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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
9 December 2004 (09.12.2004)

PCT

(10) International Publication Number
WO 2004/107751 A1

(51) International Patent Classification[7]: H04N 5/74, 9/31, G02B 26/08

(21) International Application Number: PCT/IB2004/001746

(22) International Filing Date: 28 May 2004 (28.05.2004)

(25) Filing Language: Italian

(26) Publication Language: English

(30) Priority Data:
TO2003A000393 28 May 2003 (28.05.2003) IT

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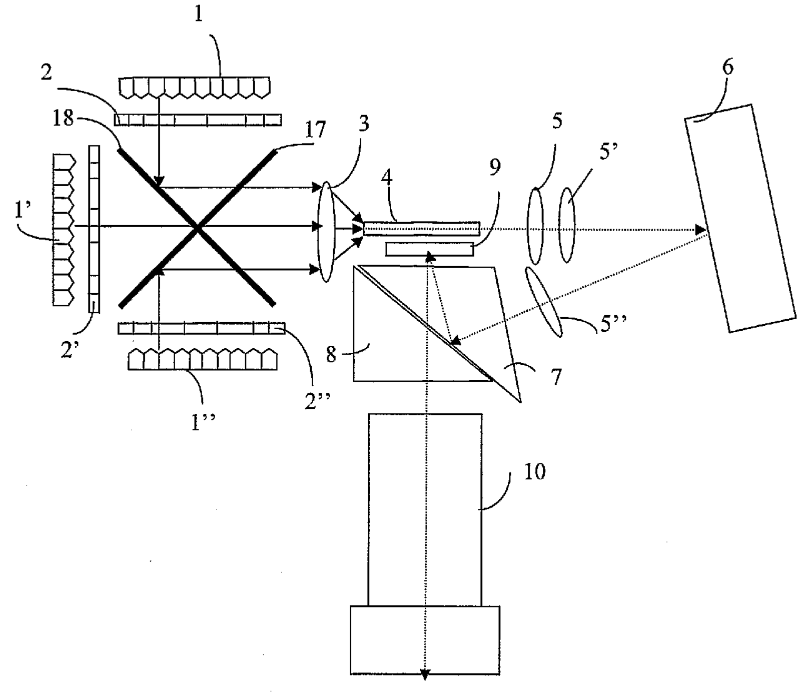
(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, 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, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:
— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designations AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE,*

[Continued on next page]

(54) Title: ILLUMINATION SYSTEM FOR VIDEOPROJECTOR UTILIZING ONE OR MORE LED DIODES MATRICES



(57) Abstract: Illumination system for a videoprojector using a light source is herein described, consisting of at least of LED (Light Emitting Diode) diodes matrix characterized in that, between the diodes matrix and a subsequent focusing system is interlaid a matrix formed with integrating lenses.

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EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW, ARIPO patent (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for the following designation US*

Published:
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

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ILLUMINATION SYSTEM FOR VIDEOPROJECTOR UTILIZING ONE OR MORE LED DIODES MATRICES

DESCRIPTION

The simultaneous use of mechanical miniaturization and technologies peculiar to semiconductors has led to the realization of small electromechanical systems, such as DMD (Digital Micromirror Device), LCD (Liquid Crystal Display), and LCoS (Liquid Crystal on Silicon), which are widely utilized in the manufacture of small size and light weighing videoprojectors, ensuring high quality images.

Briefly, a DMD device or panel consists of a set of small aluminum square mirrors with 16 μm sides, each one forming an element of the image to be projected, i.e. a pixel. The mirrors can rotate around a diagonal; rotation in either direction is produced by two electrodes located under the mirror in opposite positions with respect to axis of rotation. If the mirror is rotated in one direction, the light hitting it is reflected in a way that it does not enter the projection lens, so it is not sent to the screen, i.e. the pixel is "off"; if rotation occurs in the opposite direction the pixel is "on", since the reflected light is sent to the screen.

