(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
12 November 2009 (12.11.2009)

PCT

(10) International Publication Number
WO 2009/136218 Al

(51) International Patent Classification:
H04N 13/00 (2006.01)

(21) International Application Number:
PCT/IB2008/001 140

(22) International Filing Date:
6 May 2008 (06.05.2008)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant (for all designated States except US): MICROVISION INC. [TR/TR]; Rumelifeneri yolu, Sariyer, 34450 Istanbul (TR).

(72) Inventors; and
(75) Inventors/Applicants (for US only): UREY, Hakan [TR/TR]; Koc Universitesi, Elektrik Muhendisligi Bolumu, Muliendislik Binasi 116, Rumelifeneri yolu, Sariyer, 34450 Istanbul (TR). SAYINTA, Murat [TR/TR]; Koc Universitesi, Elektrik Muhendisligi Bolumu, Muhendislik Binasi Z-1 19, Rumelifeneri yolu, Sariyer, 34450 Istanbul (TR).

(74) Agent: ANKARA PATENT BUREAU LIMITED; Bestekar Sokak No. 10, Kavaklidere, 06680 Ankara (TR).

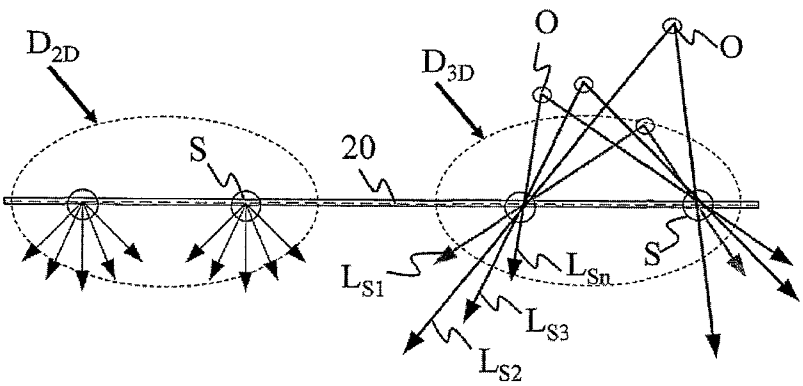
(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, 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, 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, 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: AN APPARATUS FOR DISPLAYING 3 D IMAGES

FIGURE 1



(57) Abstract: A 3D visualization apparatus is described based on the method of generating different horizontal light emitting directions from different screen positions. This is achieved by way of an array of scanning light source modules placed behind the screen. The scanning modules can be implemented by using an array of ID or 2D scanning modules where each one is coupled with at least one light source.

WO 2009/136218 A1

AN APPARATUS FOR DISPLAYING 3D IMAGES

Technical Field

The present invention relates generally to an apparatus that enables 3D displaying.

Background of the Invention

Today's developed displays with advanced technologies including "Liquid Crystal Display (LCD)" show images with very high quality. However, there is a vital inadequacy with today's 2D displays. This inadequacy is a result of expressing the 3D real world on a 2D plane and ignoring the fact that human beings experience the real world through two different eyes. In vision of the real world, two eyes correspond to two different views for the visual system while traditional displays provide only one view to the visual system —the same view towards each eye. 3D Displays seem to be the next step in the evolution of displays and will overcome this inadequacy by providing different views to different eyes. With the incredible developments in the digital video processing and visualizing technologies, first commercial 3D display products are already available in the market. It is helpful to classify 3D displays for a better understanding of their development trend and a possible classification can be as holographic displays, volumetric displays and auto-stereoscopic displays [I].

First group, holographic displays in spite of their great potential stemming from their 3D reconstruction quality, are not strong candidates for being widespread and commercial in the following years, due to high bandwidth requirements, demand for SLMs with high resolution and difficulties in achieving natural shading. Second group, volumetric displays have a variety of approaches e.g. real image methods applying static or moving displays and few commercial products realizing these approaches. Perspecta developed by Actuality Systems having a rotating disc at 900 rpm on which images are projected sequentially is a good example for real image approaches with a moving display. Fogscreen, creating an image on fog-like particles which seems to be floating in the air is a good example for real image approaches with static displays. The volumetric displays have the vital drawback of transparency. It means that objects that should be behind some other objects, are not occluded by the front object and seen by the viewer which cause a confliction in viewer's 3D perception. Another drawback with volumetric displays is their incapability of displaying surfaces having non-Lambertian intensity distributions. Today, the third group, auto stereoscopic multi-view displays e.g. Philips' multi-view display using slanted lenticular sheet or Sanyo's multi-view display using parallax barrier, seem to have the highest potential of acceptance in the display market in the following years. However, auto stereoscopic displays have also their own drawbacks including: generation of pseudoscopic viewing regions, decrease in resolution with increasing view number, discontinuities and jumps between adjacent views, eye fatigue stemming from accordance problem of accommodation and vergence mechanisms of the eye.

Holographic-like displays solve some major problems of the auto stereoscopic displays mentioned above and provide the key advantages of holographic displays such as accomrnodation-vergence synchronization and smoother motion parallax by constituting larger number of views in the field of view [1], [2]. Actually, it is found that twenty views per interocular distance is an optimum value for smooth motion parallax. There are a few examples of holographic-like displays that use micro display array and collimated light source [3], [4], a laser or array of laser diodes and 2D scanners [5], [6].

U.S. Patent no 06999071 issued in February 2006 explains such a 3D Display method. The 3D display $D3_D$ tries to realize a 2D Screen 20 with screen pixels S that can emit light with different colors and intensities to different directions Lsi to Ls_n [3]-[6]. The system transmits independently modulated light beams LM in different directions Lsi to Ls_n from a single screen point S in contrast to traditional 2D displays D_{2D} transmitting the same light information in every direction from a single screen point S as illustrated in Figure 1.

This is accomplished by illuminating numerous 2D micro displays 60 controlled according to the 3D image that will be displayed. The light from the light source 13 is collimated before illuminating the micro displays 60. Each independently modulated light beam L_M by the individual pixels S of the 2D micro displays is then transmitted in different directions by a lens system 31 and 32 present in front of each 2D micro display 60, as shown in Figure 2. By the help of screen 20, the independently modulated light beams L_M are asymmetrically diffused to the viewing zone. One of the most important advantages of such a system is its capability to be produced by integrating identical sub blocks (modules) M side by side in a modular fashion. The 3D display volumetric size is scalable in a way similar to LEGO™ blocks.

Figure 3 illustrates how the 3D display concept D_{3D} realizes 3D viewing and how different viewers with different perspective perceive different images. In the figure, there are two different viewers Vi, V2 and 4 objects points Oi, O_2, O3, O4 that are imaged behind or in front of elliptically diffusing screen 20 by different modules M. The modules M constitute an array in horizontal direction. Every module M in this array is capable of emitting independently modulated light beams L Mto pre-defined directions. The first viewer Vi can see object Oi, O_2 and O4 clearly as his both eyes E_{1R} and E_{IL} receive ray bundles from the objects Oi, O_2 and O_4. However, only his left eye EIL receives light from O_3. By this way the first viewer Vi understands that object O_3 is occluded by the object Oi. The second viewer V_2 cannot see the object Oi as it in not in his field of view. He can see the object O_3 and O_4 clearly but only his right eye E_{2R} receives light from object O_2 so that he understands that object O_2 is occluded by object O3.

Summary of the Invention

In this invention, the above 3D visualization concept, approaching 3D displays as 2D displays that have pixels emitting different color and intensity light to different directions, is realized by using an array of scanners that images properly modulated light to the proper screen pixels on their scanning path.

In a preferred embodiment of the system, ID array of light sources per each main color are integrated with ID modules scanning in torsion mode together with imaging lenses. The light sources are modulated by a driving circuitry which is mounted ON or OFF the scanning platform. There is 2D array of these scanning modules behind the screen placed with a specific periodicity to a specific distance according to the resolution requirements of the display and the number of different views the display requires to provide. The precisely controlled intersections of rays coming from several scanning modules correspond to a complete set of voxels and the viewers looking from different perspectives will see different 3D images, hi the system, light sources are preferably LEDs or organic LEDs and scanners are preferably made from polymer or silicon materials.

Another preferable scanning mode can be in-plane mode but in this mode the imaging lens will not be connected to the scanning platform. The module will scan behind a motionless lens and according to scanner's relative position to the lens; the ray bundles emitted from the light sources on the scanner will be directed to different screen pixels.

In a further advantageous implementation, the light sources can be motionless and the lens is scanned in in-plane mode in front of the light sources to image them to different screen pixels.

Different actuation mechanisms such as electrostatic or electromagnetic actuation can be used for realizing the scanning. In a preferred system, electromagnetic actuation with a magnet placed on top of the scanner interacts with an external electro coil driven with alternating current. In a further preferred system, the electro coil can be printed or fabricated on to the scanner and actuation can be realized by an external magnet.

In another implementation of the system, instead of using ID array of light sources per each main color coupled with ID scanner, a single light source per each main color coupled with 2D scanners is used. Here the light source can be preferably laser diodes, vertical cavity surface emitting diodes (VCSELs). Scanners are preferably made from polymer or silicon materials or from both of them. The light sources can be on top of the scanners or they can be external and their light can be reflected to the screen pixels by a mirror placed on top of the 2D scanners.

In all configurations, the scanning angle of the scanners can be limited to a specific narrow angle with a specific offset if only limited numbers of viewers are viewing the display from a limited viewing angle. This embodiment of the system is quiet advantageous as it will increase the efficiency and as a result brightness of the display.

In another system, a special screen that can move left and right directions according to the position of the viewers constituted from an array of cylindrical lenses that have modulatable pitch sizes can be used together with a head tracking system to send 3D information only to the specific region where viewers are standing. This system can be preferably used with personal devices. This special screen can be used either in front of displays having light sources located at the pixel positions including liquid crystal displays (LCD) or displays that have pixels scanned with at least one scanner coupled with at least one light source in a certain depth.

Brief Description of the Drawings

Figure 1 — The working principle of the quasi-holographic volumetric display

Figure 2 — The basic unit of the Holografika display

Figure 3 - Different viewers looking from different perspectives receive different views

Figure 4 - (a) ID LED arrays in RGB colors and driver IC mounted on FR4 scanner platform; (b) Scanner modules as the basic unit of the 3D display.

Figure 5 — Every pixel on the screen is illuminated by different modules whose number is equal to the number of different emission directions from the pixel

Figure 6 - Voxels rendered (i) in front of the screen, (ii) between the screen and the LED modules, (iii) behind the LED modules.

Figure 7 - The optical behavior of the system in vertical and horizontal directions.

Figure 8 — Micro lens array in superposition mode to image the light sources onto the screen

Figure 9 - Micro lens array in apposition mode to image the light sources onto the screen

Figure 10 - 3D display scanning modules implementation with lateral translations of a lens

Figure 11 - FPGA as a LED Driver on polymer scanner for driving the LED array

Figure 12 - The complete display

Figure 13 - 2D Scanning Based 3D Display Concept using laser diodes placed on top of polymer scanners

Figure 14 - 2D Scanning Based 3D Display Concept using mirrors placed on top of polymer scanners illuminated by external laser diode sources

Figure 15 - In the display concept there is an array of 2D polymer/hybrid scanners in the horizontal axis of the display

Detailed Description of Embodiments

The light source 13, collimator 31, 2D micro display panels 60, and the lens system 32 in front of the micro display 60 in figure 2 mentioned above are replaced with a one-dimensional (ID) scanning module $1O_{1D}$ coupled with at least one light source 13 per each color and an imaging lens 30 in front. In a preferred embodiment, ID LED array per color (13_R, 13_G and 13_B) is integrated onto the ID scanning module 10m as the light source 13 of the system. A one-dimensional (ID) LED array per color 13 and the LED driver IC 14 integrated on a ID scanning module IO_{ID} can be seen in Figure 4(a), which constitutes the basic functional unit of the display system. In a preferred embodiment, the scanner IOI_D is made on FR4 substrate, a fiber-glass epoxy composite, using standard PCB technology [7] and scans in torsional mode via the flexible members 11 of the ID scanning module IOI_D that are connected to a fixed platform 12 . Depending on the number of LEDs per ID scanning module IOI_D, the driver IC 14 can be mounted ON or OFF the moving platform. 2D array of such ID scanning modules IOI_D are tiled behind a special screen 20 for full system operation [8].

