(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 960 892 A1

(12) EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:
30.12.2015 Bulletin 2015/53

(21) Application number: **13875666.3**

(22) Date of filing: **20.02.2013**

(51) Int Cl.:
G09G 3/02 *(2006.01)*

(86) International application number:
PCT/JP2013/054183

(87) International publication number:
WO 2014/128865 (28.08.2014 Gazette 2014/35)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

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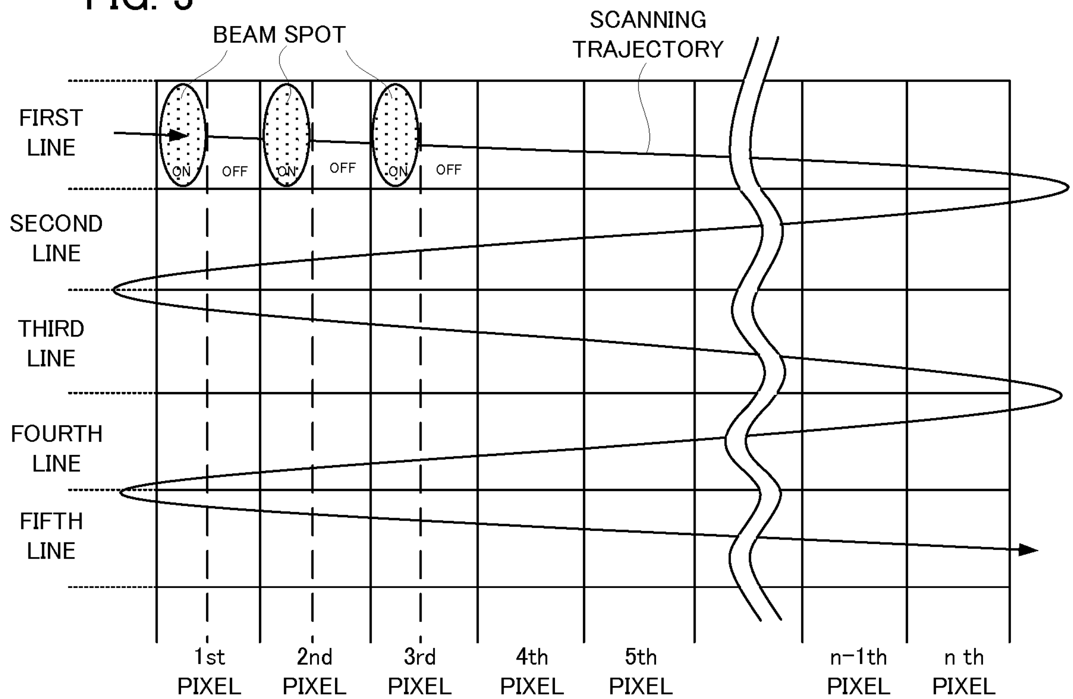
(54) IMAGE DISPLAY DEVICE

(57) An image display apparatus (1) is configured to display an image due to optical scanning by driving a mirror, which reflects a light beam irradiated from a light source (14, 15), in each of a main scanning direction and a sub scanning direction, which crosses the main scanning direction. The image display apparatus is provided with: a controlling device (13) configured to control the light source to change an irradiation period of the light beam with respect to a pixel drawing period, which is a period for drawing each of a plurality of pixel data corresponding to the image to be displayed, on the basis of luminance of a one-frame image to be displayed.

FIG. 3



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Description

Technical Field

[0001] The present invention relates to an image display apparatus configured to draw a projection image, for example, by driving a mirror, which reflects laser light, in each of a horizontal direction and a vertical direction.

Background Art

[0002] In this type of apparatus, if average luminance of a one-frame image to be drawn is reduced, output of a light source such as, for example, a laser source is reduced (i.e. a drive current supplied to the light source is reduced) according to a reduction width in many cases. Depending on the type of the laser source, however, as the drive current is reduced, linearity of a light output characteristic (or I-L characteristic) with respect to the drive current is possibly deteriorated. Then, for example, if an image with luminance slightly varying with time is drawn, a change in luminance of the drawn image increases more than expected, and flickering possibly occurs in a relatively low luminance region in the drawn image, which is technically problematic.

[0003] With respect to the technical problem, there is proposed a technology in which, for example, an acousto-optic modulator (AOM) is used to adjust light intensity without reducing the output of the laser source (refer to Patent Literature 1).