In LCD and LCoS devices a pixel consists of a layer of liquid crystals enclosed between two plates or electrodes parallel to each other; when a light beam is sent to a plate, the amount of light crossing the layer can be controlled through the voltage applied to the electrodes and with the use of appropriate polarizers. In the "transmission" type devices, usually LCD, both the electrodes are transparent; therefore, the light beam enters a plate, the controlled beam goes out from the other plate and is sent to the screen. In the "reflection" type devices, generally LCoS, one plate is transparent and the other reflecting; therefore, the light beam is sent to the transparent plate, the controlled beam is reflected towards the same plate and sent to the screen.

The pixel set forms the active surface of the panel, on which the image to be projected is formed.

According to the brightness and screen size being requested, a videoprojector can use one or more devices, obviously of the same type.

The choice of the illumination system is particularly important with reference to the performance and reliability of a videoprojector.

Arc lamps are normally used, which release a high light intensity, though they have a few non irrelevant drawbacks. First of all, the average life of a lamp is rather short, requiring frequent interventions of the Service Assistance and a consequent financial cost for the user. Moreover, the lamp produces considerable heat inside the videoprojector (usually over 100 W), so an adequate cooling system is needed to avoid jeopardizing the product reliability. Other drawbacks caused by the lamps are the crystallization phenomena impairing the light flow quality, and the so-called arc-jump, which may cause flickering of the image. Finally, as known, in the videoprojectors using one device alone, either DMD, LCD or LCoS, the primary colors are obtained filtering the light emitted by the lamp with the color wheel, which is often a source of annoying noise caused by the motor actuating the wheel, and above all reduces the system brightness.

In order to obviate to the above drawbacks, a light source consisting of one or more LED (Light Emitting Diode) diodes matrixes has been proposed; this solution removes all the above drawbacks; in particular, the average life of the LED diodes estimated in about 100.000 hours, is considerably longer than the life of a lamp. Moreover, the light radiation of the LED diodes has a wider color triangle than that obtained through a standard arc lamp with associated color wheel; therefore, when using one device alone, the chromatic result is better, i.e. several color tones can be reproduced.

However, since the diodes emission does not occur uniformly within the emitting angle (intensity is maximum in the middle and decreasing towards the ends) and, additionally, empty spaces forcedly exist between the diodes, the beam emitted by a matrix is not homogeneous; this entails a considerable light reduction, which is not acceptable, particularly when the videoprojectors have to be manufactured for large screens.

It is the object to the present invention to provide an illumination system with LED diodes, which obviates to the above drawbacks and ensures the manufacture of high reliability and long duration videoprojectors, which, at the same time, are capable of reaching high performances.

In order to reach such aims it is the object of the present invention to provide an optic system of illumination incorporating the features described in the annexed claims, which form an integral part of the description herein.

Further objects and advantages of the present invention will become apparent from the following detailed description and annexed drawings, which are supplied by way of non limiting example, wherein:

- Fig. 1 shows a first embodiment of an illumination system according to the invention;
- Fig. 2 shows a few details of the illumination system according to the invention;
- Fig.3 shows a second embodiment of an illumination system according to the invention;
- Fig. 4 shows a third embodiment of an illumination system according to the invention.

The blocks indicating the same reference number in the various figures perform the same function.

Figure 1 is representing an illumination system according to the present invention, wherein the videoprojector uses one DMD device alone; however, the present invention can be also applied for applications using LCD or LcoS devices. The blocks identified with reference 1, 1' and 1'' represent a top view of three different bi-dimensional matrixes, each one of them with LED diodes having the same primary color: for instance, matrix 1 consists of LED diodes emitting red color light, matrix 1' has LED diodes emitting green color light and matrix 1'' LED diodes emitting blue color light.