Each ID scanning module IOID creates a horizontal scan line by way of electromagnetic actuation in this preferred embodiment [9]. A magnet is placed onto the backside of the ID scanning module $1O_{1D}$ and modulated by an external electrocoil. In order to realize the screen 20 capable of emitting different color and intensity light to different directions from its pixels S, red, green, and blue LEDs, 13_R, 13_G and 13_B are modulated individually during scan and the images for each color LED can be overlapped in space by introducing slight time-shifts in between R, G, B LED drive signals during the scan.

As illustrated in Figure 4(b), each ID scanning module 10m address an array of screen pixels S on the special screen 20 and provide independently modulated light beams L_M with different angles for each screen pixel S. Screen pixels S are illuminated by a number of such ID scanning modules IOI_D with independently modulated light beams L_M with different ray angles. The number of emission directions for each screen pixel S is equal to the number of ID scanning modules IO_{ID} illuminating the screen pixel S. Placing mirrors 22 at the sides of the display would create virtual modules 1Oy and create the missing illumination directions Ls for the screen pixels S near the edge of the display as illustrated in Figure 5 . A virtual source point or voxel O is perceived at the intersection of two properly modulated ray bundles received by the left and right eyes of a viewer. The precisely controlled intersections of rays coming from several scanning units IO_ID correspond to a complete set of voxels O and the two viewers V_1, V_2 looking from different perspectives will see different 3D images as shown in Figure 4. As illustrated in Figure 6, voxels O can be rendered at different depths. In Figure 6(i), Oi is rendered in front of the screen 20; in figure 6(ii), O_2 is rendered between the screen 20 and ID scanning modules IOI_D; and in figure 6(iii), O_3 is rendered behind the modules IO_{ID}. Note that the viewer's focus and vergence are in coordination and different for each voxel O depth, eliminating the binocular rivalry.

The screen 20 is capable of diffusing light into a narrow angle in the horizontal direction and into a wide angle in the vertical direction - i.e., elliptically diffusing screen 20. A narrow angle is required in the horizontal direction as each screen pixel S on the display should emit light with different color and intensity to separate horizontal directions without any crosstalk between neighboring directions. The wide angle in the vertical direction is required as the display is designed to provide motion parallax only in the horizontal direction (i.e., the same image is received by the viewer at the same horizontal position and different vertical positions of the eye pupils.)

The number of different views for the display is the same with the number of independently controllable horizontal emission directions from the screen pixels S. In a preferred embodiment, there are 40 different views using 1° divergence for each emission direction and 40° scan angle. The resolution of the display can be calculated using the following relationship:

$$N_{11} = \frac{n_h \times p}{r} \qquad \textbf{(D}$$

$$N_V = n_v \times l \qquad (2)$$

- N_H, N_V: number of screen pixels S in the horizontal and vertical directions,
- «/„ n_V: number of ID scanning modules 10m in the horizontal and vertical directions,
- p : number of horizontal screen pixels S addressed by each ID scanning module 1Om
- r : number of different ray directions through each screen pixel S
- /: number of LED color triads on a line in each ID scanning module I O_{ID}

The number of voxels O (N_T) fed into the data channel per frame in the 3D display system is given by the product of total number of LEDs and p :

$$N_r = n_h n_v l p \qquad (3a)$$

Equivalently, number of voxels O (N_T) can also be calculated using the total number of screen pixels S and ray directions:

$$N_T = N_h N_v r \tag{3b}$$

Table 1 provides an exemplary system design parameters for 2 million and 20 million voxels O with different display depths.

Voxels	$2x10^6$	$2x10^6$	$20x10^6$	$20x10^6$
N_H	240	240	720	720
N_v	160	160	576	576
n_h	80	48	240	144
n_v	5	5	18	18
p	150	250	150	250
l	32	32	32	32
r	50	50	50	50
FOV	50	50	50	50
Display Thickness	160 mm	268 mm	160 mm	268 mm

Table 1 —Examplary system design parameters for 2 Million and 20 Million voxels in 3D space for two systems with different sizes.

The table implies that the resolution of the system can be increased by increasing the number of ID scanning modules **I O_ID** without altering the ID scanning module **I O_ID** design or the screen 20 depth, resulting in a scalable architecture. Another implication of the table is that the screen 20 depth can be reduced by reducing p and increasing n_h.

The optics for the system is rather simple and illustrated in Figure 7. Each ID scanning module **IOID** has an imaging lens 30 that rotates together with the module 10m and provides imaging of LEDs onto the screen 20 with some magnification. The imaging lens 30 can be either refractive or diffractive. The focal length of the lenses 30 and the distance of the lenses 30 to the LEDs 13 are determined by the distance of the screen 20 to the ID scanning modules 10ID and the emission area of the LEDs 13. The vertical cross section of the display as illustrated in Figure 7(a) shows an array of ID LED arrays 13 and the horizontal cross section as illustrated in Figure 7(b) shows an array of single LEDs 13. Each LED 13 on a module $1O_{1D}$ provides illumination to a fraction of one row of the screen 20 in a light efficient manner by turning the LED 13 ON only while traversing a screen pixel S. The vertical resolution is increased by tiling ID scanning modules IO_ID in the vertical axis and number of ray angles from each screen pixel S is increased by tiling ID scanning modules 10_ID in the horizontal axis.

Plurality of microlens arrays 30M can also be used as the imaging lens 30 in front of each ID scanning module 10_{1P}. There are different modes of microlens arrays that can be used to image the light sources 13 to the screen 20. The first mode is superposition mode as illustrated in Figure 8. In this mode all the microlenses of the first microlens array $30M_I$ collect light from all individual light sources 13_i - 13„ and plurality of micro lens arrays 30M image them onto the screen 20. In the second mode as shown in Figure 9, light emitted from each light source 13i - 13_n is collected by a specific micro lens in the first micro lens array 30MI and each light source 13i - 13_n is imaged separately from separate microlenses .

As can be seen in Figure 10, the same 3D Display concept in horizontal direction can be realized by an imaging lens 30 in front of the light source 13, preferably LED array, that is not connected to the ID scanning module IO_ID and moving continuously in the lateral direction with a speed and rate determined by the display requirements (the number of spreading angles from each module). In this configuration, the lens 30 scans instead of the LED array integrated ID scanning module IO_ID. This configuration also seems to be easy to implement. However aberrations can give rise to quality problems in lens 30 moving system due to light bundles imaged from lens 30 edges.

The LED arrays will be driven with a LED driving IC 14 which will also be placed on top of the polymer ID scanning platform IOI_D to produce a compact system with minimum electrical connections through the flexible members 11 of the ID scanning module $1O_{ID}$ that are connected to a fixed platform 12 . The second way of LED driving will be using an external LED driving circuitry with a field programmable gate array (FPGA), complex programmable logic device (CPLD) or an ASIC. Placing the LED driving IC 14 on top of the ID scanning platform $1O_{1D}$ provides a more compact design and gives the opportunity of increasing the number of LEDs on a single FR4 scanner as fewer electrical signals 15 should be carried through the flexible members 11 of the ID scanning module $1O_{1D}$. These signals 15 would be limited, in the case of an FPGA, with the FPGA supply voltages Vcco, $V_{CC}AU_X$ and V_CC_INT, JTAG programming interface signals, 1 bit clock signal and 1 bit serial input data that would modulate the LEDS connected to the FPGA I/O pins. In this case, the number of the LEDs that can be driven will be limited with the number of I/O pins of the FPGA which can be quite high; more than four hundred with an I/O optimized FPGA as shown in Figure 11.

The LEDs are driven by pulse width modulation (PWM) method. N bit depth level PWM provides 2^N different intensity levels. A counter is synthesized within FPGA whose output value is compared with a reference value for each single output pin and produces PWM LED drive signal. N-bit video input determines the LED drive pulse width.

The input video data frequency at which the data will be fed into the FPGA will be:

$$f_V = \frac{3l\, n\, 2p\, f_D\, d_{PWM}}{d_W} \qquad (4)$$

- f_V: the frequency of the input video data
- l: number of LEDs per color on a line on each 1D scanning module 10_{1D}
- n: the number of 1D scanning modules 10_{1D} driven with the same driver
- p: number of horizontal screen pixels S addressed by each 1D scanning module 10_{1D}
- f_D: display refresh rate
- d_{PWM}: PWM bit depth
- d_W: input video data line width

As an example, assume f_D=60 Hz scan frequency- typical refresh rates of displays and l=30 (or 90 LEDs per module), d_{PWM}=10-bit, n=l (scanners controlled by each driver), p=100 pixels/LED (=200 modulations per cycle due to bidirectional scanning). In such a case, if 1 bit per color (d_W = 3) serial input video data is fed into the FPGA then 3.6 MHz clock frequency would be required. Taking into account the sinusoidal speed variation of the scanner during resonant operation, this average data rate need to vary by about a factor of 2 from the center to the edge of the scan line.

The whole display concept D_{3D} is shown in Figure 12. There is 2D array of 1D integrated polymer 1D scanning modules 10_{1D} behind the special screen 20 elliptically diffusing the light coming from the LEDs. Each module 10_{1D} illuminates a specific portion 20M of the screen 20 as illustrated in Figure 12.

In the case of limited number of viewers, viewing the display from a limited field of view (FOV), the scanning angle of the scanners can be limited to a specific narrow angle with an offset angle enough to feed all the viewers in the limited FOV. Each actuated 1D scanning module 10_{1D} - electromagnetically in the above configuration - is applied a certain constant magnetic force according to the viewers' position in the FOV of the display. The ID scanning modules I O_{ID} are scanned with an alternating magnetic force around this offset value to provide the left and right eye views simultaneously for the limited number of viewers. By this way, the display system D_{3D} works more efficiently and the display will be brighter as the number of views is limited.

The above 3D display concept D3D can also be realized by using single laser diode or vertical cavity surface emitting laser (VCSEL) for each red, green and blue colors as the light source 13 of the display scanned with 2D scanning modules I O_{2D} instead of the ID LED array for each red, green and blue colors scanned with ID scanning modules 10m. Two different configurations can be designed for the system using 2D scanning. In the first configuration, the laser light sources 13R, 13_G, 13B are placed on top of the 2D scanning modules 1O2D as shown in Figure 13 similar to the ID LED array placed on top of the ID polymer scanners IOID. In Figure 13, the light sources 13R, 13Q, 13_B are placed in the horizontal direction; however they can be also placed in the vertical direction. In the second configuration, mirrors 14 are placed on top of the 2D scanning modules $1O_{2D}$ and 2D scans the light emitted by external laser diodes/VCSELs 13 as illustrated in Figure 14. The 2D scanning modules 10_{2D} scan via the flexible members 11 that are connected to the fixed platform 12 as illustrated in Figure 13 and Figure 14. In the system, there is ID array of 2D scanning modules 10_{2D} in horizontal direction as shown in Figure 15. Similar to the ID array configuration that is illustrated in Figure 10, the light sources 13 can be kept still and the imaging lens 30 in front of the light sources 13 can be actuated in 2D to image the light sources 13 on to the screen pixels S.

