch that is near 6 times the horizontal pitch of the LCD pixels, whereby the output from the LCD screen repeats on each alternate row of pixels.

15 With repetition of each second row, it may be seen that image file sizes can be reduced by approximately $1/n$ compared to images for which the output of each row is independent of others.

The invention also resides in a pixel-based display wherein the aspect ratio of the
20 pixel triplets is 2:1 or 3:1 with the long axis in the vertical direction.

DESCRIPTION

The invention can best be appreciated with reference to the accompanying figures which show a preferred embodiment. Figure 3 shows a diagram of the arrangement
25 for 18 views and figure 4 illustrates the arrangement for 27 views, whilst figure 5 shows a pixel geometry for achieving a similar result.

Referring to figure 3, an LCD display presents red, green and blue sub-pixels 1, a set of which constitutes a pixel as shown by outline 2 which is generally square. The numerals within each pixel refer to a relative view number and the R, G, B letters denote the colour of the sub-pixel. The axis of one cylindrical element of a lenticular lens is shown by the dashed line 3, and the axis of an adjacent element is shown by dashed line 4. The inclination of the axis is such that it can pass through two vertically adjacent sub-pixels. This angle corresponds to $\text{atan}(1/6)$ which is approximately 9.46 degrees from vertical.

10 It can be seen that, say, a red component of a white image will repeat every sixth pixel in the vertical direction, and also every sixth pixel in the horizontal direction. Hence the resolution is preserved in both directions.

The input to the display is programmed such that every second row is repeated.
15 With the use of a dedicated circuitry in the form of a chip, the image requires much less data than that of a full resolution image and should enable image file sizes to be near half the size of an equivalent full resolution image. The technology to produce the image data does not form part of the invention, but is considered rudimentary to someone in the computing field.

20

Figure 4 shows a configuration for a 27-view display. Such quantity of views would only be suitable for displays that approach 10,000 pixels in the horizontal direction, the labels have the same meaning as for figure 2, with the difference being that the inclination of the axes 3 and 4 is such that they pass through three vertically adjacent sub-pixels. This angle corresponds to $\text{atan}(1/9)$ which is approximately 6.34 degrees from vertical.

25

Although the above two descriptions refer to a single display panel of high definition, the principle can be applied to multiple displays of lower resolution tiled to produce large displays.

- 5 While the above descriptions refer to cylindrical lens, it refers to any optical element that serves to focus the light in one direction and includes holographic means and faceted surfaces. It also includes barrier or parallax filters.

10 An alternative version of the above embodiment is to provide a pixel geometry in which the sub-pixels have an aspect ratio of 6:1 rather than the conventional 3:1, and the input image could have a vertical resolution which is half that of a full resolution (3:1 sub-pixel aspect ratio) display.

15 Figure 5 shows a pixel geometry which is designed to provide 18 views and not require doubling of outputs to pairs of rows. Referring to the figure, sub-pixels 1 have an aspect ratio which is near 6:1. A pixel boundary is indicated by 2, whilst the axes of a lenticular lens are shown as 3 and 4.

EXAMPLES

20 A 45-inch (114 cm across diagonal) display with 3840 horizontal pixels and 2160 vertical pixels is employed to deliver auto-stereoscopic images using a lenticular lens for an optimum viewing distance of 3 metres. For an eye separation of 6.5 cm, the angular width of each view should be $\text{atan}(6.5/300) = 1.24^\circ$. For an 18-view display, the angular width of the 18 views would be about 22° . The normal desired viewing
25 angle is about 30 degrees either side of the 'straight on' position, and so three sets of

the 18 views would be required with two transition zones between them. This low number allows for much more comfortable viewing and the wider viewing angle between sets enables a greater 3D effect as a viewer can see further round edges of objects.

5

The above specified display would have a pixel size of 0.257 mm or a sub-pixel width of 0.0857 mm. So a lenticular lens would require a pitch in the horizontal direction of $0.257 \text{ mm} \times 6 = 1.542 \text{ mm}$. This figure would in fact be reduced by a small factor to take into account the viewing distance, such that a particular view
10 observed centrally will also be seen near the edges of the screen where the particular view will have to be directed inwards towards a viewer centrally positioned. The inclination of the axis of the lens is about 9.46 degrees, so the pitch in a direction normal to the lenticle axis can be calculated to be 1.521 mm.