In order to ensure an even and efficient collection of the light produced by the matrixes and obtain a homogeneous parallel light beam, three integrating systems are used, each one for each matrix, as represented in Figure 1 with reference numbers 2, 2' and 2''. An integrator is formed by a set of small rectangular integrating lenses, each one facing a corresponding matrix diode, as schematically illustrated in Figure 2 illustrating the matrix 1 and to the associated integrating system 2. In particular, Figure 2a) illustrates a side view of the matrix 1 and integrator 2; Figure 2b) illustrates a front view of some diodes of matrix 1; Figure 2c) illustrates a front view of some integrating lenses forming the integrator 2, and Figure 2d) illustrates a front view of the diodes matrix 1 and integrator 2 as a whole. Obviously, the representation of Figure 2 applies to the matrixes 1' and 1'' and integrators 2' and 2'', too. Each integrator lens has a focal distance equaling the distance that separates it from the associated LED; in order to optimise the illumination, it is preferable to use rectangular integrating lenses, wherein the ratio between the greater side and the minor side equal the ratio of the relevant sides of the device employed, in this case of the DMD; therefore, the preferred values of such a ratio will be 4:3 or 16:9.

The light emitted by the diodes of the three matrixes 1, 1' and 1'' is collected by the corresponding integrating systems 2, 2' and 2'', which have at their outlet three homogeneous parallel light beams meeting a pair of dichroic filters, 17 and 18, crossed at 90°. The choice of the dichroic filters 17 and 18 occurs in such a way to send the three monochromatic beams at the output of the integrating systems 2, 2' and 2'' in one sole direction. In the instance of Figure 1, both filters let the color of the parallel light beam at the output of matrix 1' go through, e.g. green, whereas the filter 17 reflects the color of the parallel light beam at the output of matrix 2'', e.g. blue, letting the color of the parallel light beam at the output of matrix 2 go through, e.g. red. The filter 18 reflects the color of the parallel light beam at the output of matrix 2, e.g. red, letting the color of the parallel light beam at the output of matrix 2'' go through, e.g. blue. Based on this filters selection, the parallel light beam at the output of matrix 2' will continue straight on through the two dichroic filters 17 and 18 and reach the aspheric condenser 3, while the parallel light beams at the output of the other two matrixes 2 and 2'' are reflected by the first dichroic filter they meet, 18 and 17 respectively, so the reflected beam is parallel to the light beam at the output of matrix 2'.

The three light beams are collected by the aspheric condenser 3 which focuses the light at the inlet of integrating bar 4, consisting of an optic glass parallelepiped, which uniforms the light beam at the output of the condenser.

The light at the output of the integrating bar is collected by a lens and mirror system, which, in the case under test, has 3 convergent lenses known as relay lens, indicated with references 5, 5' and 5'', and a mirror indicated with reference 6. Theses lenses convey the light towards the DMD device, indicated with reference 9, whereon a focused image is being formed, which appears enlarged with respect to the image at the output of the integrating bar. The optical path from the integrating bar to the device 9, indicated in the figure by dotted lines and arrows, undergoes 2 deflections: a first deflection due to a reflecting surface, in this case the mirror 6, and a second deflection due to the prism indicated with the reference number 7. This prism, which conveys the light beam towards the DMD device, is of the kind known as TIR (Total Internal Reflection), therefore it has the property of reflecting, like a mirror, all the incident light beams having an angle typical of the chosen prism. The light beam reflected by the DMD device goes through the prism 7 without being reflected, since the incidence angle between the light beam and the prism walls is such to avoid a reflection of said beam. Since the beam reflected by the DMD device is in reality a set of beams originated by the LED's of the activated matrix, each one of these beams follows slightly different paths with consequent delays between the single beams; in order to correct these delays, a prism indicated with reference number 8 is interlaid between the prism 7 and the projection lens indicated with reference number 10, which projects the image on a screen not shown in Figure 1.

The three diodes matrixes 1, 1' and 1'' turn on and off in a sequential mode, so every instant only one matrix is activated and the light beams corresponding to the three primary colors are sequentially sent to the DMD; thus, the color wheel is no longer necessary while the optic system acquires a higher efficiency; as a result, for a contrast equal to that of illumination systems with lamp, a lower brilliancy of the light source, i.e. of the LED diodes, is required. For instance, using LED diodes with a light intensity of 7 cd for red, 10 cd for green and 3 cd for blue, a good illumination is obtained through the adoption of 240 LED circular matrixes, with a total consumption of about 43 W for all three matrixes. As a result, a considerable brilliancy is obtained with a low amount of heat dissipated inside the videoprojector.