The horizontal resolution calculation of the system is the same with the above 3D system. The only difference appears in the vertical resolution calculation. The vertical resolution is the number of the vertical screen pixels S addressed by each scanning module 1O2D. The optics for the system is simple, only an imaging lens 30 for each 2D scanning module 10_2D is required. The horizontal and the vertical cross section of the system can be seen in Figure 16(a) and 16(b) respectively. Both the vertical and the horizontal cross sections of the display show an array of 2D scanning modules 10_{2D}. Each light source 13 on a single 2D scanning module 10_{2D} provides illumination to an area enclosing all the screen pixels S on a fraction of the screen 20_M- The number of 2D scanning modules 10_{2D} in vertical direction is determined by the scanning requirements of each 2D scanning modules 10_{2D} in the vertical direction.

Similar to the 1D scanning module 10_{1D} with 1D light source array, 2D scanning module 10_{2D} can also work with a constant force and actuate around a specific angle only to feed a limited number of viewers in a limited FOV. Similar to the 1D case, scanning in a narrower angle increases the efficiency of the system and brighter images the viewers receive.

A single viewer 3D display more appropriate for personal devices using scanning light concept can be realized by using a dynamic screen 40 - e.g. an array of cylindrical lenses (lenticular sheet) in front of the light sources 13 as shown in figure 17 and 18. The dynamic screen 40 has an array of pitch size modulatable microlenses 43. According to the viewer's V distance to the screen - exit pupil 45 distance to the screen, the pitch sizes of the pitch size modulatable microlenses 43 can be increased or decreased as shown in Figure 17 via flexible members connecting micro lenses 42. In a preferred embodiment, this functionality can be realized by using piezoelectric materials for the flexible members connecting micro lenses 42. The dynamic screen 40 is also capable of moving left and right with constant lens pitch sizes by flexible members 41 connected to fixed frame 44 to follow the viewer's movement - exit pupil 45 movement to the left and the right direction for a specific viewing distance to the screen 40. The concept is illustrated in Figure 18. For a specific position of the viewer in FOV of the display, the screen 40 changes its position successively in two different appropriate positions for providing the left and right eye views of the viewer as shown in Figure 17 and Figure 18.

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CLAIMS

What is claimed is;

1) An apparatus for displaying 3D images comprising

A screen 20;

3D video electronics;

Plurality of ID scanning platforms 10π>;

At least one light source 13 coupled with each scanning platform 10ID;

Imaging optics coupled with each scanning platform 10m.

2) The apparatus of claim 1 wherein the at least one light source 13 is laser, OLED, or LED.

3) The apparatus of claim 1 further comprising an imaging lens 30 mounted to the scanning platform IOI_D.

4) The apparatus of claim 1 wherein the imaging lens 30 is refractive lens, diffractive lens, or a compound eye formed with plurality of microlens arrays 30M or plurality of reflectors.

5) The apparatus of claim 1 further comprising driver electronics 14 for the at least one light source 13 mounted to the scanning platform $I O_{ID}$.

6) The apparatus of claim 1 wherein the scanning platform IOI_D comprise

an actuating mechanism to produce an angular displacement for the scanning platform $I O_{ID}$ to project light from the at least one light source 13 in different directions based on the angular displacement of the scanning platform IOID.

7) The apparatus of claim 1 wherein the scanning platform $1O_{1D}$ comprise a polymer or silicon material.

8) The apparatus of claim 1 wherein the scanning platform IO_{ID} is connected to a fixed platform 12 via at least one flexible member 11.

9) The apparatus of claim 1 wherein at least one flexible membrane 11 includes at least one metal trace to provide electrical connectivity to the at least one light source 13.

10) The apparatus of claim 1 wherein the at least one light source 13 is fabricated on the scanning platform $1O_1D$-

11) The apparatus of claim 1 wherein each scanning module IO_{ID} is rotated with a different DC bias to provide higher brightness 3D image to fewer viewers than the more general case of scanning large angles.

12) The scanning platform $1O_1D$of claim 6 wherein the at least one light source 13 and the coupled drive electronics 14 are integrated with the scanning platform $1O_1D$.

13) A scanning platform $1O_1D$ as claimed in claim I_5 wherein the scanning platform IO_{ID} is driven to oscillate at the video frame rate of about 60 Hz.

14) An apparatus for displaying 3D images comprising

A screen 20;

3D video electronics;

Plurality of 2D scanners 10_{2D};

At least one light source 13 coupled with each scanner 10_{2D};

Imaging optics coupled with each scanner 10_{2D}.

15) The apparatus of claim 14 wherein the 2D scanning is obtained by rotation of a two 1D scanner 10_{1D} or one 2D scanner 10_{2D}.

16) The apparatus of claim 14 wherein the 2D scanning is obtained by 2D translations of a lens 30 or the at least one light source 13 relative to each other in a plane substantially perpendicular to the light emission direction of the at least one light source 13.

17) The apparatus of claim 14 wherein the 2D scanning is obtained by 2D translations of at least one microlens array 30_M or the at least one light source 13 relative to each other in the a plane substantially perpendicular to the light emission direction of the at least one light source 13.

18) The apparatus of claim 14 wherein the at least one light source 13 is laser, OLED, or LED.

19) The apparatus of claim 14 further comprising an imaging lens 30 mounted to the scanning platform 10_{2D}.

20) The apparatus of claim 14 wherein the imaging lens 30 is refractive lens, diffractive lens, or a compound eye formed with plurality of microlens arrays 30M or plurality of reflectors.

21) The apparatus of claim 14 further comprising driver electronics for the at least one light source 13 mounted to the scanning platform 10_{2D}.

22) The apparatus of claim 14 wherein the scanning platform 10_{2D} comprise an actuating mechanism to produce an angular displacement for the scanning platform 10_{2D} to project light from the at least one light source 13 in different directions based on the angular displacement of the scanning platform 10_{2D}.

23) The apparatus of claim 14 wherein the scanning platform 10_{2D} comprise a polymer or silicon material.

24) The apparatus of claim 14 wherein the scanning platform 10_{2}D is connected to a fixed platform 12 via at least one flexible member 11.

25) The apparatus of claim 14 wherein at least one flexible membrane 11 includes at least one metal trace to provide electrical connectivity to the at least one light source 13.

26) The apparatus of claim 14 wherein the at least one light source 13 is fabricated directly on the scanning platform 10_{2}D.

27) The apparatus of claim 14 wherein each scanning module IO_{2D} is rotated with a different DC bias to provide higher brightness 3D image to fewer viewers than the more general case of scanning large angles.

28) The scanning platform of claim 22 wherein the at least one light source 13 and the coupled drive electronics 14 are integrated with the scanning platform $1O_{2D}$-

29) An apparatus for displaying 3D images and adjusting the exit pupil 45 locations comprising;

An array of light generating elements 13 at pixel S locations;

3D video electronics;

A dynamic screen 40 to generate different light emitting directions from each pixel S controlled by the 3D video electronics;

An actuator coupled with the dynamic screen 40.

30) The apparatus of claim 29 wherein the light sources 13 are LEDs, organic LEDs, fluorescent screen, or LCD panel with backlight.

31) The apparatus of claim 29 wherein the lenticular screen comprising at least one flexible member 41 connected to an actuator to change the pitch of the lenticulars to affect the screen 40 to exit pupil 45 or viewing zone distance for the 3D viewing positions.

32) The apparatus of claim 29 wherein the lenticular screen comprising at least one flexible member 41 connected to an actuator to change the lateral position of the lenticulars to affect the exit pupil 45 or viewing zone locations.

33) The apparatus of claim 29 wherein the actuator comprising a piezoelectric, electrostatic, or electromagnetic means to generate the actuation force.

34) The dynamic lens screen of claimed 29 wherein the actuator is driven to oscillate at the video frame rate multiplied by the number of desired 3D views.