15 The radius of the lenticles and the thickness of the lens depends on the width of any airspace which may be either intentionally near zero or a defined spacing such as 5 mm. Readily available optical software is available which can specify the radius and thickness of the lenticles based on the refractive index of the lens material – normally acrylic.

20

The lens is fabricated using conventional plastic forming technologies such as injection moulding, extrusion, hot-forming between rollers or hot-forming between plates in a press.

25 The content delivered to the display is suitably generated, divided into 18 views and spliced together. This aspect of the technology is not the subject of the invention.

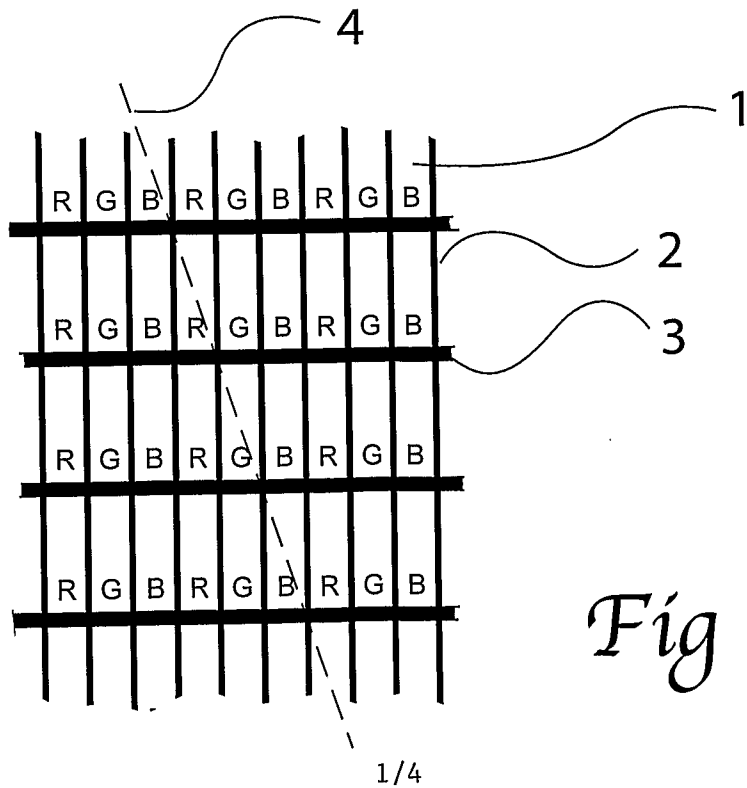
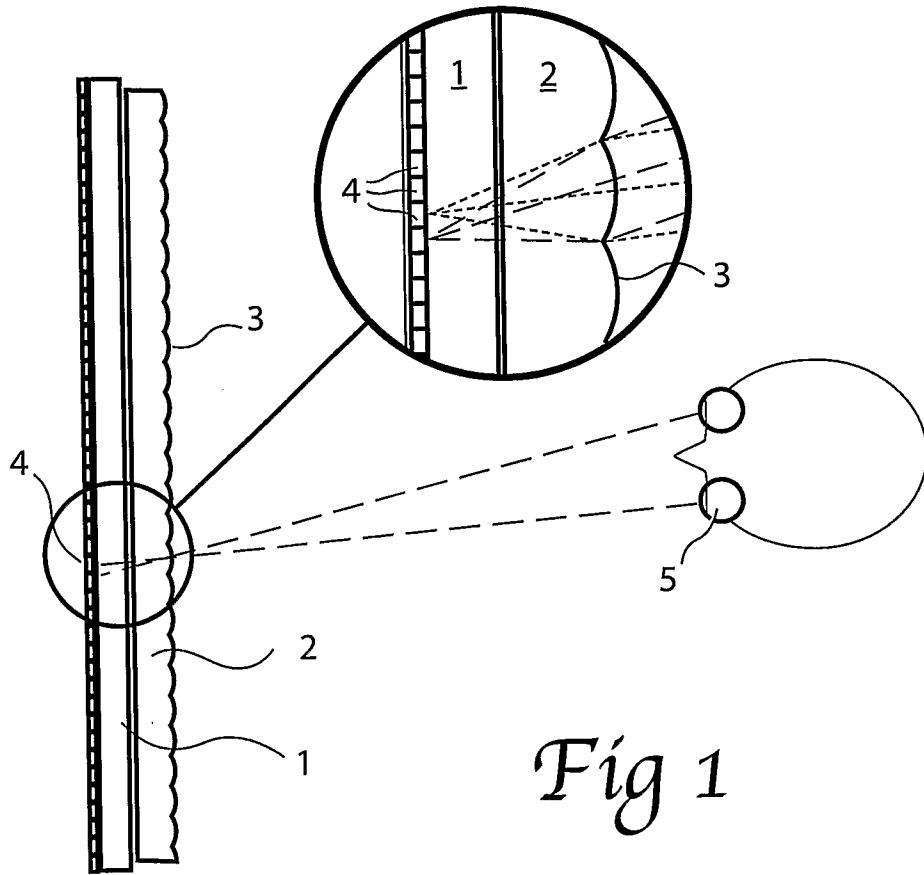
Several content providers exist who have developed software for such auto-stereoscopic displays.