Figure 3 is representing an illumination system according to the present invention, in case of a videoprojector with three DMD devices, indicated with reference numbers 9, 9' and 9''. In this configuration, the three diodes matrixes 1, 1' and 1'' are always on and the aspheric condenser 3 is reached by a light beam consisting of the three primary colors. In order to obtain colored images, a set of prisms, indicated with reference 19, splits the light beam in the three primary components which are sent to the relevant DMD devices, and resets the beams reflected by the DMD devices in one sole light beam that is sent to the projection lens 10 through the prisms 7 and 8.

The present invention can be applied to videoprojectors for both front and rear projection following some simple arrangements known to the man skilled in the technical branch.

It is clear that many changes can be made to the illumination system according to the present invention without exiting from the novelty principles of the inventive idea.

In those instances, where the videoprojector is not requested to emit a very high brilliancy, one device alone can be used, such as a DMD illuminated by one LED diodes matrix emitting a white light with a relevant integrating system, as shown in the Figure 4 with reference 1''' and reference 2''', respectively. A white light LED matrix consists of a set of triads, each one of them formed by three LED diodes corresponding to the three primary colors, red, green and blue, which can be activated separately. Therefore, the color image is obtained activating the triad diodes in sequence, such as lighting first the diodes with green light, then the ones with red light and, finally, the ones with blue light. Thus, the device is reached sequentially by three monochromatic light beams corresponding to the three primary colors.

CLAIMS

1. An illumination system for videoprojector using a light source, which consists of at least a LED (Light Emitting Diode) diodes matrix, characterized in that a matrix formed with integrating lenses is interlaid between the diodes matrix and a subsequent focusing system.

2. An illumination system for videoprojector according to claim 1, characterized in that each matrix diode is associated to an integrating lens.

3. An illumination system for videoprojector according to claim 2, characterized in that said integrating lens has a focal distance substantially equal to the distance separating said integrating lens from said associated diode.

4. An illumination system for videoprojector according to claim 1, characterized in that said videoprojector uses at least a DMD device (Digital Micromirror Device).

5. An illumination system for videoprojector according to claim 1, characterized in that said videoprojector uses three DMD devices (Digital Micromirror Device).

6. An illumination system for videoprojector according to claim 1, characterized in that said videoprojector uses at least an LCD device (Liquid Crystal Device).

7. An illumination system for videoprojector according to claim 1, characterized in that said videoprojector uses three LCD devices (Liquid Crystal Device).

8. An illumination system for videoprojector according to claim 1, characterized in that said videoprojector uses at least an LcoS device (Liquid Crystal on Silicon).

9. An illumination system for videoprojector according to claim 1, characterized in that said videoprojector uses three LcoS devices (Liquid Crystal on Silicon).

10. An illumination system for videoprojector according to one of the claims 3 to 9, characterized in that the ratio between the sides of said integrating lens equals the ratio between the sides of the active surface of the used device.

11. An illumination system for videoprojector according to claim 10, characterized in that said ratio between the sides is 4:3.

12. An illumination system for videoprojector according to claim 9, characterized in that said ratio between the sides is 16:9.

13. An illumination system for videoprojector according to claim 1, characterized in that it employs three diode matrixes.

14. An illumination system for videoprojector according to claim 13, characterized in that each matrix emits a light beam corresponding to a primary color (RGB).

15. An illumination system for videoprojector according to claim 13, characterized in that said light beams emitted by said diodes matrixes and integrated by corresponding lenses hit two dichroic filters placed substantially at 90 degrees.

16. An illumination system for videoprojector according to claim 1, characterized in that it uses at least a diodes matrix capable of emitting white light.

17. An illumination system for videoprojector according to claim 16, characterized in that said matrix consists of a plurality of triads, each one comprising three LED diodes, each diode emitting a light beam corresponding to a different primary color.

18. An illumination system for videoprojector according to claim 17, characterized in that said diodes of each triad can be activated one by one.

19. An illumination system for videoprojector according to claim 17, characterized in that each triad is associated to an integrating lens.

20. An illumination system for videoprojector according to claim 1, characterized in that said videoprojector is used to perform a front projection.

21. An illumination system for videoprojector according to claim 1, characterized in that said videoprojector operates in rear projection.

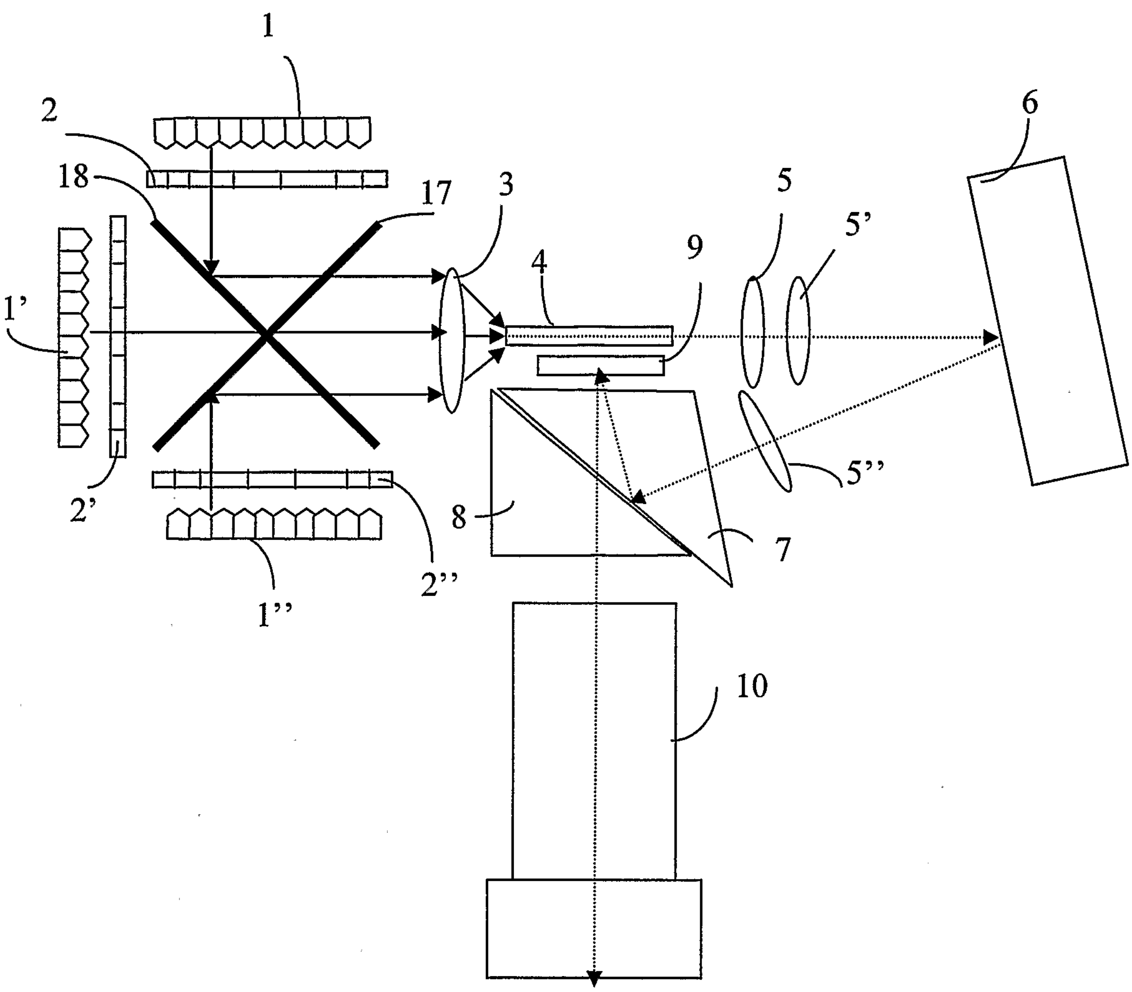

Fig. 1

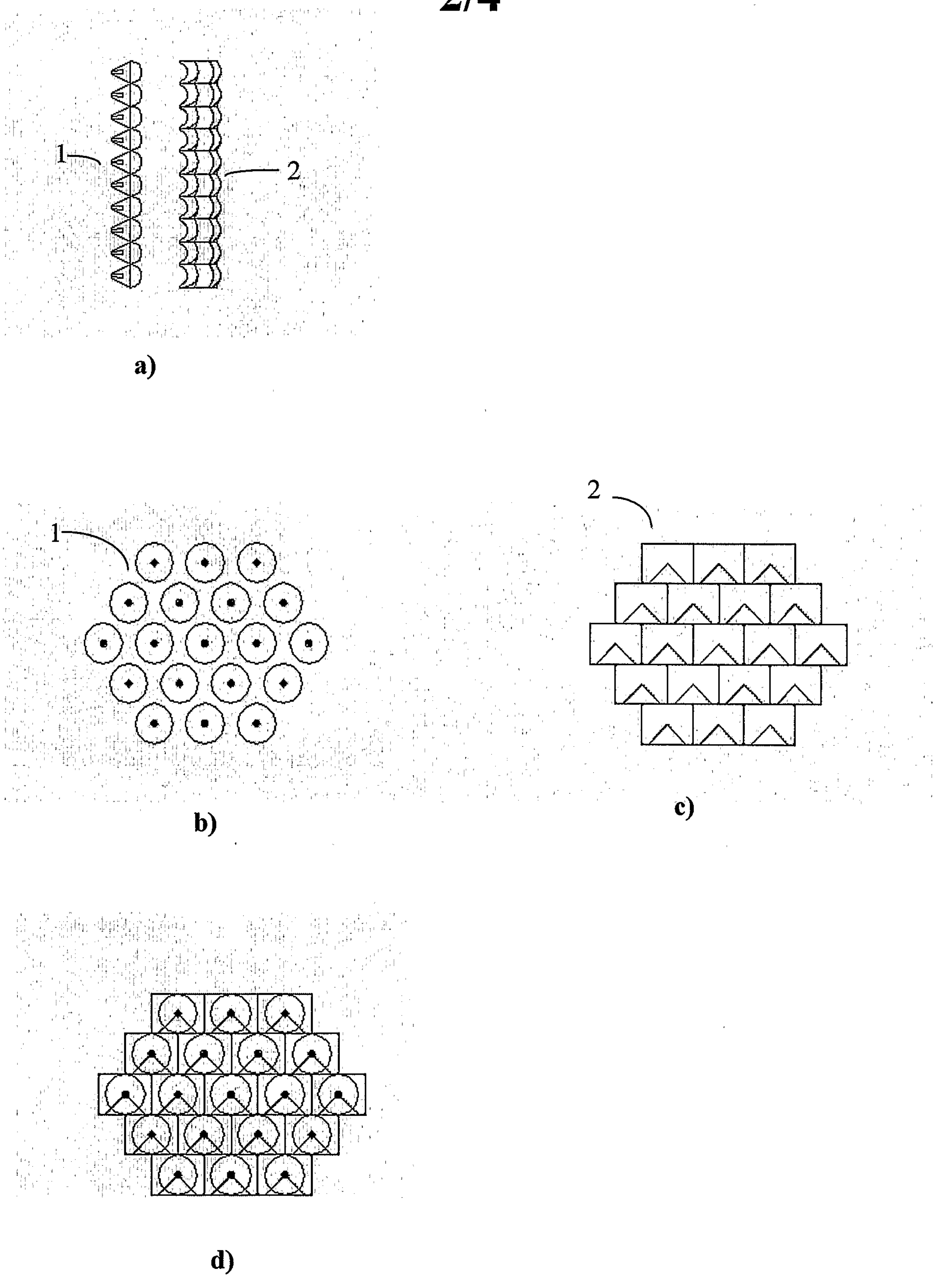

Fig. 2

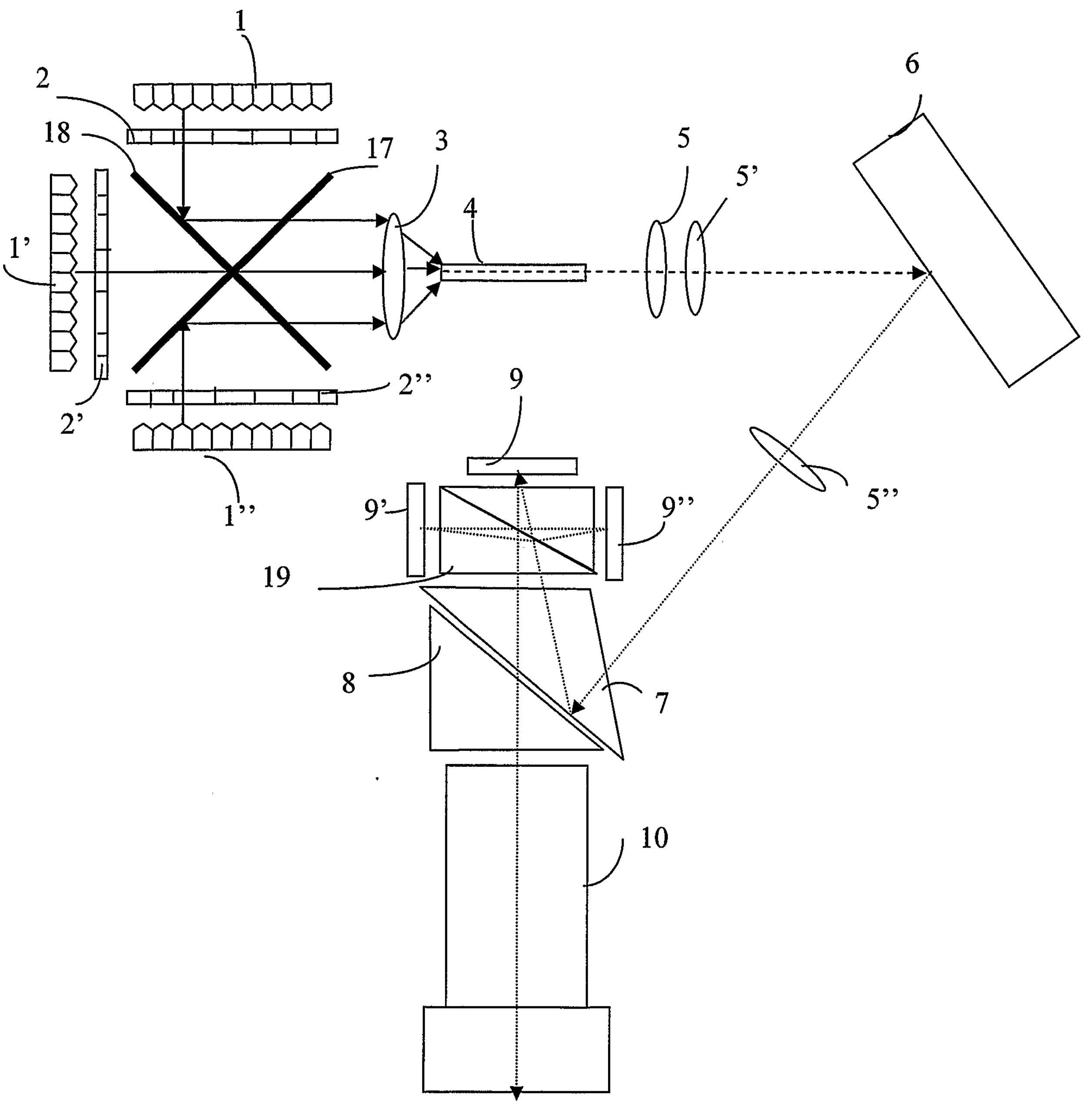

Fig. 3

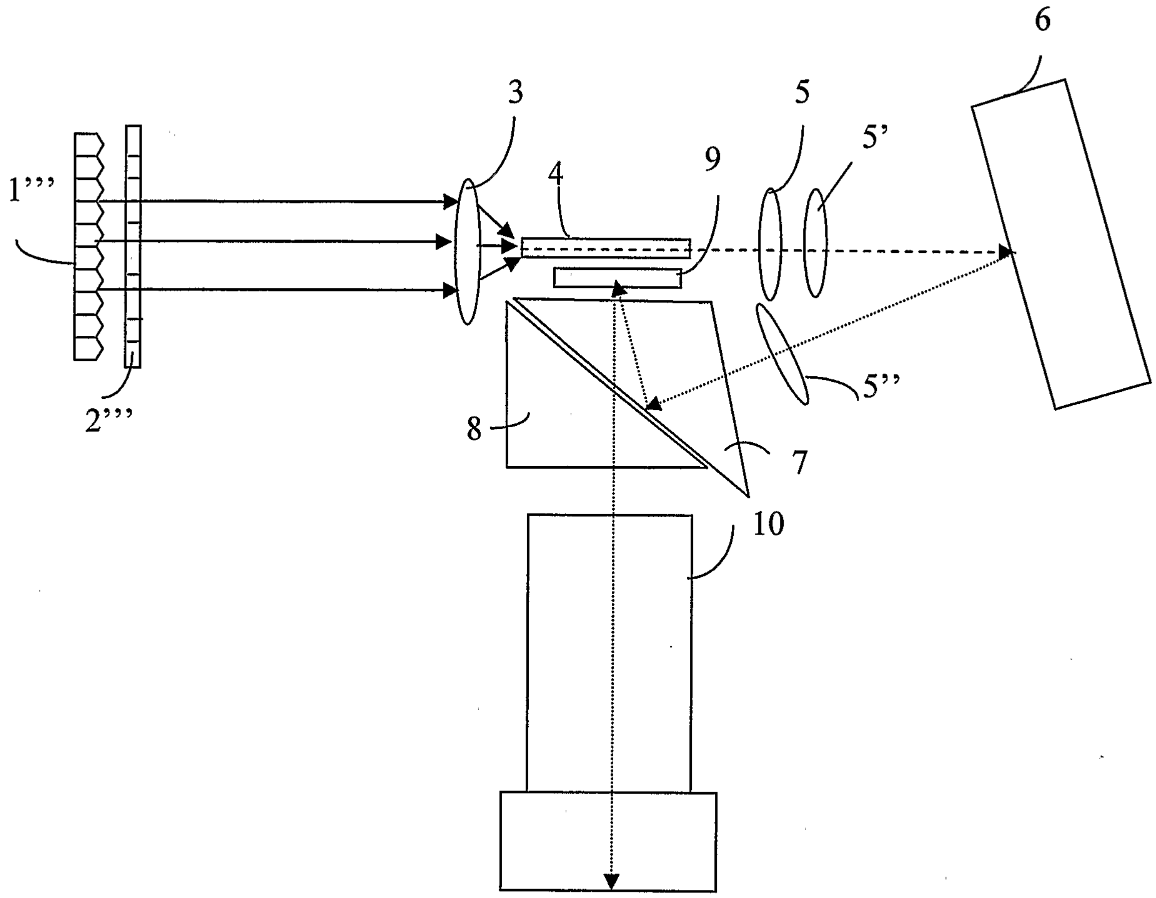

Fig. 4

INTERNATIONAL SEARCH REPORT

ional Application No
IB2004/001746

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04N5/74 H04N9/31 G02B26/08

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)
IPC 7 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, WPI Data, PAJ, COMPENDEX, IBM-TDB, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	EP 0 985 952 A (MITSUBISHI ELECTRIC CORP) 15 March 2000 (2000-03-15) abstract; figures 1-15 paragraphs '0042! - '0091!	1-9,13, 14 10-12, 15-21
Y	US 6 224 216 B1 (PARKER FRED ET AL) 1 May 2001 (2001-05-01) column 2, lines 32-67; figures 3,4,8,9 column 4, lines 11-67 column 8, lines 39-56	10-12, 15-21
Y	US 2003/086148 A1 (NAITO KEIJIRO) 8 May 2003 (2003-05-08) paragraphs '0005! - '0007!, '0017! - '0021!, '0039! - '0041!, '0044! - '0054!; figures 1,4-6	10-12, 15-21

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
28 September 2004	05/10/2004

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IB2004/001746

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 504 514 A (NELSON WILLIAM E) 2 April 1996 (1996-04-02) column 3, lines 26-30; figures 6,8,10 column 5, line 55 - column 8, line 29 -----	1-21

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Information on patent family members

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