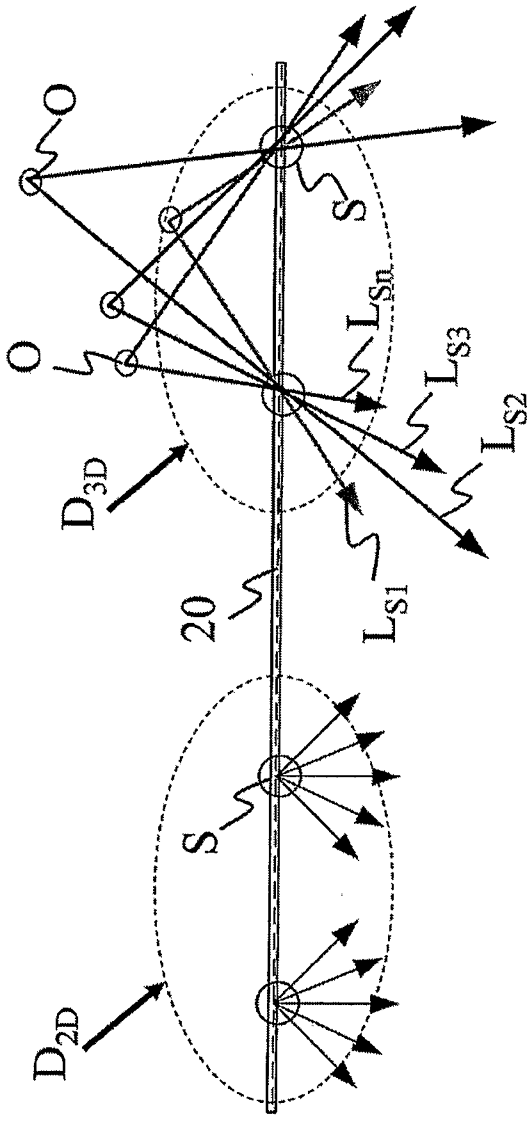


FIGURE 1

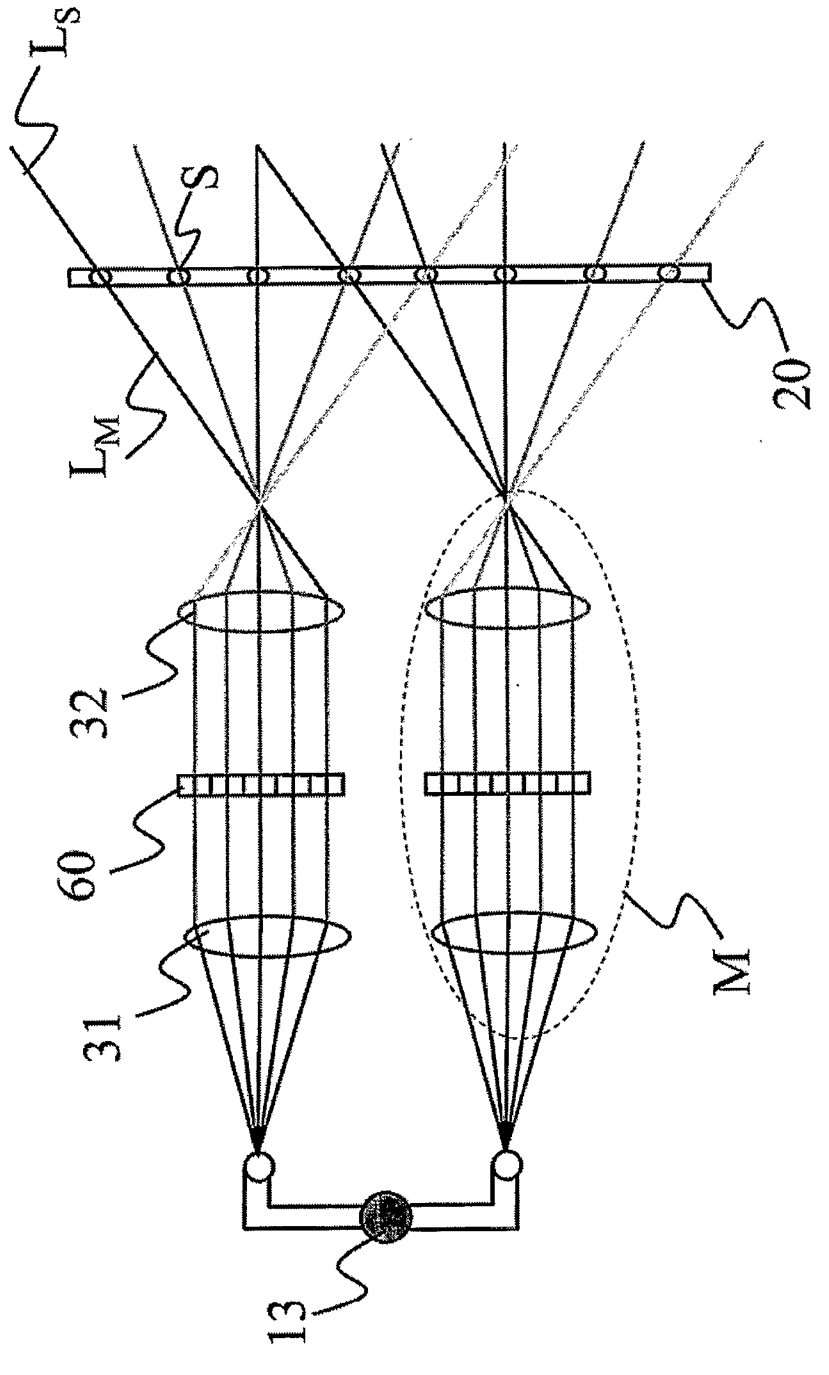


FIGURE 2

FIGURE 3

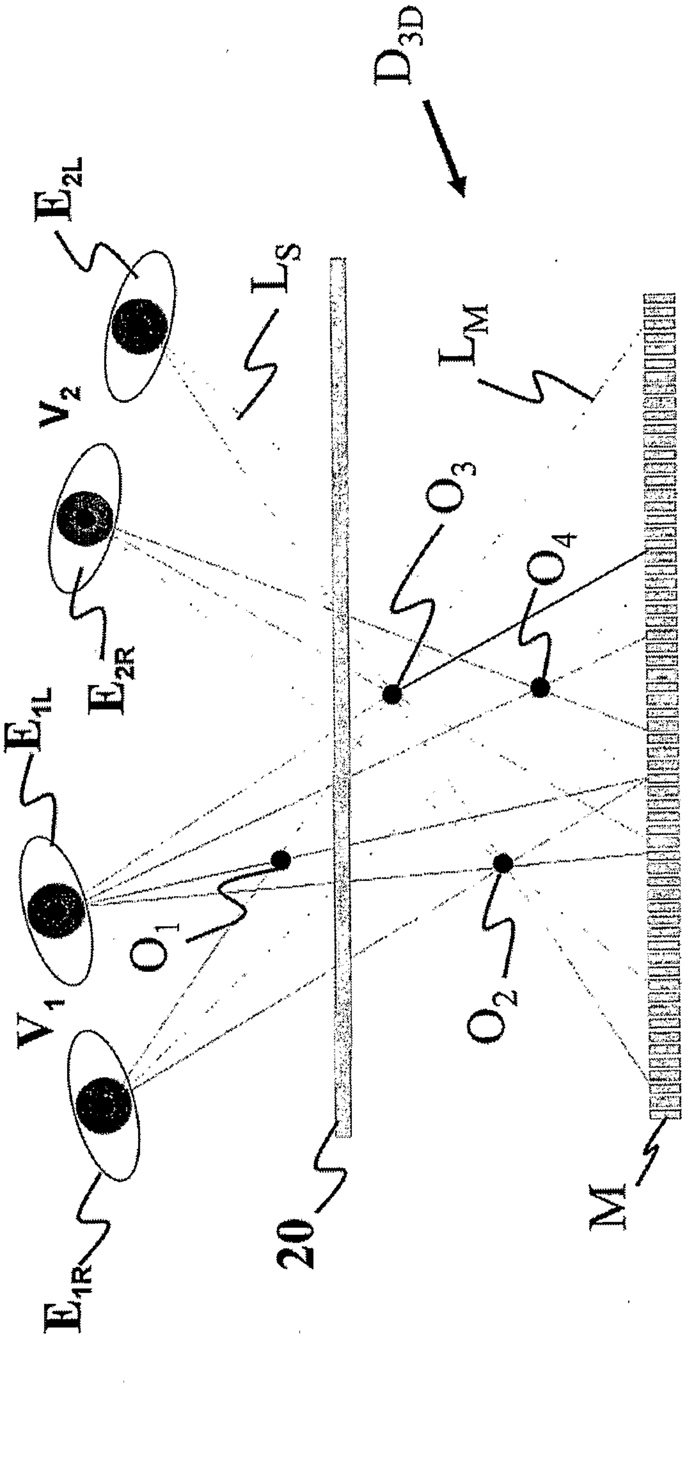
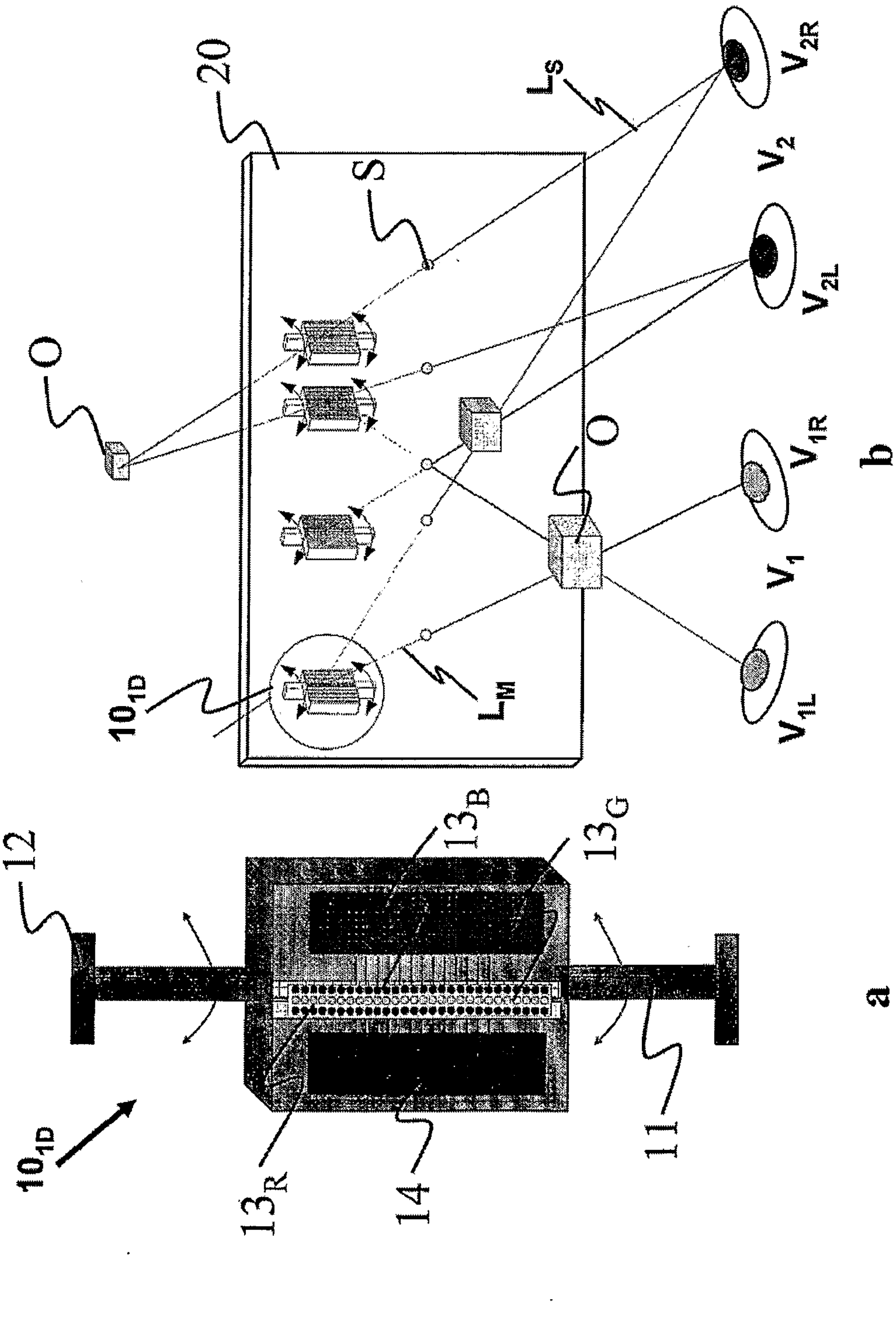


FIGURE 4


10_{1D}
12
13_B
13_G
13_R
14
11
a
20
S
L_S
O
O
V_{2R}
V_2
V_{2L}
V_{1R}
V_1
V_{1L}
L_M
10_{1D}
b

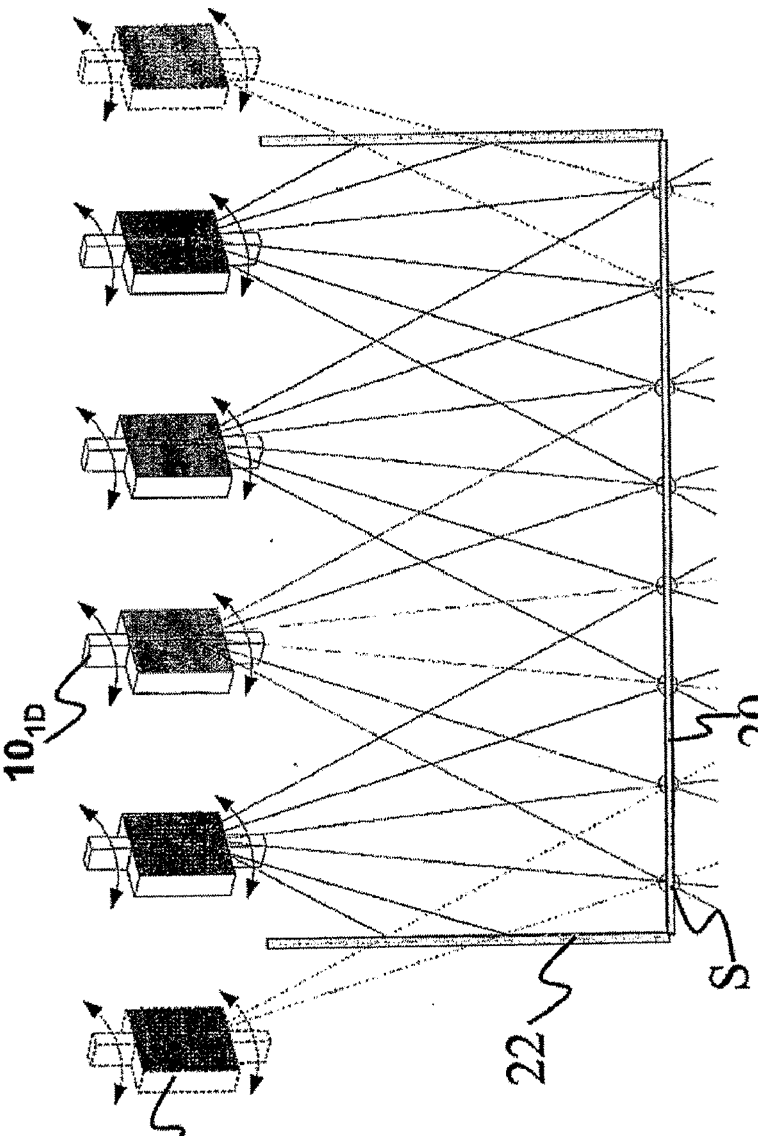


FIGURE 5

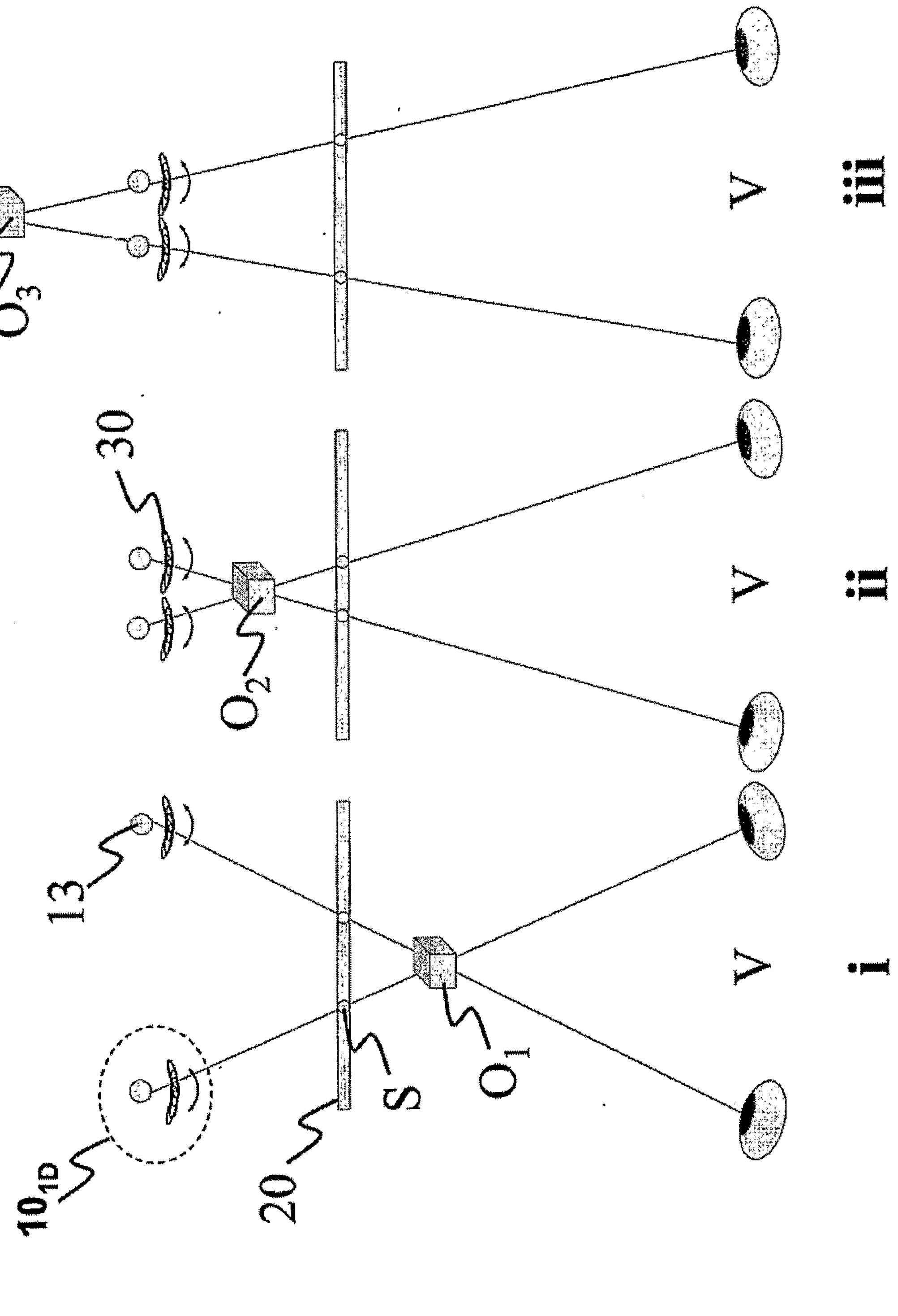
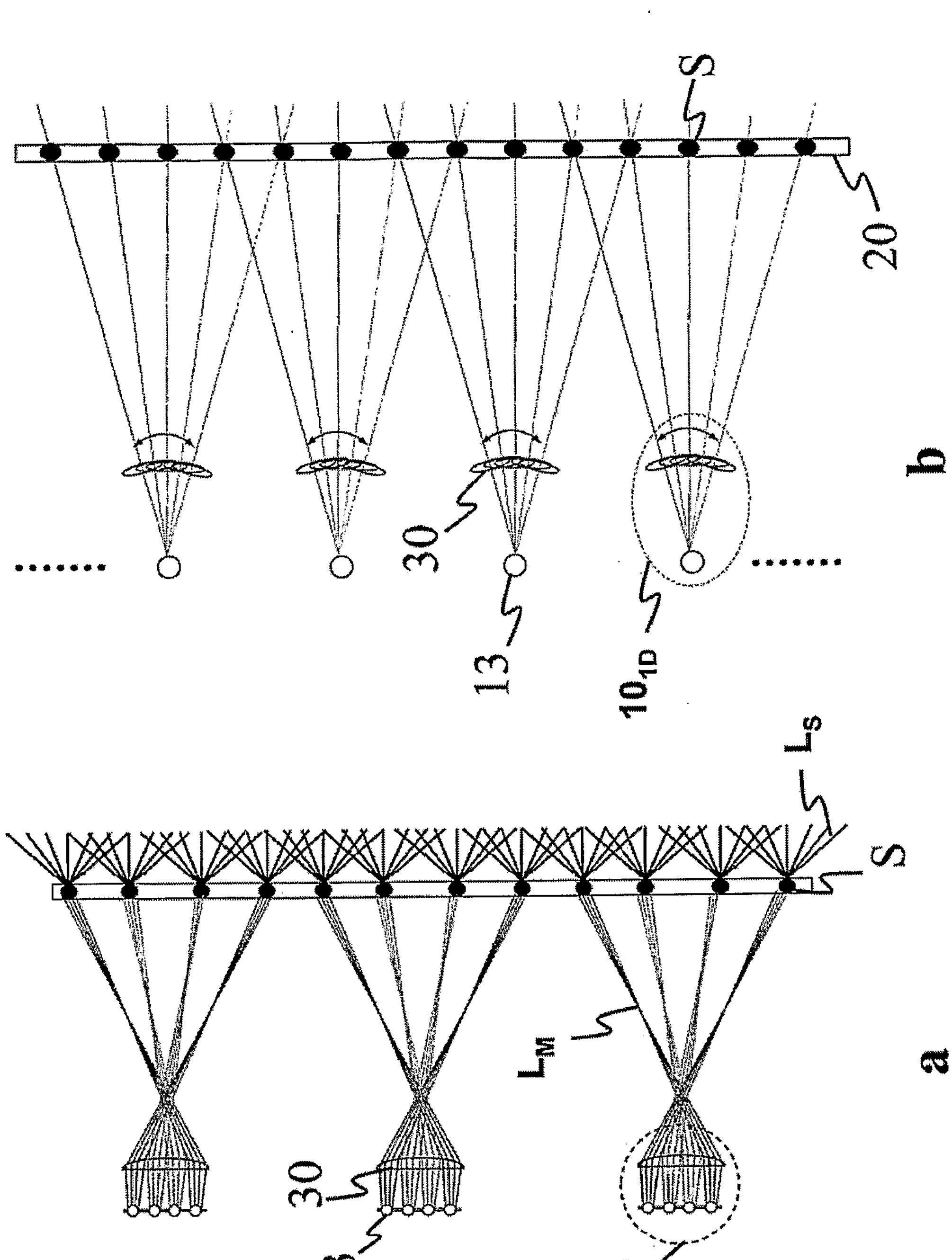


FIGURE 6

FIGURE 7



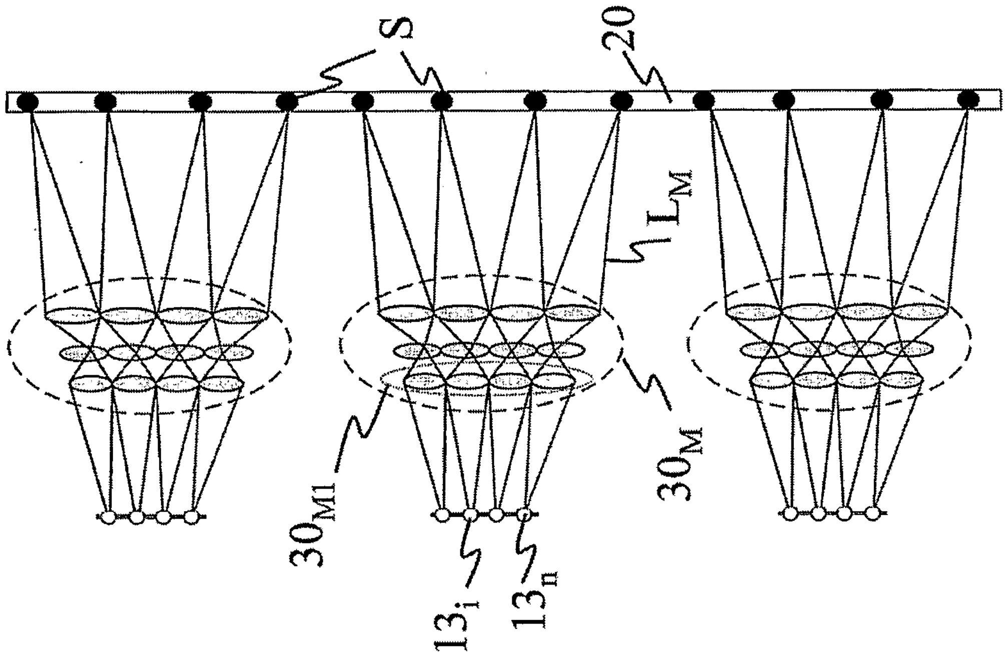


FIGURE 8

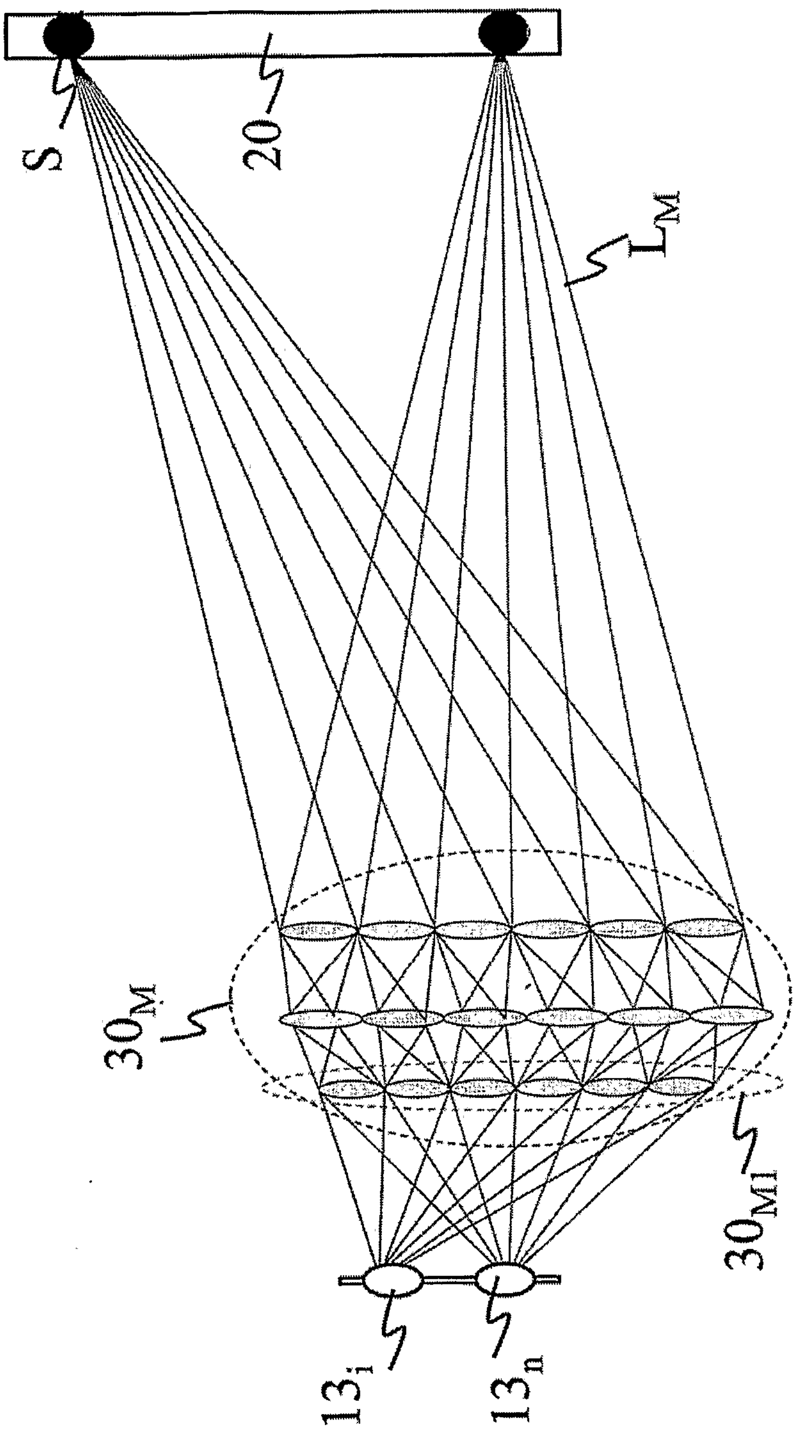


FIGURE 9

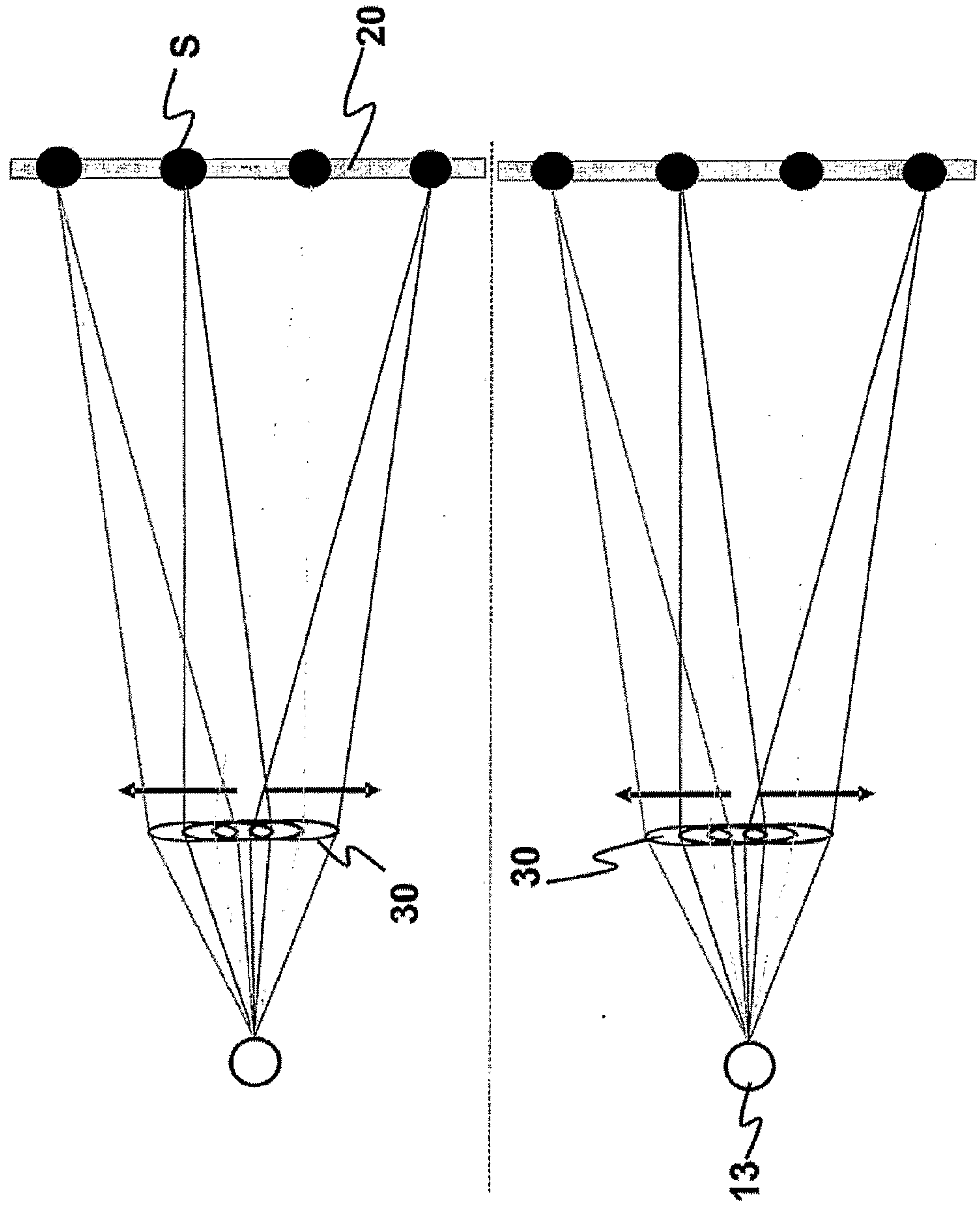


FIGURE 10

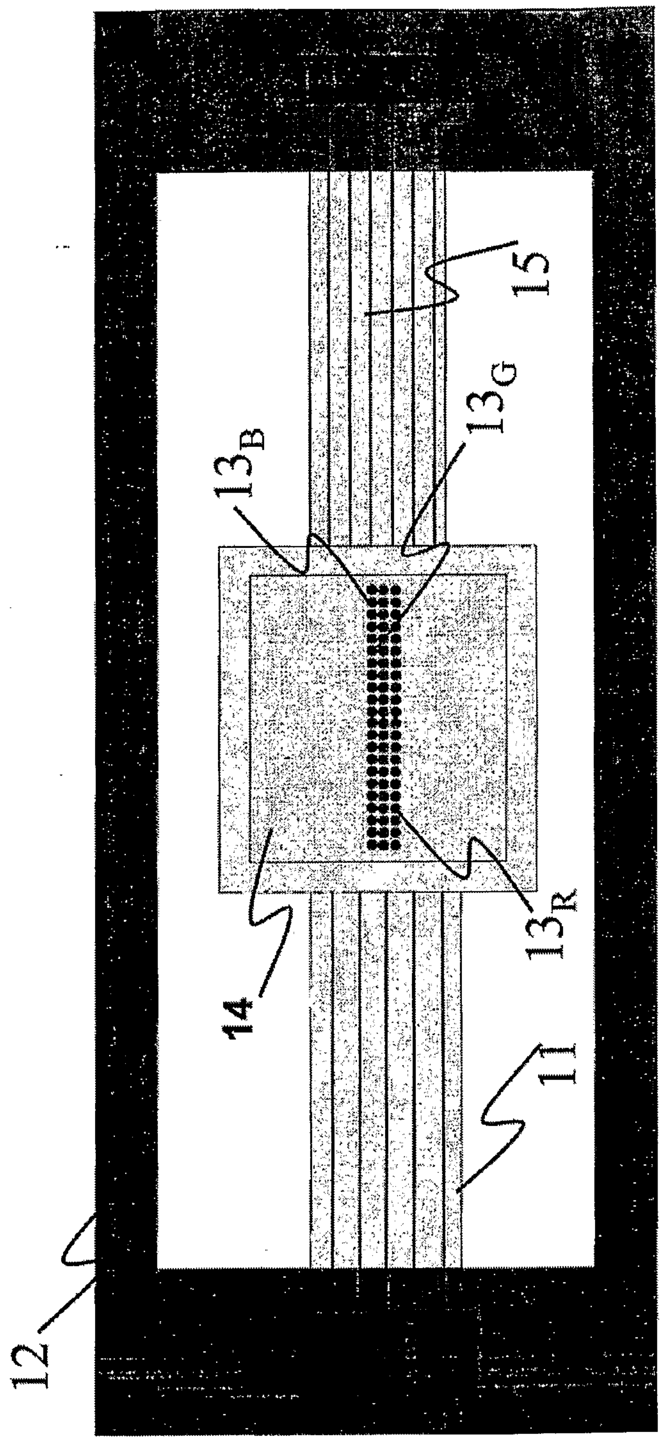


FIGURE 11

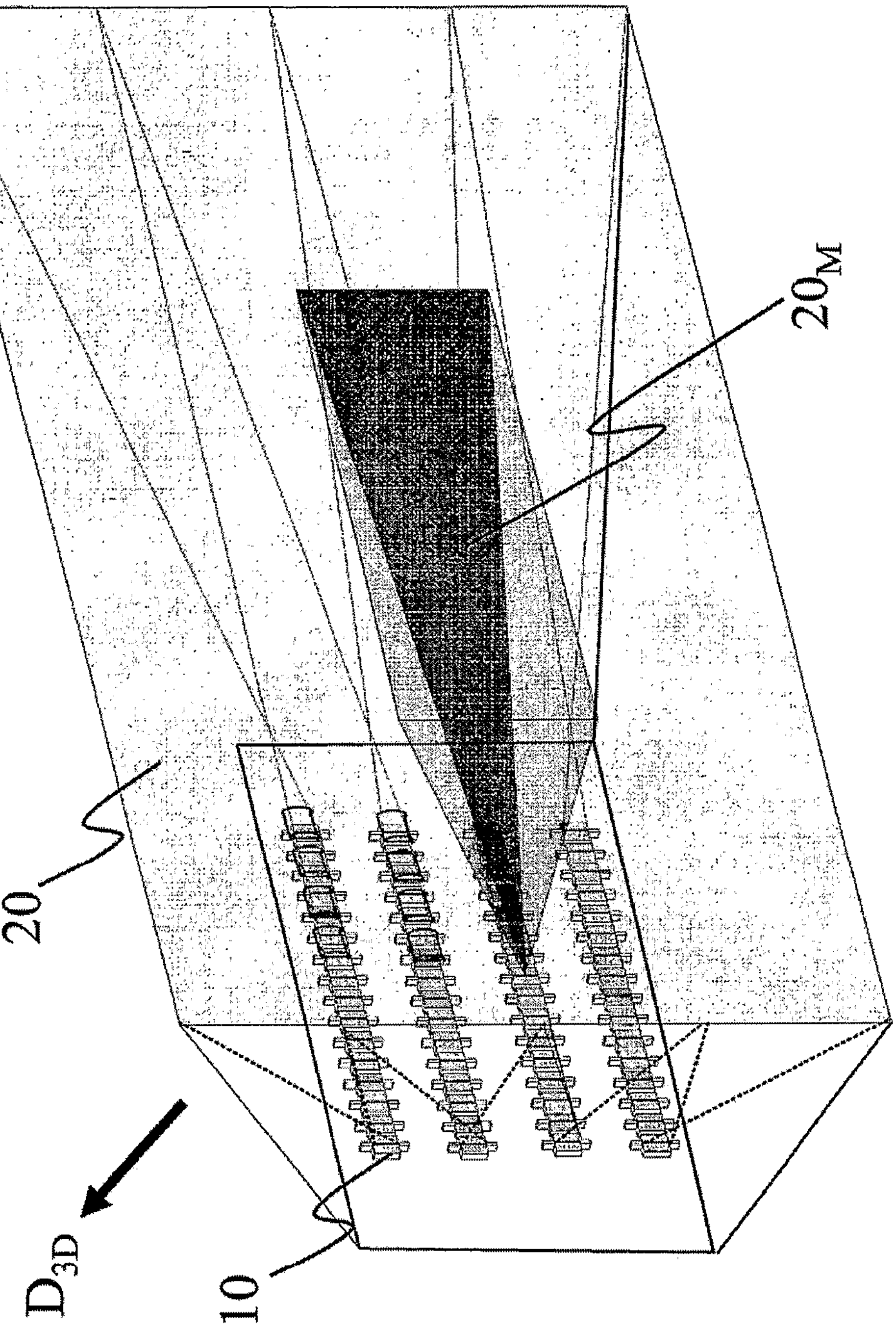


FIGURE 12

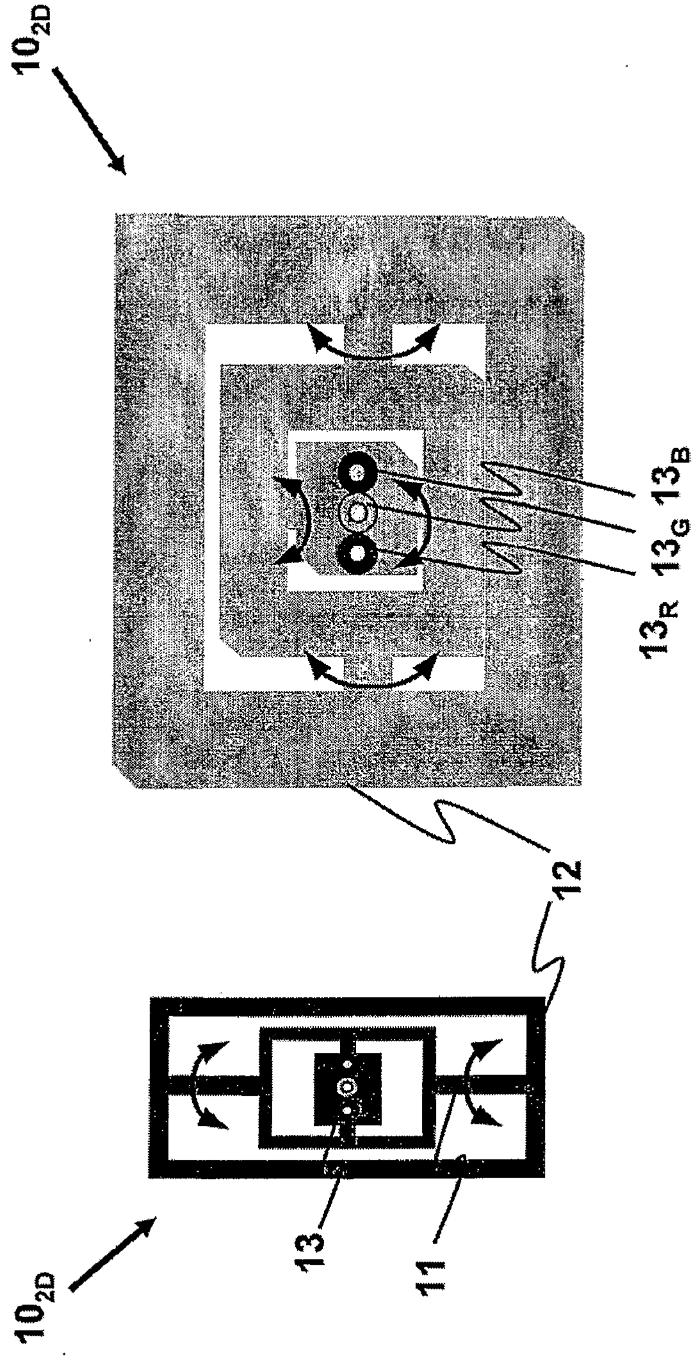


FIGURE 13

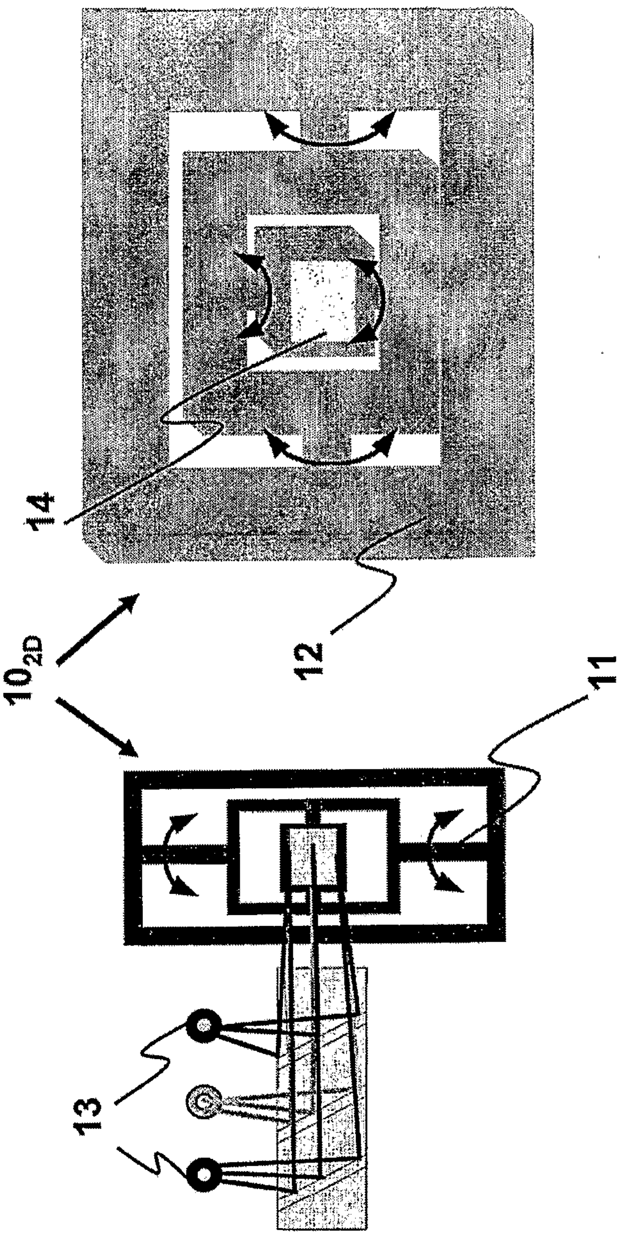


FIGURE 14

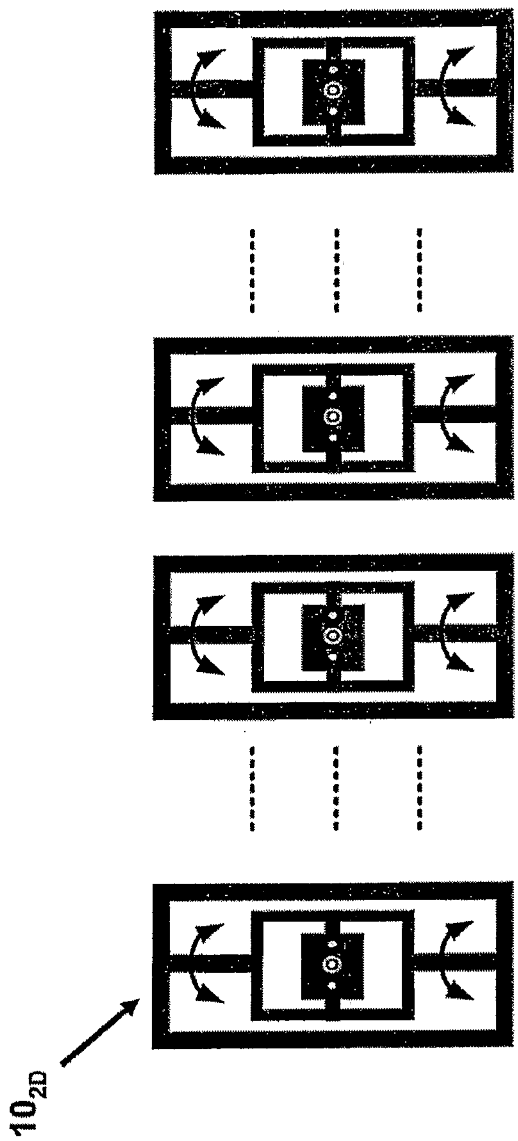


FIGURE 15

FIGURE 16

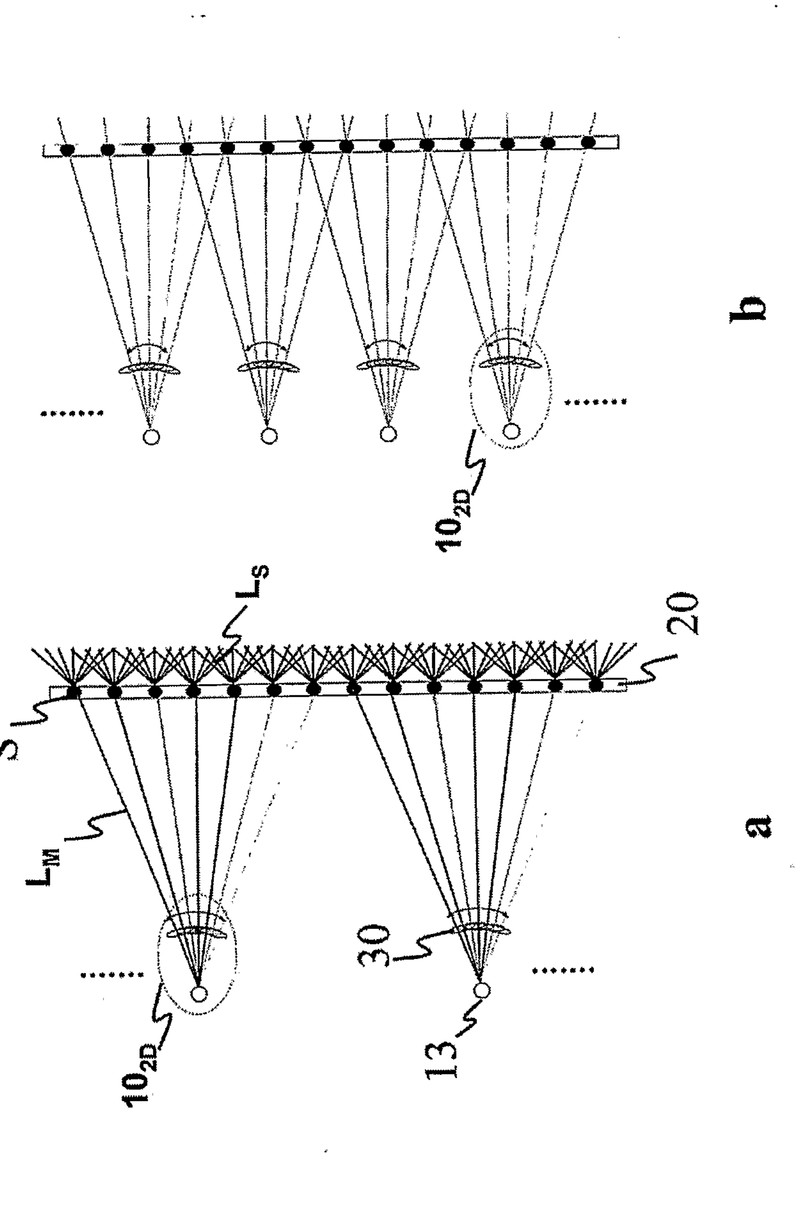


FIGURE 17

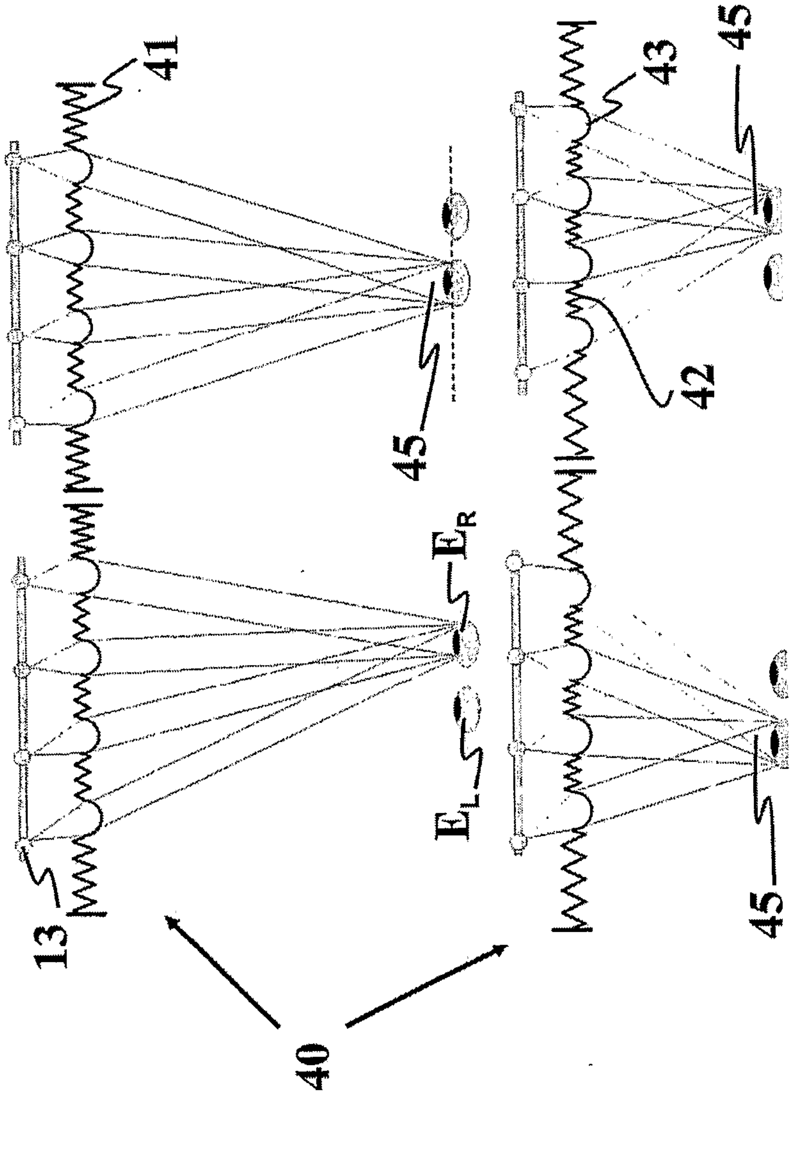
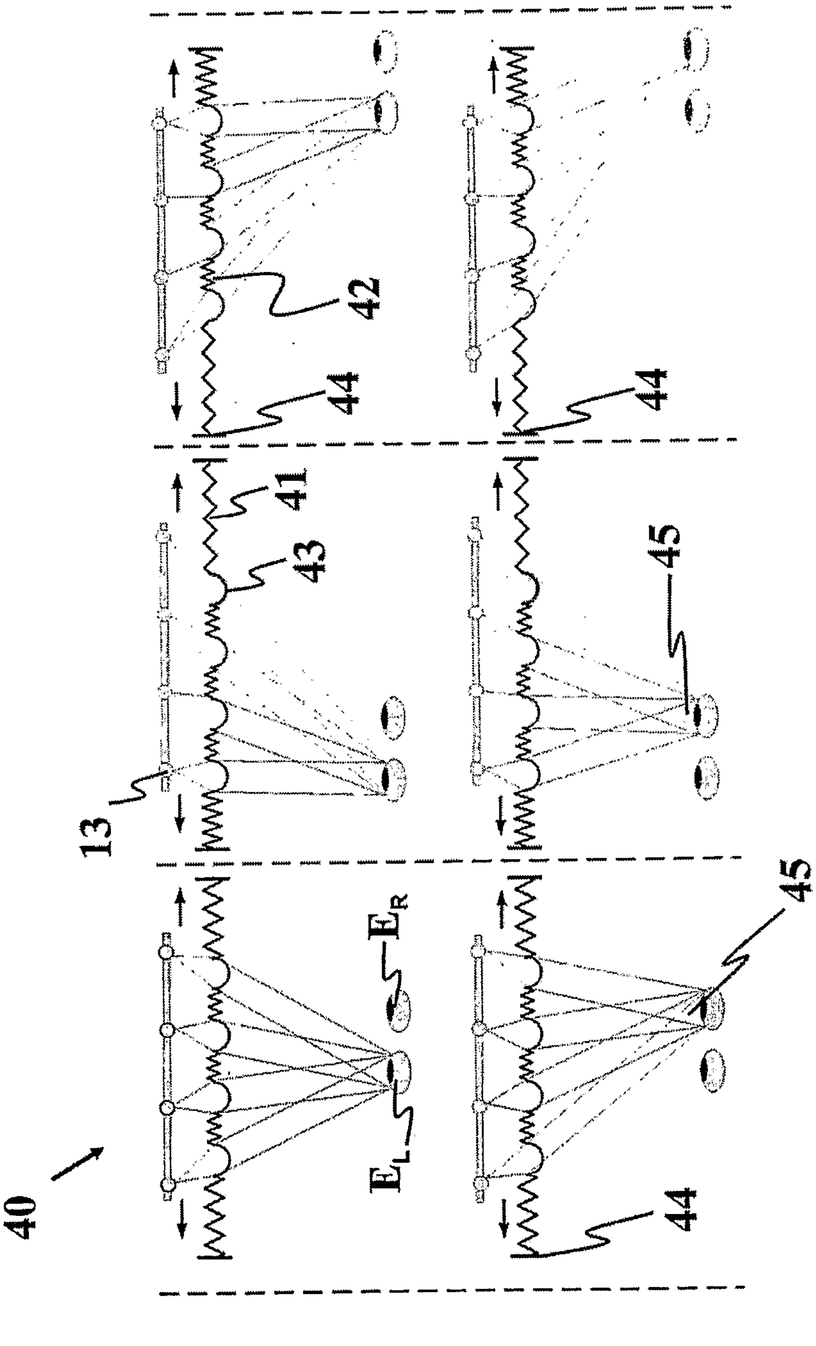


FIGURE 18



INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2008/001140

A. CLASSIFICATION Of SUBJECT MATTER
INV. H04N13/00

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)
H04N G02B

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, wilh indication, where appropriate, of the relevant passages	Relevant to claim No
A	WO 01/88598 A (BALOGH TIBOR [HU])- 22 November 2001 (2001-11-22) cited in the application page 1, lines 4-14 page 3, lines 26-28 page 6, lines 3-5 page 24, lines 13-20 page 41, lines 10-19	1-13

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[X] Further documents are listed In the continuation of Box C

[X] 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 prionty claim(s) or which is cited Io 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	Date of mailing of the international search report
31 March 2009	06/04/2009

Name and mailing address of the ISA'	Authorized officer
European Patent Office, P B 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel (+31-70) 340-2040, Fax (+31-70) 340-3016	Borcea, Veronica

4

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	MURAT SAYINTA ET AL: "Scanning LED Array Based Volumetric Di spl ay" 3DTV CONFERENCE, 2007, IEEE, PI , 1 May 2007 (2007-05-01) , pages 1-4, XP031158202 ISBN: 978-1-4244-0721-7 cited i n the appl icati on page 1, left-hand col umn, paragraph 1 page 2, left-hand col umn, paragraph 3 - right-hand col umn, paragraph 3 figure 3 -----	1-13 14-28
X	EP 0 804 042 A (FUJITSU LTD [JP]) 29 October 1997 (1997-10-29) page 2, l ines 7-12 page 2, l ines 42, 43 page 14, l ines 16-18 page 14, l ine 52 - page 15, l ine 17 figures 40,41 -----	14
Y	UREY H: "Resonant MOEMS scanner design and dynaxnics" OPTICAL MEMS, 2002. CONFERENCE DIGEST. 2002 IEEE/LEOS INTERNATIONAL CO NFERENCE ON 20-23 AUG. 2002, PISCATAWAY, NJ, USA, IEEE, 20 August 2002 (2002-08-20) , pages 83-84, XP010602715 ISBN: 978-0-7803-7595-6 the whole document -----	14-28
X	EP 0 829 743 A (SHARP KK [JP]) 18 March 1998 (1998-03-18) col umn 4, l ine 57 col umn 7, l ine 41 - column 8, l ine 46 figures Ia, Ib, 2 -----	29-34
X	JP 09 185015 A (CANON KK) 15 July 1997 (1997-07-15) abstract -----	29-34
A	UREY H ET AL: "Two-axis MEMS scanner for displ ay and imaging appl ications" OPTICAL MEMS AND THEIR APPLICATIONS CONFERENCE, 2005. IEEE/LEOS INTERN ATIONAL CONFERENCE ON OULU, FINLAND AUG. 1-4, 2005, PISCATAWAY, NJ, USA, IEEE, 1 August 2005 (2005-08-01) , pages 17-18, XP010853225 ISBN: 978-0-7803-9278-6 the whole document -----	1-28

International application No.
PCT/IB2008/001140

INTERNATIONAL SEARCH REPORT

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 additi onal sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers allsearchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an 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 reportcovers 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.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-13

alternative 3D display with horizontal parallax

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2. claims: 14-28

3D display with full parallax

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3. claims: 29-34

3D display with exit pupil location adjustment

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2008/001140

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JP 9185015 A	15-07-1997	NONE	