5 A second example features sixteen 45" displays of pixel content 1920 x 1080. The displays are disposed closely together in a tiled fashion. To drive sixteen displays at full resolution would demand high file sizes and data transfer rates. By adopting principles of this invention, the file size can be substantially reduced by sacrificing resolution of each display by a factor of four in the vertical direction and including a lenticular lens that provides 36 views, so that the effective resolution of the collection
10 of displays is 1920 x 1080. Although seemingly coarse for a large display with an effective size of 180", when viewed from a distance such as 8 metres it would be quite acceptable.

15 It will be appreciated that the above described invention provides an improvement in the 3D experience using auto-stereoscopic displays, allowing for a large number of views and equal resolution in the horizontal and vertical axes.

CLAIMS

1. An auto-stereoscopic display comprising a lenticular lens coupled to an LCD screen comprising an array of pixels, characterised by the lens having parallel
5 cylindrical lenselets inclined near 9.5 degrees to a vertical axis and having a horizontal pitch that is near 6 times the horizontal pitch of the LCD pixels, whereby data input to each alternate rows of pixels is repeated on each adjacent row.
2. A lenticular lens for use with LCD screens, the lens having parallel cylindrical
10 lenselets inclined near 9.5 degrees to a vertical axis.
3. A lenticular lens as in claim 2 whereby the horizontal pitch of the lens is near 6 times the horizontal width of the pixels of an LCD screen to which the lens is intended to couple.
15
4. A display as in claim 1 wherein the lens sheet is fabricated from acrylic.
5. An auto-stereoscopic display characterised by the inclusion of an electronic chip which serves to duplicate the signal to each output row of the display's LCD
20 matrix, said display being coupled to a lenticular lens.
6. A slanted lenticular lens comprising cylindrical lenselets coupled to a pixel-based display such as an LCD whereby it presents sets of $9.n$ views where n is an integer greater than 1, characterised by the pixel output being duplicated in adjacent
25 row sets of n pixel rows and the axis of the lenselets being inclined to vertical at an angle of $\text{atan}(1/3n)$ and the horizontal pitch of the lenselets being $3n$ times greater than the width of the display pixels.