Citation List

Patent Literature

[0004] Patent Literature 1: Japanese Patent Application Laid Open No. H6-61562

Summary of Invention

Technical Problem

[0005] According to the technology described in the Patent Literature 1 described above, however, it is necessary to separately provide an element to adjust the light intensity. Thus, there are such technical problems as an increase in manufacturing cost and the complication of a structure and a control process.

[0006] In view of the aforementioned problems, it is therefore an object of the present invention to provide an image display apparatus configured to relatively easily suppress image flickering.

Solution to Problem

[0007] The above object of the present invention can be achieved by a first image display apparatus configured to display an image due to optical scanning by driving a mirror, which reflects a light beam irradiated from a light source, in each of a main scanning direction and a sub scanning direction, which crosses the main scanning direction, said image display apparatus is provided with: a controlling device configured to control the light source to change an irradiation period of the light beam with respect to a pixel drawing period, which is a period for drawing each of a plurality of pixel data corresponding to the image to be displayed, on the basis of luminance of the entire image to be displayed.

[0008] The above object of the present invention can be achieved by a second image display apparatus configured to display an image due to optical scanning by driving a mirror, which reflects a light beam irradiated from a light source, in each of a main scanning direction and a sub scanning direction, which crosses the main scanning direction, said image display apparatus is provided with: a controlling device configured to control the light source to make an irradiation period of the light beam to a pixel drawing period, which is a period for drawing one of a plurality of pixel data corresponding to the image to be displayed, 1/n of the pixel drawing period, if the one pixel data has 1/n of maximum luminance, wherein n is a positive real number.

[0009] The operation and other advantages of the present invention will become more apparent from embodiments and examples explained below.

Brief Description of Drawings

[0010]

[FIG. 1] FIG. 1 is a block diagram illustrating a configuration of an image display apparatus according to a first example.

[FIG. 2] FIG. 2 is a characteristic diagram illustrating one example of a light output characteristic of a green semiconductor laser.

[FIG. 3] FIG. 3 is a conceptual diagram illustrating one example of optical scanning according to the first example.

[FIG. 4] FIG. 4 is a conceptual diagram illustrating one example of a luminance distribution according to the first example.

Description of Embodiments

[0011] Hereinafter, an image display apparatus according to embodiments of the present invention will be explained.

<First Embodiment>

[0012] An image display apparatus according to a first embodiment of the present invention will be explained.

[0013] The image display apparatus according to the first embodiment is an image display apparatus configured to display an image due to optical scanning by driving a mirror such as, for example, a micro electro mechanical systems (MEMS) mirror, which reflects a light beam irradiated from a light source, in each of a main scanning direction and a sub scanning direction, which crosses the main scanning direction.

[0014] A controlling device, which is provided with, for example, a memory, a processor, and the like, controls the light source to change an irradiation period of the light beam with respect to a pixel drawing period, which is a period for drawing each of a plurality of pixel data corresponding to the image to be displayed, on the basis of luminance of a one-frame image (corresponding to the "entire image" according to the present invention) to be displayed. Here, the "luminance of the one-frame image" means luminance that represents the image. Specifically, for example, average luminance of the one-frame image or the like corresponds to the "luminance of the one-frame image".

[0015] If the luminance of the one-frame image is reduced, as described in the aforementioned Background Art, the output of the light source is reduced according to the reduction width in many cases. Then, due to the light output characteristic of the light source, the flickering possibly occurs in a relatively low luminance region in the drawn image.

[0016] In the embodiment, however, as described above, the light source is controlled by the controlling device to change the irradiation period of the light beam with respect to the pixel drawing period, on the basis of the luminance of the one-frame image to be displayed. Specifically, for example, if the luminance of the one-frame image is halved, the controlling device controls the light source to change the irradiation period of the light beam to the pixel drawing period to half. Then, in view of one pixel drawing period, a light amount of the light beam irradiated is halved. It is thus possible to halve the luminance of the one-frame image without reducing the light amount of the light beam.

[0017] In addition, since the irradiation period may be changed, there is no need to separately install a special element. Therefore, according to the image display apparatus in the embodiment, the image flickering can be relatively easily suppressed.