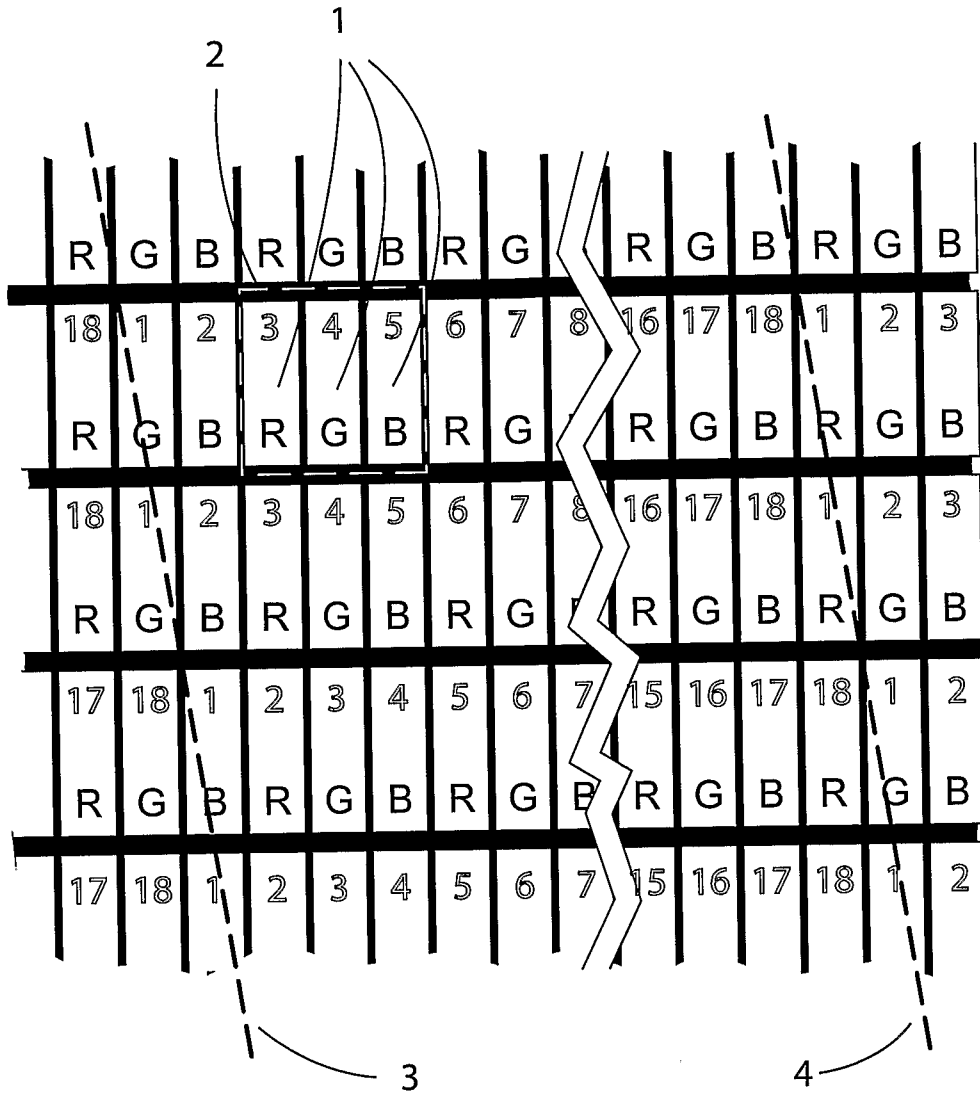


Fig 3

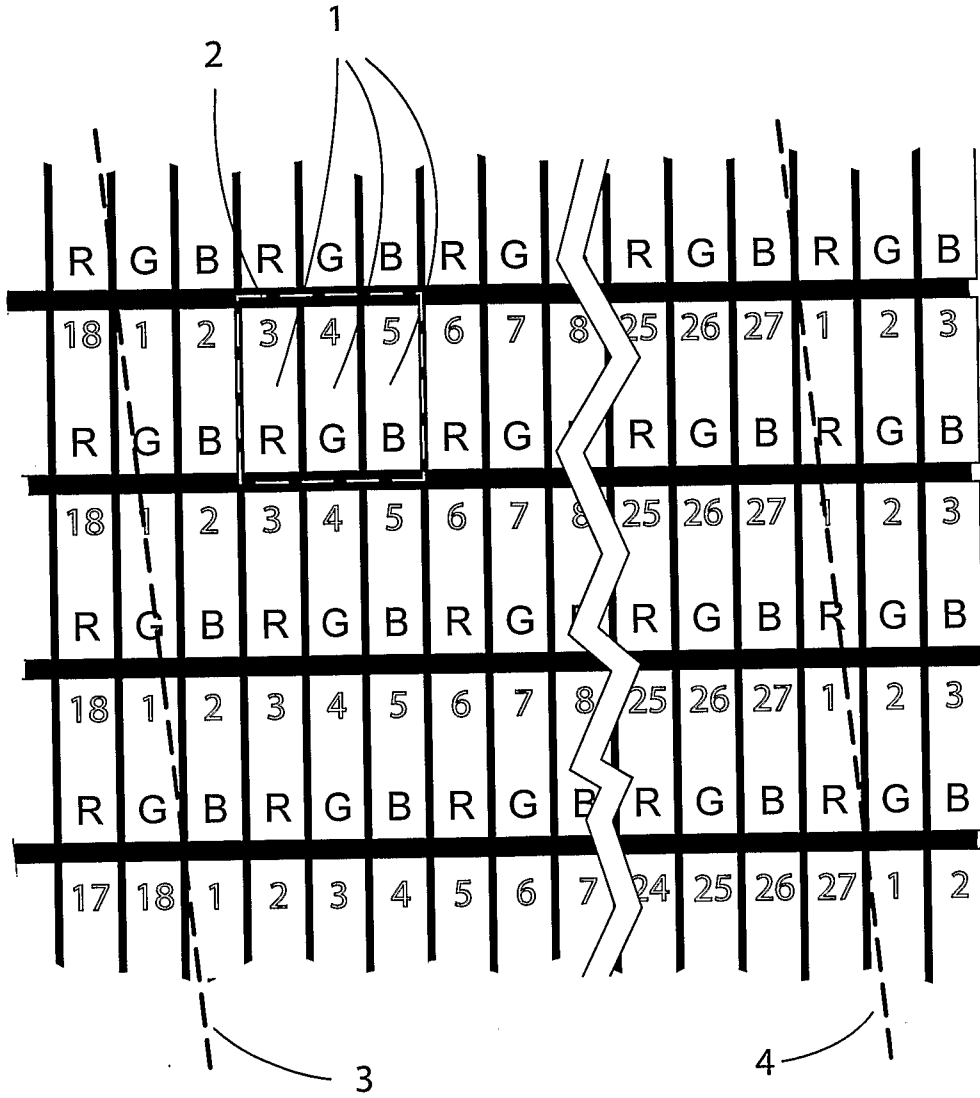


Fig 4

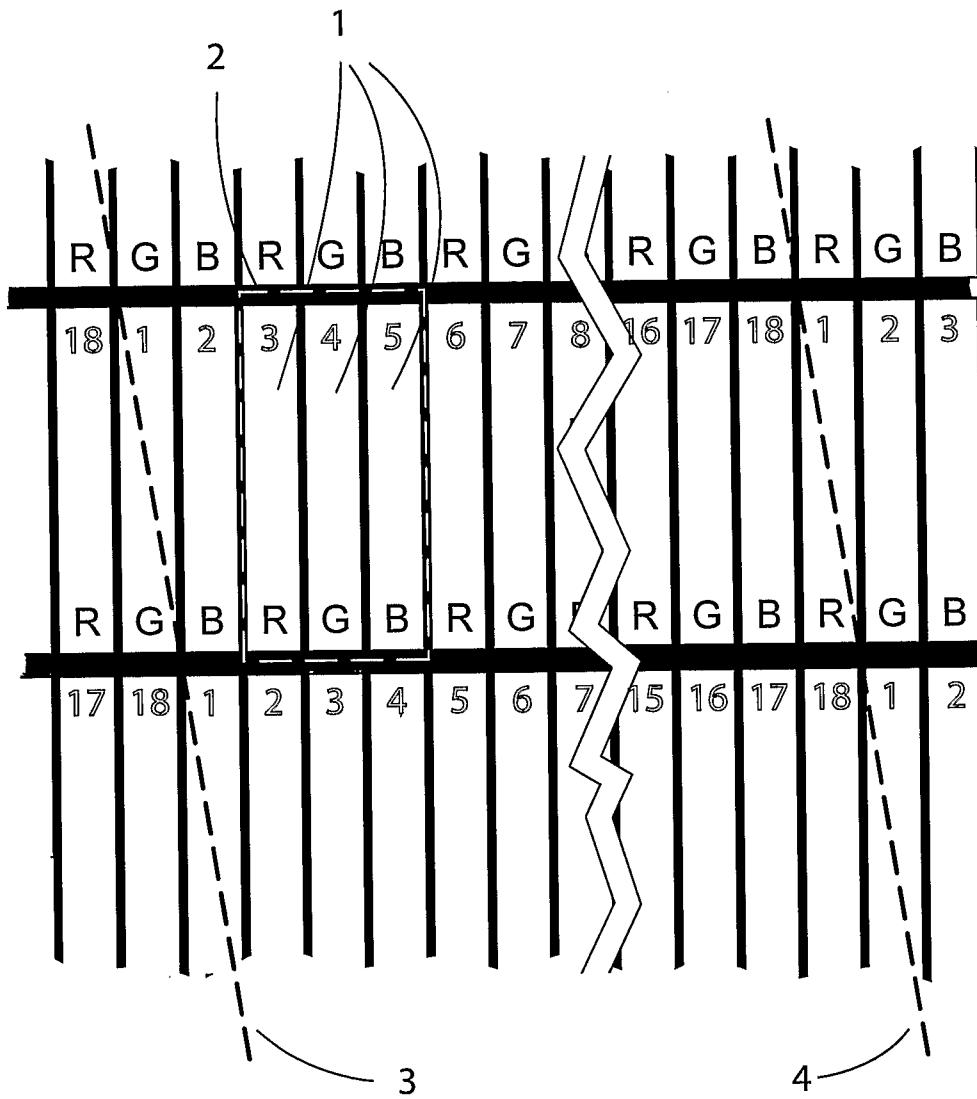


Fig 5

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2008/000152

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

H04N 15/00 (2006.01) **G02B 27/22** (2006.01)

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)

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 practicable, search terms used)

DWPI: IPC G02B 27/22, G02B 27/24, G02B 27/26, H04N 13/ , H04N 15/ and keywords display, screen, television, lenticular, cylinder, angle, pitch, incline, pixel, chip, processor, duplicate, repeat and similar terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6064424 A (VAN BERKEL ET AL.) 16 May 2000 Abstract, Figure 2 and Columns 8-9.	2, 3
X	US 2006/0268240 A1 (MILES) 30 November 2006 Figures 3A-3C and Paragraph [0027]	2, 3

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

"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

"E" earlier application or patent but published on or after the international filing date

"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

"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)

"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

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