[0018] If the irradiation period of the light beam with respect to the pixel drawing period is changed in order to change the luminance of the one-frame image, it is desirable to make different starting times of the irradiation period in the pixel drawing period, in two continuous frame periods. Such a configuration makes it possible to suppress uneven luminance in one pixel, which is extremely useful in practice.

<Second Embodiment>

[0019] An image display apparatus according to a second embodiment of the present invention will be explained.

[0020] In the image display apparatus according to the second embodiment, a controlling device, which is provided with, for example, a memory, a processor, and the like, controls the light source to make an irradiation period of the light beam to a pixel drawing period, which is a period for drawing one of a plurality of pixel data corresponding to the image to be displayed, 1/n of the pixel drawing period, if the one pixel data has 1/n (wherein n is a positive real number) of maximum luminance, wherein n is a positive real number. Here, the "one pixel data" means luminance in the corresponding pixel drawing period, i.e. luminance associated with the pixel data.

[0021] The aforementioned Background Art describes the technical problems that can occur if the luminance of the one-frame image is reduced. The same technical problem caused by the light output characteristic of the light source possibly occurs even when pixels with relatively low luminance are drawn, which has been found from the study of the present inventors.

[0022] Thus, in the embodiment, as described above, the light source is controlled by the controlling device to make the irradiation period of the light beam to the pixel drawing period for drawing the one pixel data 1/n of the pixel drawing period, if the luminance associated with the one pixel data is 1/n of the maximum luminance. Specifically, for example, if the luminance associated with the pixel data is half the maximum luminance, the controlling device controls the light source to make the irradiation period of the light beam to the pixel drawing period half. Then, in view of one pixel drawing period, the light amount of the light beam irradiated is halved. It is thus possible to set the luminance of the pixel to half the maximum luminance without reducing the light amount of the light beam.

[0023] Therefore, according to the image display apparatus in the embodiment, the image flickering caused by the drawing of the pixels with relatively low luminance can be relatively easily suppressed.

[0024] By the way, the light amount of the light beam outputted from the light source is determined according to each of the pixel data corresponding to the image to be displayed, in many cases. Thus, if the luminance associated with one pixel data is 1/n of the maximum luminance, the controlling device controls the light source to change the irradiation period of the light beam to the pixel drawing period associated with the one pixel data to 1/n, and to irradiate the light beam with the light amount that is n times the light amount of the light beam corresponding to the luminance associated with the one pixel data.

[0025] More specifically, for example, the controlling device may multiply, by n, the luminance associated with the pixel data used to determine the light amount of the light beam, thereby irradiating the light beam with the light amount that is n times the original light amount. Alternatively, the controlling device may multiply, by n, a gain associated with an amplifier, which is electrically connected between a light source and a power supply configured to supply electric power to the light source, thereby irradiating the light beam with the light amount that is n times the original light amount.

Example

[0026] Hereinafter, an image display apparatus according to an example of the present invention will be explained with reference to the drawings.

<First Example>

[0027] An image display apparatus according to a first example of the present invention will be explained with reference to FIG. 1 to FIG. 4.

(Configuration of Image Display Apparatus)

[0028] Firstly, a configuration of the image display apparatus according to the example will be explained with reference to FIG. 1. FIG. 1 is a block diagram illustrating the configuration of the image display apparatus according to the first example.

[0029] In FIG. 1, an image display apparatus 1 is provided with a deflector 11, a deflector controller 12, a video processor 13, a current output D/A converter (DAC) 14, a laser source 15, and an illuminance sensor 16.

[0030] The deflector 11 is provided with a MEMS mirror (hereinafter referred to a "mirror" as occasion demands) and a drive apparatus configured to drive the mirror. The drive apparatus of the deflector 11 drives the mirror according to a horizontal drive signal and a vertical drive signal, which are outputted from the deflector controller 12. More specifically, the drive apparatus applies an electric field to a piezoelectric thin film formed on a substrate of the mirror, according to the horizontal drive signal and the vertical drive signal, thereby driving the mirror. Since various known aspects can be applied to a method of driving the mirror, an explanation of the details of the method will be omitted.

[0031] In the example, the horizontal drive signal is a sinusoidal signal, and the vertical drive signal is a sawtooth signal. The deflector 11 is thus driven by resonant vibration in a sinusoidal manner in a horizontal direction, and is driven in a sawtooth manner in a vertical direction. With regard to a scanning trajectory resulting from the drive of the mirror, a scanning direction associated with the horizontal direction is reversed for each line. This results in acquisition of a relatively high-resolution projection image even if horizontal resonance frequency associated with the horizontal drive signal is relatively low. The "projection image" is an image displayed in a period other than a vertical blanking period in an optical scanning range.

[0032] The video processor 13 is inputted with a plurality of pixel data (hereinafter referred to as "input pixel data" as occasion demands) corresponding to an image to be displayed. The video processor 13 is also inputted with an illuminance signal indicating an illuminance or degree of illumination detected by the illuminance sensor 16. The video processor 13 generates pixel data to be outputted (hereinafter referred to as "output pixel data" as occasion demands) to the current output DAC 14.

[0033] The current output DAC 14 supplies a drive current, which is proportional to the output pixel data, to the laser source 15. As a result, laser light with a light amount corresponding to the output pixel data is irradiated from the laser source 25 to the mirror. The current output DAC 14 is provided with a power supply configured to supply the drive current to the laser source 15, and an amplifier configured to amplify the drive current outputted from the power supply.

[0034] Here, in particular, the video processor 13 changes average luminance of a one-frame image to be displayed, on the basis of the illuminance indicated by the illuminance signal. The change in the average luminance of the one-frame image may be realized, specifically, for example, by reducing the average luminance of the one-frame image to predetermined luminance, on condition that the illuminance becomes lower than a predetermined threshold value.

[0035] As described above, the average luminance of the one-frame image to be displayed is changed on the basis of the illuminance, which makes it possible to display an image with luminance suitable for a place in which the image display apparatus 1 is located. It is extremely useful in practice.

[0036] In the example, a value of the drive current supplied to the laser source 15 is in a range of a region in which the linearity of a light output characteristic associated with the laser source 15 is maintained (i.e. a linear region).

(Method of Controlling Laser Source)

[0037] Next, a method of controlling the laser source 15 will be explained.

[0038] If the average luminance of the one-frame image to be displayed is set to be lower than average luminance corresponding to the input pixel data, in the conventional technology, the input pixel data is reduced according to the reduction width to generate the output pixel data in many cases. As described above, the drive current, which is proportional to the output pixel data, is outputted from the current output DAC 14. Thus, the laser source 15 is supplied with a current that is smaller than a current corresponding to the input pixel data, and the average luminance of the one-frame image to be displayed can be reduced.

[0039] Depending on the type of the laser source, however, the light output characteristic is not linear, and the linearity is possibly deteriorated as the drive current is reduced. Specifically, for example, some green semiconductor laser has a light output characteristic as illustrated in FIG. 2. As is clear from FIG. 2, the green semiconductor laser has significantly deteriorated linearity if the drive current is less than or equal to one quarter of the maximum value. In FIG. 2, there is drawn a ratio of a measured value to an ideal value (i.e. a value based on the assumption that the light output characteristic is linear).

[0040] Then, in the conventional technology, for example, if an image with luminance slightly varying with time is displayed, the change in luminance of the displayed image increases more than expected, and the flickering possibly occurs in the relatively low luminance region in the displayed image.

[0041] In the example, however, if the average luminance of the one-frame image to be displayed is reduced, an irradiation period of the laser light with respect to a pixel period, which is a period for drawing one output pixel data, is reduced according to the reduction width.

[0042] Specifically, for example, if the average luminance of the one-frame image to be displayed is set to be half the average luminance corresponding to the input pixel data, the video processor 13 outputs one input pixel data as the output pixel data without change, from the start of one pixel period corresponding to the one input pixel data to a lapse of half the one pixel period. The video processor 13 then outputs zero data (i.e. luminance=0) as the output pixel data, from the lapse of half the one pixel period to the end of the one pixel period.

[0043] Then, the laser light is emitted from the laser source 15 from the start of the one pixel period to the lapse of half the one pixel period. The laser light is not emitted (i.e. lights-off) from the lapse of half the one pixel period to the end of the one pixel period (refer to FIG. 3). Thus, the average luminance of the one pixel period is half the luminance of the corresponding one input pixel data. As a result, according to the image display apparatus 1 in the example, even if the average luminance of the one-frame image to be displayed is reduced, the flickering of the displayed image can be suppressed.

[0044] In the example, moreover, if the irradiation period of the laser light with respect to the pixel period is changed, a horizontal diameter of a beam spot of the laser light irradiated is changed according to the irradiation period of the laser light (refer to FIG. 3). Such a configuration makes it possible to reduce the overlap of adjacent pixels, thereby improving resolution of the displayed image.

[0045] By the way, in the case where the average luminance of the one-frame image to be displayed is reduced, if the laser light is repeatedly turned on or off at the same timing every time, an output intensity distribution of the laser light becomes uneven, which produces lines with gradations in the displayed image.

[0046] The video processor 13 thus makes different starting times of laser-light-irradiation in the pixel period, in two continuous frame periods, for example, as illustrated in FIG. 4. Such a configuration makes it possible to average luminance distributions in the two continuous frame periods.

[0047] The "video processor 13" and the "pixel period" according to the example are respectively one example of the "controlling device" and the "pixel drawing period" according to the present invention. The "current output DAC 14" and the "laser source 15" according to the example are one example of the "light source" according to the present invention.

<Second Example>

[0048] An image display apparatus according to a second example of the present invention will be explained. The second example is configured in the same manner as in the first example, except that the video processor 13 performs a different process. Thus, in the second example, the same explanation as that in the first example will be omitted, and basically, only a different point will be explained.

(Method of Controlling Laser Source)

[0049] In the example, if one input pixel data has 1/n (wherein n is a positive real number) of the maximum luminance, the video processor 13 controls the current output DAC 14 to change the irradiation period of the laser light to the pixel period to 1/n, and to irradiate the laser light with a light amount that is n times a laser amount corresponding to the one input pixel data.

[0050] Here, as a method of controlling the current output DAC 14 to irradiate the laser light with the light amount that is n times the light amount corresponding to the one input pixel data, for example, pixel data obtained by multiplying the one input pixel data by n may be outputted to the current output DAC 14, as the output pixel data. Alternatively, a gain associated with an amplifier provided for the current output DAC 14 may be multiplied by n.

[0051] Specifically, for example, if one input pixel data has half the maximum luminance, the video processor 13 outputs image data with luminance that is twice the luminance of the one input pixel data, as the output pixel data, from the start of one pixel period corresponding to the one input pixel data to a lapse of half the one pixel period. The video processor 13 then outputs zero data as the output pixel data, from the lapse of half the one pixel period to the end of the one pixel period.

[0052] Then, the laser light with a light amount that is twice the laser amount corresponding to the one input pixel data is emitted from the laser source 15, from the start of the one pixel period to the lapse of half the one pixel period. The laser light is not emitted (i.e. lights-off) from the lapse of half the one pixel period to the end of the one pixel period. Thus, the average luminance of the one pixel period is equal to the luminance of the corresponding one input pixel data.

[0053] By virtue of such a configuration, it is possible to suppress a reduction in the drive current when drawing input pixel data with relatively low luminance. In other words, a low drive current region in which the light output characteristic of the laser source 15 has significant nonlinearity can be avoided. To put it differently, the laser source 15 can be driven in a drive current region in which the light output characteristic of the laser source 15 has good linearity.

[0054] The present invention is not limited to the aforementioned embodiments and examples, but various changes may be made, if desired, without departing from the essence or spirit of the invention which can be read from the claims and the entire specification. An image display apparatus which involves such changes is also intended to be within the technical scope of the present invention.

Description of Reference Numerals

[0055]

1	image display apparatus
11	deflector
12	deflector controller
13	video processor
14	current output DAC
15	laser source
16	illuminance sensor

Claims

1. An image display apparatus configured to display an image due to optical scanning by driving a mirror, which reflects a light beam irradiated from a light source, in each of a main scanning direction and a sub scanning direction, which crosses the main scanning direction, said image display apparatus comprising:

    a controlling device configured to control the light source to change an irradiation period of the light beam with respect to a pixel drawing period, which is a period for drawing each of a plurality of pixel data corresponding to the image to be displayed, on the basis of luminance of the entire image to be displayed.

2. An image display apparatus configured to display an image due to optical scanning by driving a mirror, which reflects a light beam irradiated from a light source, in each of a main scanning direction and a sub scanning direction, which crosses the main scanning direction, said image display apparatus comprising:

    a controlling device configured to control the light source to make an irradiation period of the light beam to a pixel drawing period, which is a period for drawing one of a plurality of pixel data corresponding to the image to be displayed, 1/n of the pixel drawing period, if the one pixel data has 1/n of maximum luminance, wherein n is a positive real number.

3. The image display apparatus according to claim 2, wherein said controlling device controls the light source to irradiate the light beam with a light amount that is n times a light amount of the light beam corresponding to the one pixel data.

4. The image display apparatus according to claim 3, wherein said controlling device multiples the one pixel data by n, thereby controlling the light source to irradiate the light beam with the light amount that is n times.

5. The image display apparatus according to claim 3, wherein
the light source comprises:

    a power supply; and
    an amplifier configured to set a value of current outputted from the power supply, to a value according to the one pixel data, and
    said controlling device multiplies a gain associated with the amplifier by n, thereby controlling the light source to irradiate the light beam with the light amount that is n times.

6. The image display apparatus according to claim 1, wherein said controlling device makes different starting times of the irradiation period in the pixel drawing period, in two continuous frame periods.

7. The image display apparatus according to claim 1 or 2, wherein said controlling device controls the light source to change a spot diameter of the light beam according to the irradiation period.

8. The image display apparatus according to claim 1 or 2, wherein a value of a drive current supplied to the light source is in a range of a linear region of a light beam amount characteristic associated with the light source.

FIG. 1

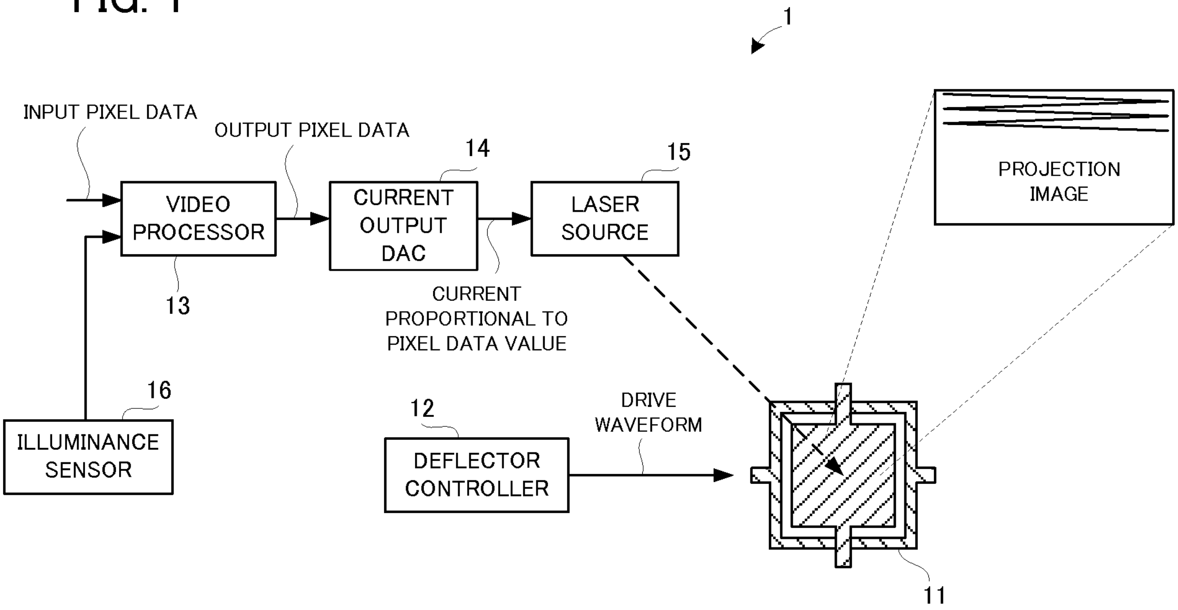

1
INPUT PIXEL DATA
OUTPUT PIXEL DATA
14
15
VIDEO PROCESSOR
CURRENT OUTPUT DAC
LASER SOURCE
PROJECTION IMAGE
13
CURRENT PROPORTIONAL TO PIXEL DATA VALUE
16
ILLUMINANCE SENSOR
12
DEFLECTOR CONTROLLER
DRIVE WAVEFORM
11

FIG. 2

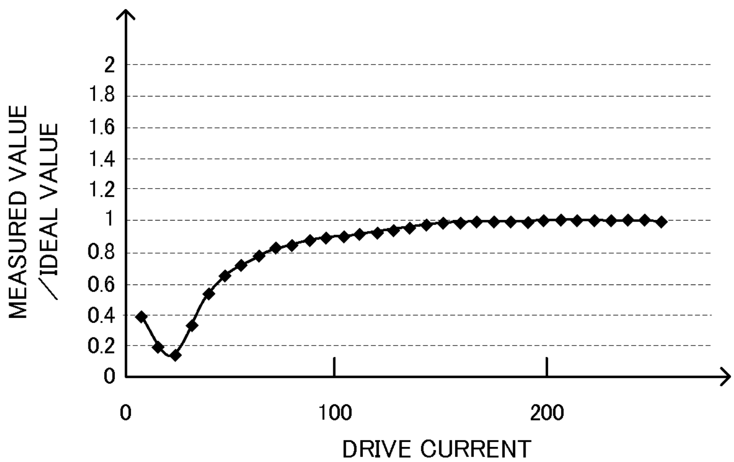

MEASURED VALUE
／IDEAL VALUE
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
100
200
DRIVE CURRENT

FIG. 3

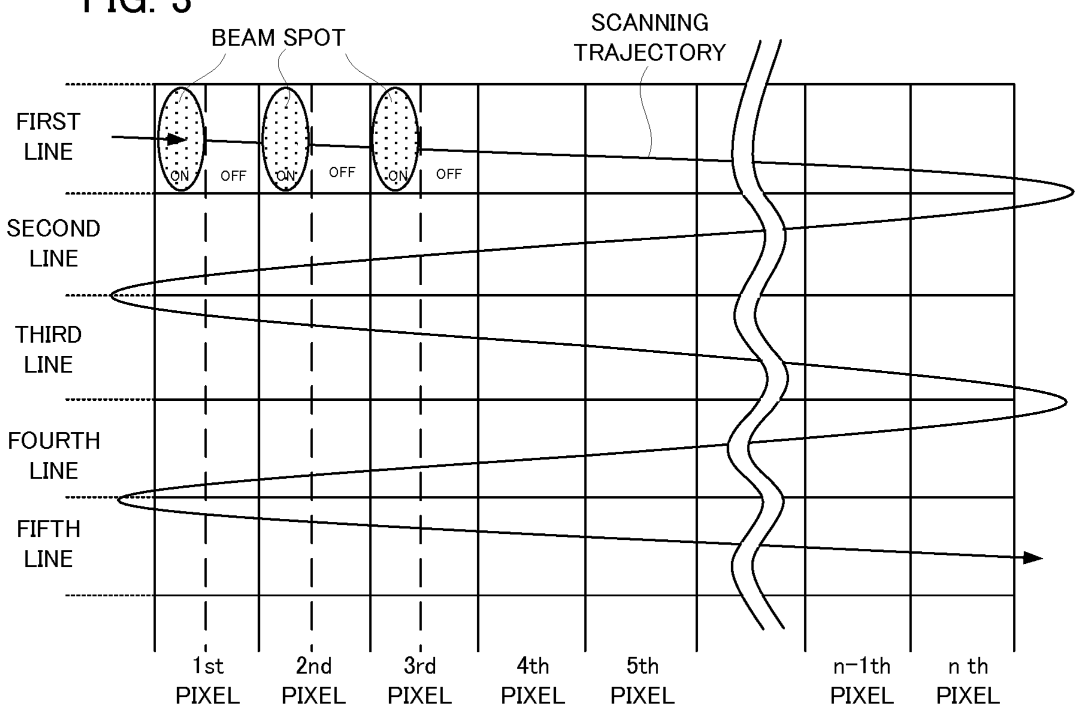
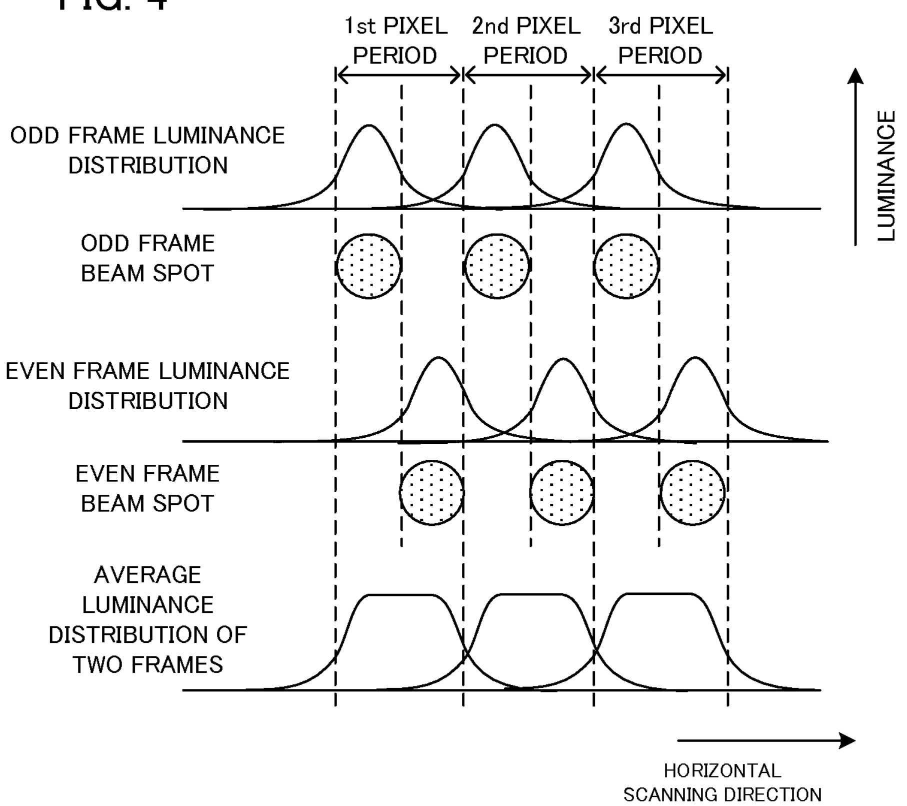

BEAM SPOT
SCANNING TRAJECTORY
FIRST LINE
SECOND LINE
THIRD LINE
FOURTH LINE
FIFTH LINE
ON
OFF
1st PIXEL
2nd PIXEL
3rd PIXEL
4th PIXEL
5th PIXEL
n-1th PIXEL
n th PIXEL

FIG. 4


1st PIXEL PERIOD
2nd PIXEL PERIOD
3rd PIXEL PERIOD
LUMINANCE
ODD FRAME LUMINANCE DISTRIBUTION
ODD FRAME BEAM SPOT
EVEN FRAME LUMINANCE DISTRIBUTION
EVEN FRAME BEAM SPOT
AVERAGE LUMINANCE DISTRIBUTION OF TWO FRAMES
HORIZONTAL SCANNING DIRECTION

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2013/054183

A. CLASSIFICATION OF SUBJECT MATTER
G09G3/02(2006.01)i

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)
G09G3/00-3/38

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2013
Kokai Jitsuyo Shinan Koho	1971-2013	Toroku Jitsuyo Shinan Koho	1994-2013

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	JP 2001-264660 A (Matsushita Electric Industrial Co., Ltd.), 26 September 2001 (26.09.2001), paragraphs [0038], [0041] (Family: none)	1-2,8 3-7
X A	JP 2007-43068 A (Canon Inc.), 15 February 2007 (15.02.2007), paragraphs [0018], [0024], [0031] to [0033] (Family: none)	1-2,8 3-7
X A	JP 2008-309935 A (Seiko Epson Corp.), 25 December 2008 (25.12.2008), paragraphs [0071] to [0072], [0080] to [0083] (Family: none)	1-2,8 3-7

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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"P" document published prior to the international filing date but later than the priority date claimed
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 March, 2013 (27.03.13)	09 April, 2013 (09.04.13)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2013/054183

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2012/081308 A1 (NEC Corp.), 21 June 2012 (21.06.2012), entire text; fig. 1 to 9 (Family: none)	1-8
A	JP 2012-103327 A (Funai Electric Co., Ltd.), 31 May 2012 (31.05.2012), entire text; fig. 1 to 14 & WO 2012/063430 A & WO 2012/063430 A1	1-8
A	WO 2011/136065 A1 (NEC Corp.), 03 November 2011 (03.11.2011), entire text; fig. 1 to 17 & CN 102812508 A	1-8

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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- JP H661562 A **[0004]**