"&" document member of the same patent family

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

Date of the actual completion of the international search
09 April 2008Date of mailing of the international search report
17 MAR 2008Name and mailing address of the ISA/AU
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Supplemental Box

(To be used when the space in any of Boxes I to IV is not sufficient)

Continuation of Box No: III

This International Application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept.

In assessing whether there is more than one invention claimed, I have given consideration to those features which can be considered to potentially distinguish the claimed combination of features from the prior art. Where different claims have different distinguishing features they define different inventions.

This International Searching Authority has found that there are different inventions as follows:

- Claims 1, 4-6. It is considered that repeating data input to adjacent row of pixels comprises a first distinguishing feature.
- Claims 2, 3. It is considered that a lenticular lens for use with LCD screens, the lens having parallel lenselets inclined near 9.5 degrees to a vertical axis comprises a second distinguishing feature.

PCT Rule 13.2, first sentence, states that unity of invention is only fulfilled when there is a technical relationship among the claimed inventions involving one or more of the same or corresponding special technical features. PCT Rule 13.2, second sentence, defines a special technical feature as a feature which makes a contribution over the prior art.

The only feature common to all of the claims is a lenticular lens for use with LCD screens. However this common feature is generic in the art. This means that the common feature can not constitute a special technical feature within the meaning of PCT Rule 13.2, second sentence, since it makes no contribution over the prior art.

Because the common feature does not satisfy the requirement for being a special technical feature it follows that it cannot provide the necessary technical relationship between the identified inventions. Therefore the claims do not satisfy the requirement of unity of invention *a posteriori*.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2008/000152

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

See supplemental box

1. As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2008/000152

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	6064424	EP	0791847	JP	9236777	JP	2007188097
US	2006268240	EP	1883920	US	2006268013	WO	2006127677

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX