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(54) ILLUMINATOR AND PROJECTOR

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(57) ABSTRACT

An illuminator according to an embodiment of the present disclosure includes a first light source configured to output first light having a first wavelength band; a second light source configured to output second light having a second wavelength band different from the first wavelength band; a light combiner having a first surface and a second surface different from the first surface; and a light receiving sensor configured to receive the first light and the second light. The light combiner includes a substrate, and a reflection film layered on the substrate. The reflection film has transmittance higher than reflectance in the first wavelength band, and the reflectance is higher than 0% in the first wavelength band. The reflection film has transmittance lower than the reflectance in the second wavelength band, and the transmittance is higher than 0% in the second wavelength band. The first light is incident on the first surface, and the second light is incident on the second surface. The light receiving sensor is configured to receive the first light reflected off the first surface and the second light passing through the second surface.

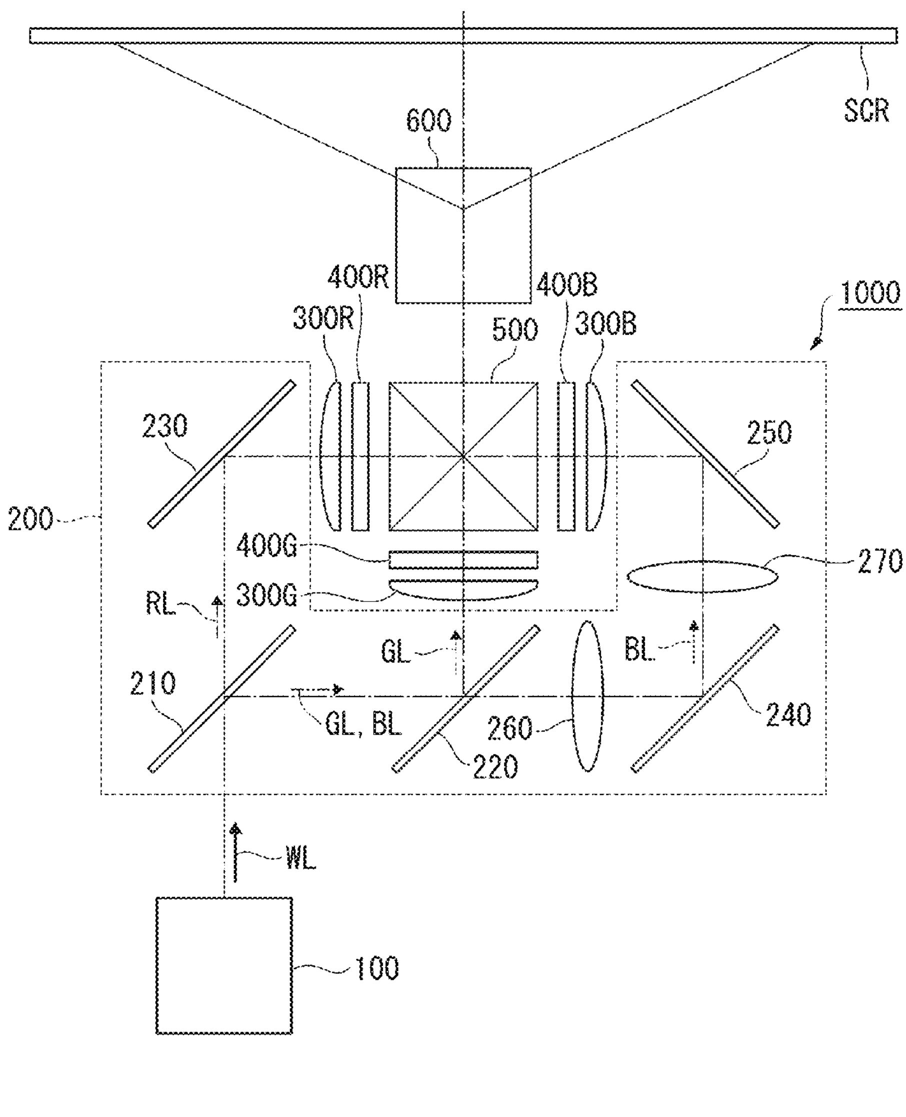
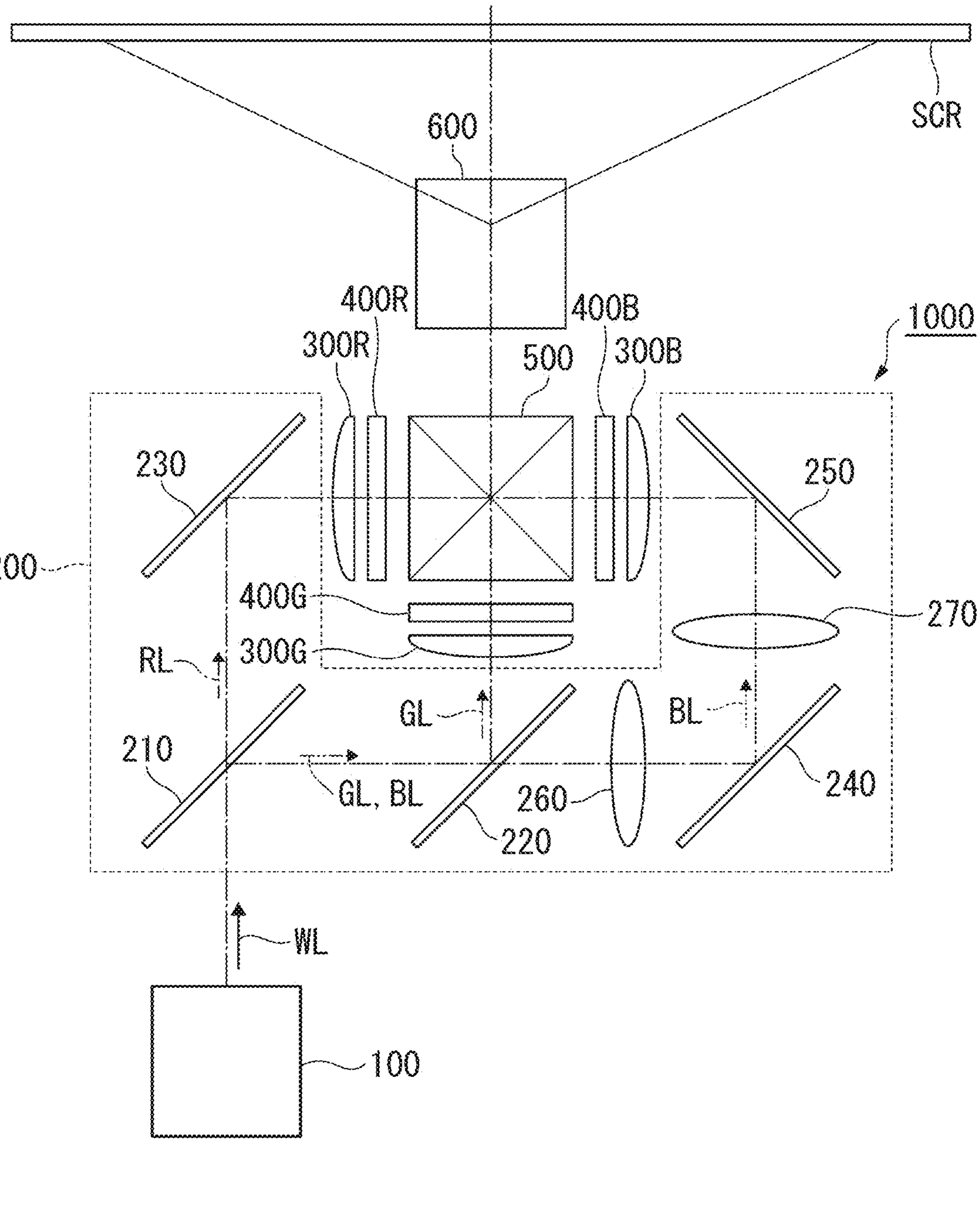


FIG. 1



600
SCR
400R
400B
1000
300R
500
300B
230
250
200
400G
270
300G
RL
GL
BL
210
GL, BL
240
260
220
WL
100

FIG. 2

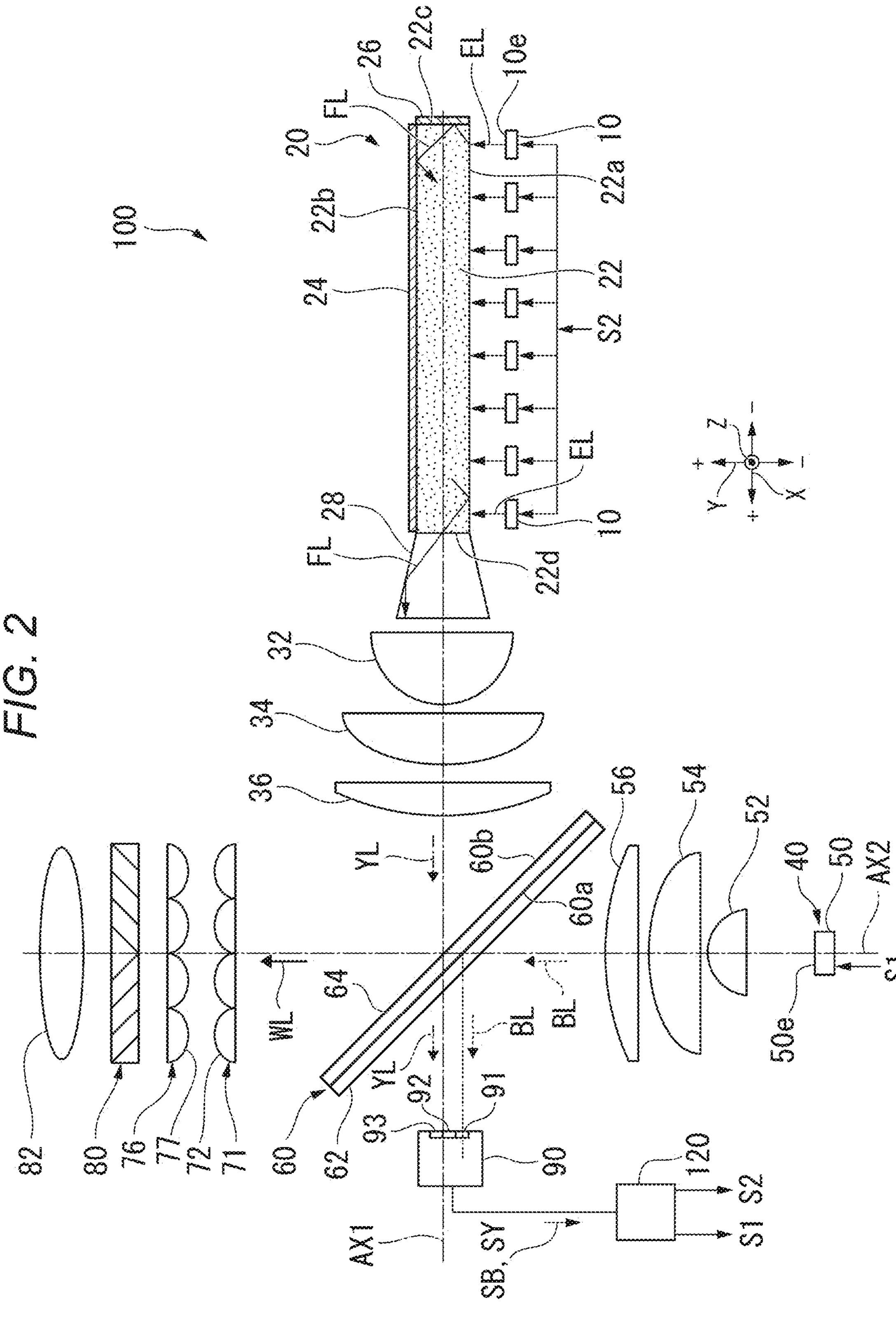

100
20
FL
26
22c
EL
10e
10
22a
22b
22
24
S2
EL
10
28
FL
22d
Z
Y
X
32
34
36
56
54
52
40
50
AX2
S1
50e
YL
60b
60a
WL
64
BL
BL
YL
60
62
93
92
91
90
82
80
76
77
72
71
120
S2
S1
AX1
SB, SY

FIG. 3

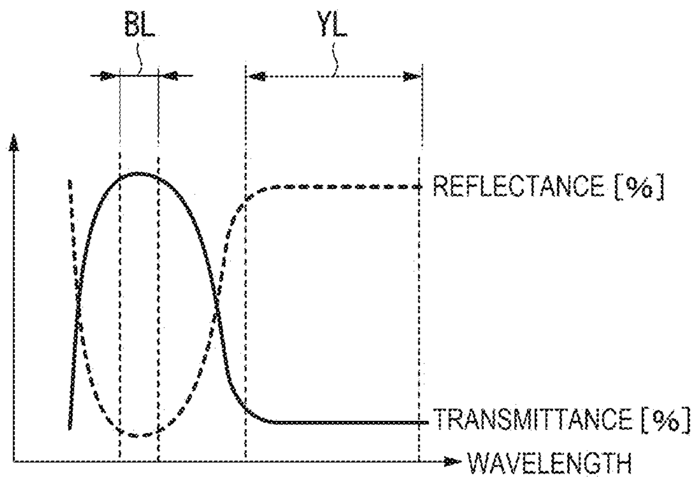

BL
YL
REFLECTANCE [%]
TRANSMITTANCE [%]
WAVELENGTH

FIG. 4

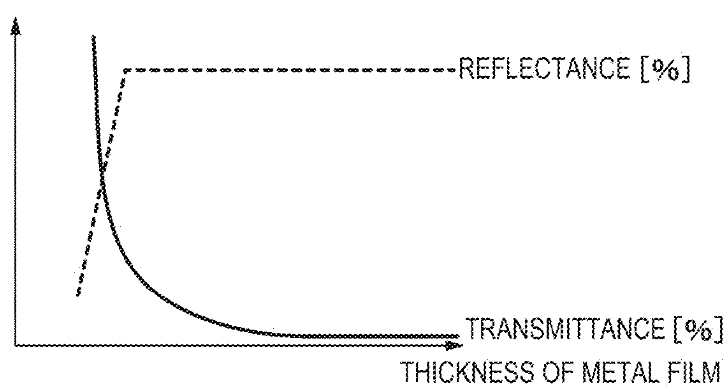

REFLECTANCE [%]
TRANSMITTANCE [%]
THICKNESS OF METAL FILM

FIG. 5

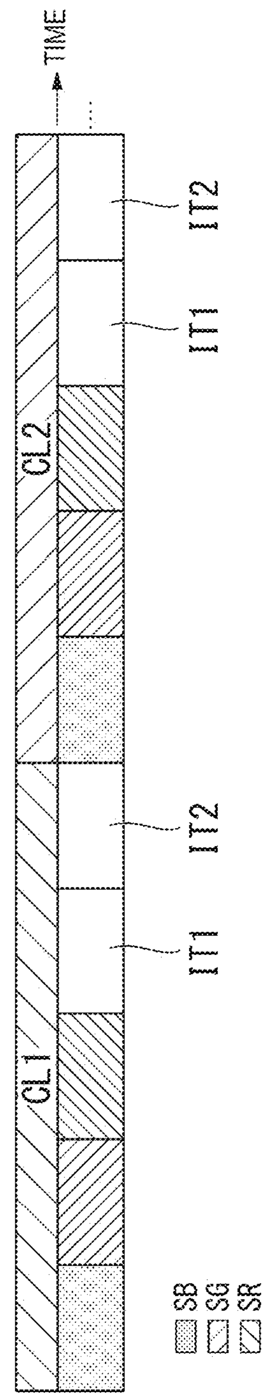


FIG. 6

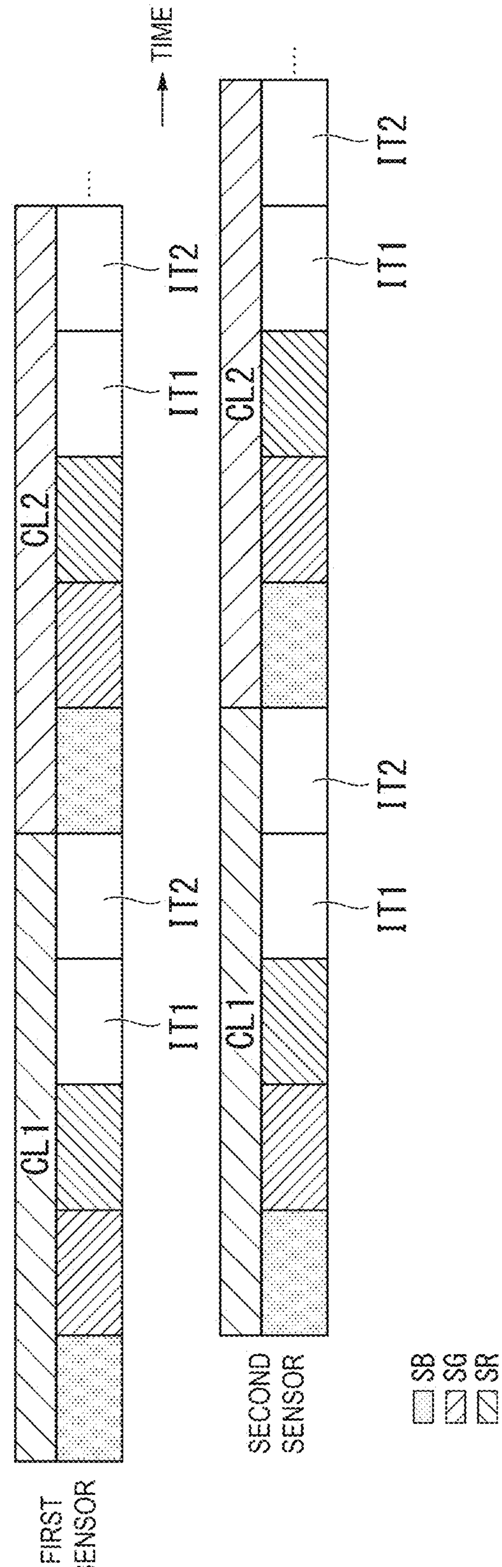

TIME
CL1
CL2
IT1
IT2
IT1
IT2
CL1
CL2
IT1
IT2
IT1
IT2
FIRST SENSOR
SECOND SENSOR
SB
SG
SR

FIG. 7

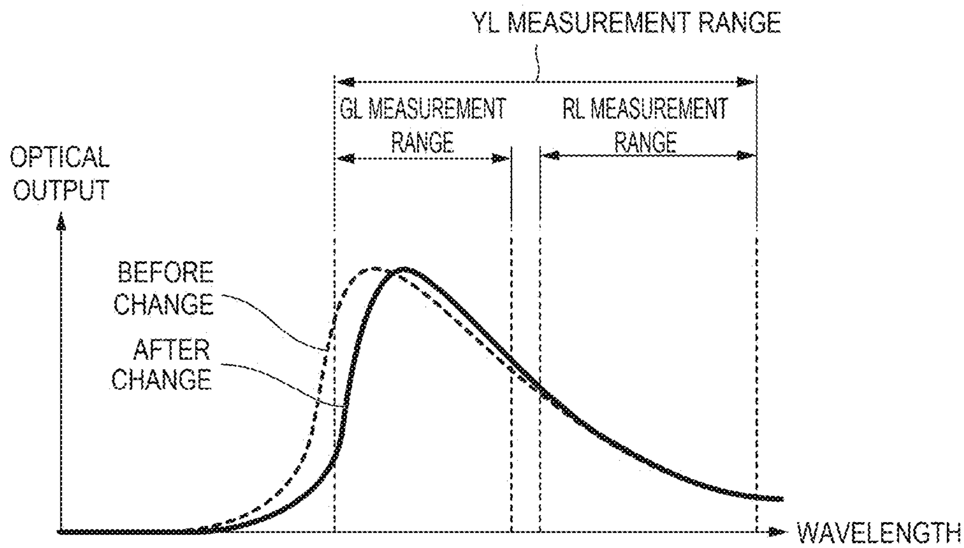
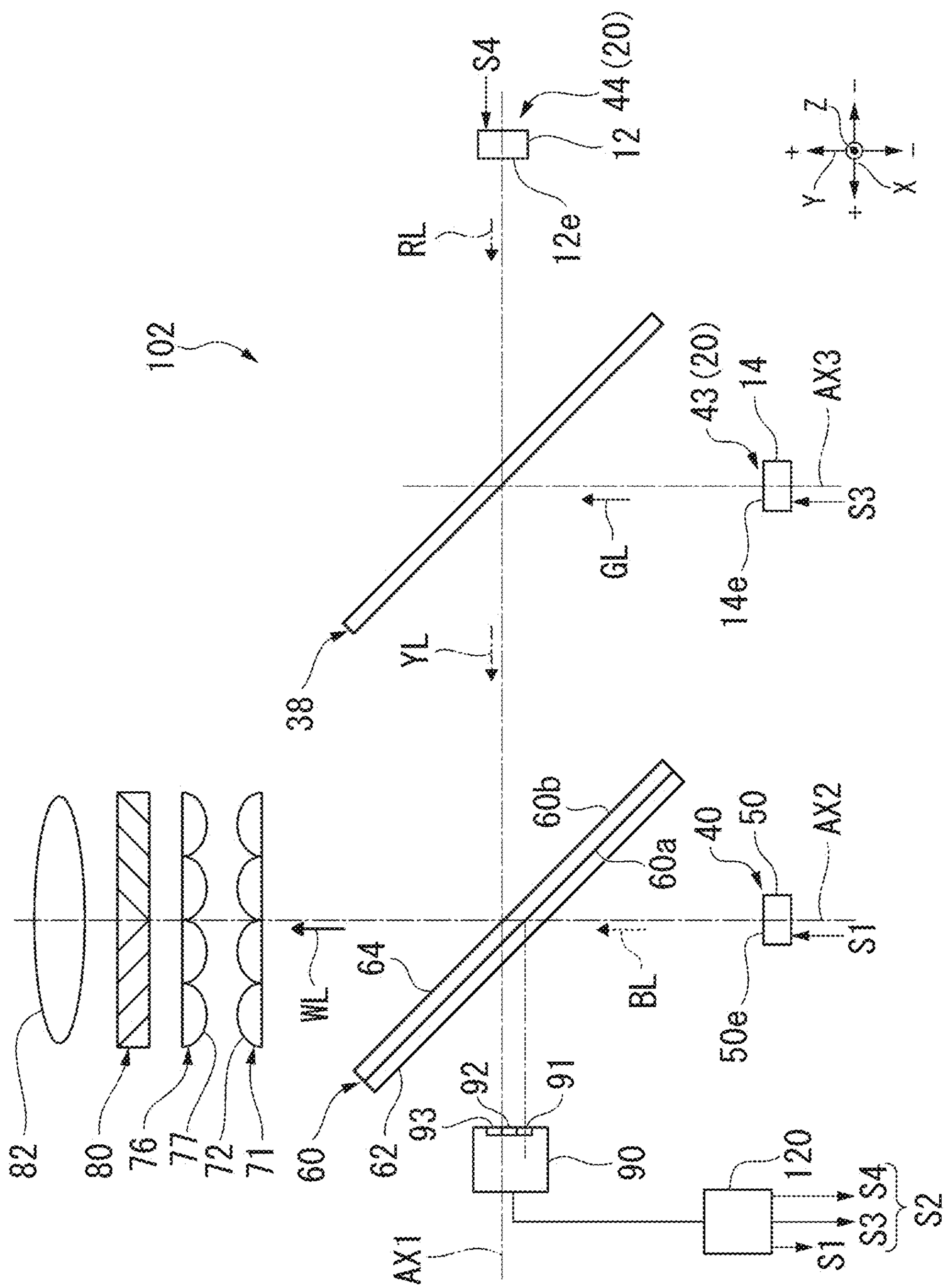
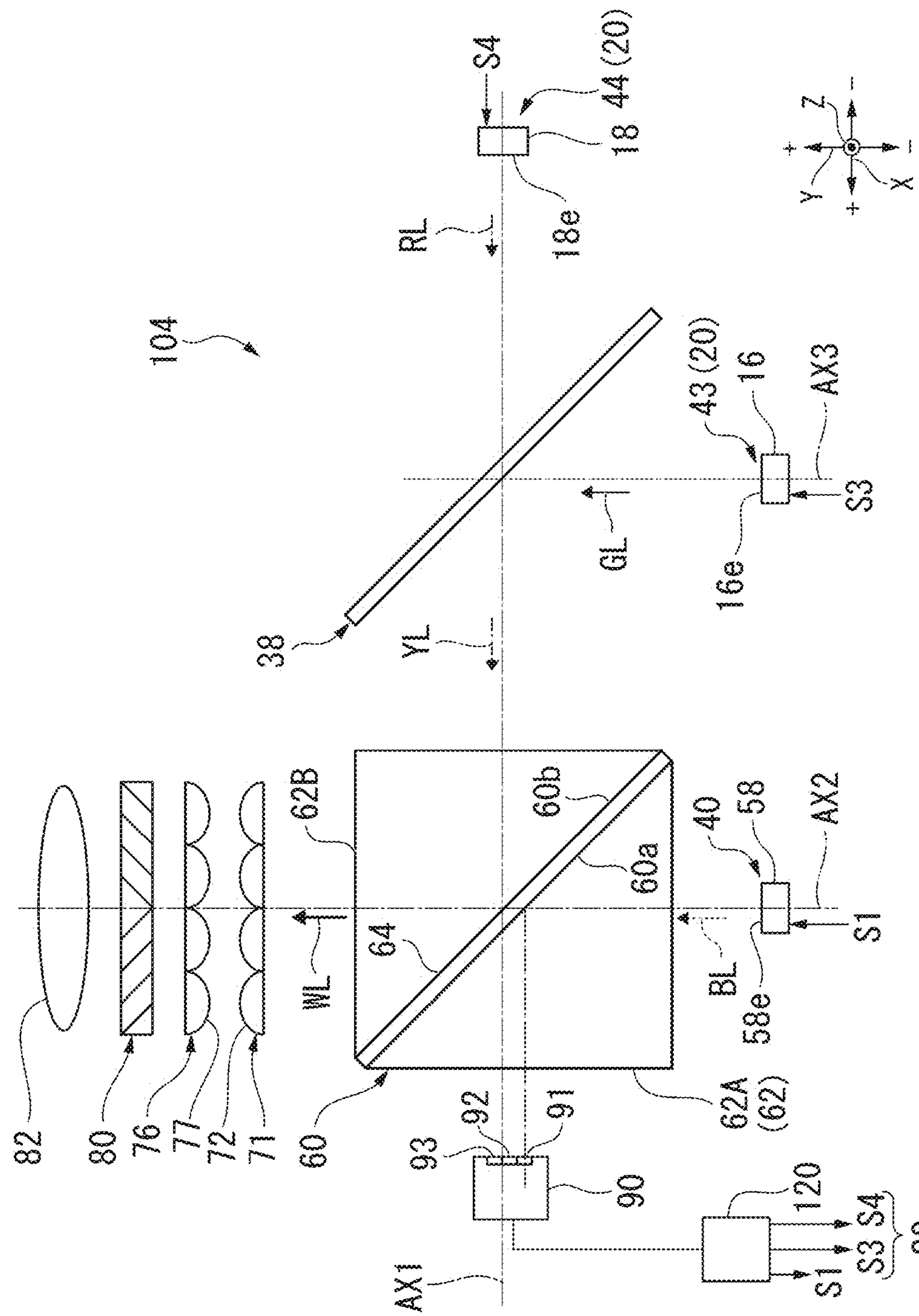

YL MEASUREMENT RANGE
GL MEASUREMENT RANGE
RL MEASUREMENT RANGE
OPTICAL OUTPUT
BEFORE CHANGE
AFTER CHANGE
WAVELENGTH

FIG. 8



102
S4
44 (20)
12
12e
RL
38
YL
GL
14e
14
43 (20)
AX3
S3
82
80
76
77
72
71
60
62
93
92
91
90
64
WL
60b
60a
BL
40
50
50e
AX2
S1
120
S1
S3 S4
S2
AX1
Y
X
Z

FIG. 9


104
S4
44 (20)
18
18e
RL
38
YL
43 (20)
16
AX3
S3
16e
GL
Z
Y
X
60b
60a
62B
64
WL
40
58
AX2
S1
BL
58e
82
80
76
77
72
71
60
93
92
91
62A
(62)
90
120
S4
S3
S1
S2
AX1

ILLUMINATOR AND PROJECTOR

[0001] The present application is based on, and claims priority from JP Application Serial Number 2024-024103, filed Feb. 20, 2024, the disclosure of which is hereby incorporated by reference herein in its entirety.

BACKGROUND

1. Technical Field

[0002] The present disclosure relates to an illuminator and a projector.

2. Related Art

[0003] There is a known projector including a light source that outputs color light, a light modulator that modulates the color light output from the light source in accordance with image information to generate image light, and a projection system that enlarges the image light output from the light modulator and projects the enlarged image light onto a projection receiving surface such as a screen. The projector includes a light source apparatus including, for example, a blue light source that outputs blue light, an excitation light source that is provided separately from the blue light source and outputs blue light, and a phosphor that is excited by the blue light output from the excitation light source to emit yellow light. In the thus configured projector, white light containing the blue light and the yellow light is output from the light source apparatus, and the multiple types of color light contained in the white light are converted into multiple types of image light by a common light modulator or light modulators disposed on a color light basis.

[0004] In the projector described above, a laser diode (LD) or a light emitting diode (LED) is, for example, used as each of the blue light source and the excitation light source. The luminance or intensity of the light output from each of the LDs or the LEDs of the light source apparatus vary in accordance with the period for which the projector and the light source apparatus are used, the temperature at which they are used, voltages applied thereto, and other factors. The variation in luminance or intensity of the light from the light source apparatus affects the color balance or the image quality of an image enlarged and projected onto the projection receiving surface. There has been a proposed configuration in which the luminance or intensity of part of the multiple types of color light output from the light source apparatus is detected, and the state or the degree of deterioration of each of the light sources in the projector is determined.

[0005] For example, JP-A-2016-114738 discloses a projector including a detection apparatus that detects the luminance of part of each of blue light and red light. In the projector disclosed in JP-A-2016-114738, red light and green light output from a first light source section and blue light output from a second light source section are superimposed on each other in the same optical path, and then separated by filters that each separate light having wavelengths within a preset range into the three types of color light that travel along different optical paths. The detection apparatus detects the luminance of the blue light having been separated by the corresponding filter so as to travel along the optical path for the blue light and then having passed through a reflection mirror, and detects the luminance of the red light having been separated by the corresponding filter so as to travel along the optical path different from the optical path of the blue light and then having passed through a reflection mirror. In the projector disclosed in JP-A-2016-114738, the color balance of a projection image is adjusted based on information relating to the luminance of the blue light and the luminance of the red light detected by the detection apparatus.

[0006] JP-A-2016-114738 is an example of the related art.

[0007] In the technology disclosed in JP-A-2016-114738 described above, since the detection apparatus is disposed at each of the reflection mirror through which part of the incident blue light passes and the reflection mirror through which part of the red light passes, there is a possibility of an increase in the size of the projector and complication of the configuration thereof. That is, it has been required to provide an illuminator that can detect information relating to the intensity of color light output from a light source and can have a small, simple configuration, and a projector including the illuminator.

SUMMARY

[0008] An illuminator according to an aspect of the present disclosure includes a first light source configured to output first light having a first wavelength band; a second light source configured to output second light having a second wavelength band different from the first wavelength band; a light combiner having a first surface and a second surface different from the first surface; and a light receiving sensor configured to receive the first light and the second light. The light combiner includes a substrate, and a reflection film layered on the substrate. The reflection film has transmittance higher than reflectance in the first wavelength band, and the reflectance is higher than 0% in the first wavelength band. The reflection film has transmittance lower than the reflectance in the second wavelength band, and the transmittance is higher than 0% in the second wavelength band. The first light is incident on the first surface, and the second light is incident on the second surface. The light receiving sensor is configured to receive the first light reflected off the first surface and the second light passing through the second surface.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1** is a schematic view of a projector according to a first embodiment.

[0010] FIG. **2** is a schematic view of an illuminator of the projector shown in FIG. **1**.

[0011] FIG. **3** is a diagrammatic view relating to the transmittance and reflectance of a reflection film of a light combiner of the illuminator shown in FIG. **2**.

[0012] FIG. **4** is a diagrammatic view relating to the transmittance and reflectance in a case where a reflection film of configured with a metal thin film is provided at the light combiner of the illuminator shown in FIG. **2**.

[0013] FIG. **5** is a diagrammatic view relating to electric signals output from a light receiving sensor of the illuminator shown in FIG. **2**.

[0014] FIG. **6** is a diagrammatic view relating to electric signals output from a light receiving sensor of an illuminator of related art.

[0015] FIG. **7** is a diagrammatic view of the spectrum of yellow light output from a light source of the illuminator shown in FIG. **2**.

[0016] FIG. **8** is a schematic view showing an illuminator according to a second embodiment.

[0017] FIG. **9** is a schematic view showing an illuminator according to a third embodiment.

DESCRIPTION OF EMBODIMENTS

[0018] Embodiments of the present disclosure will be described below with reference to the drawings. In the drawings, elements are drawn at different dimensional scales in some cases for clarity of each of the elements.

First Embodiment

[0019] A first embodiment of the present disclosure will first be described with reference to FIGS. **1** to **7**.

Projector

[0020] FIG. **1** is a schematic view showing the configuration of a projector **1000** according to the first embodiment of the present disclosure. The projector **1000** is a projection-type display apparatus that displays an image and a video on a screen SCR. The projector **1000** includes an illuminator **100**, a color separation system **200**, field lenses **300**R, **300**G, and **300**B, light modulators **400**R, **400**G, and **400**B, a light combining system **500**, and a projection system **600**. The projector **1000** is a three-panel projector including three light modulators.

[0021] The illuminator **100** outputs white light WL, which contains blue light BL, green light GL, and red light RL, toward the color separation system **200**. The red light RL, the green light GL, and the blue light BL form illumination light in the projector **1000**. In the following description, at least one of the blue light BL, the green light GL, and the red light RL output from the illuminator **100** is referred to as color light in some cases. The configuration of the illuminator **100** will be described later.

[0022] The color separation system **200** separates the incident white light WL into the red light RL, the green light GL, and the blue light BL, and causes the three types of color light to travel along respective optical paths. The color separation system **200** includes, for example, dichroic mirrors **210** and **220**, total reflection mirrors **230**, **240**, and **250**, and relay lenses **260** and **270**.

[0023] The dichroic mirror **210** is disposed in the optical path of the white light WL output from the illuminator **100**. The dichroic mirror **210** transmits the red light RL and reflects the green light GL and the blue light BL. Out of the white light WL incident on the dichroic mirror **210**, the red light RL and the combination of the green light GL and the blue light BL are separated from each other and caused to travel along optical paths different from each other. The red light RL passes through the dichroic mirror **210** and exits toward the total reflection mirror **230**. The green light GL and the blue light BL are reflected off the dichroic mirror **210** and output toward the dichroic mirror **220**.

[0024] The dichroic mirror **220** is disposed in the optical path common to the green light GL and the blue light BL output from the dichroic mirror **210**. The dichroic mirror **220** transmits the blue light BL and reflects the green light GL. The green light GL and the blue light BL incident on the dichroic mirror **220** are separated from each other and caused to travel along optical paths different from each other. The green light GL is reflected off the dichroic mirror **220** and output toward the light modulator **400**G. The blue light BL passes through the dichroic mirror **220** and exits toward the total reflection mirror **240**.

[0025] The total reflection mirror **230** is disposed in the optical path of the red light RL output from the dichroic mirror **210**, and reflects the incident red light RL toward the light modulator **400**R. The total reflection mirror **240** is disposed in the optical path of the blue light BL output from the dichroic mirror **210**, and reflects the incident blue light BL toward the total reflection mirror **250**. The total reflection mirror **250** is disposed in the optical path of the blue light BL output from the total reflection mirror **240**, and reflects the incident blue light BL toward the light modulator **400**B.

[0026] The relay lens **260** is disposed in the optical path of the blue light BL between the dichroic mirror **220** and the total reflection mirror **240**. The relay lens **270** is disposed in the optical path of the blue light BL between the total reflection mirror **240** and the total reflection mirror **250**. The optical path length of the blue light BL from the dichroic mirror **210** to the light modulator **400**B is longer than the optical path length of the red light RL from the dichroic mirror **210** to the light modulator **400**R and the optical path length of the green light GL from the dichroic mirror **210** to the light modulator **400**G. When no relay lenses are disposed in the optical path of the blue light BL, the optical loss of the blue light BL is greater than the optical loss of the red light RL and the green light GL. The aforementioned arrangement of the relay lenses **260** and **270** compensates for the optical loss of the blue light BL.

[0027] The field lens **300**R is disposed in the optical path of the red light RL output from the total reflection mirror **230**. The field lens **300**R aligns the traveling directions of the incident red light RL in a peripheral region thereof and having an illuminance lower than a predetermined illuminance with one another in the plane that intersects with the optical axis of the red light RL to suppress a decrease in the amount of light in the peripheral region, and outputs the red light RL toward the light modulator **400**R.

[0028] The field lens **300**G is disposed in the optical path of the green light GL output from dichroic mirror **220**. The field lens **300**G aligns the traveling directions of the incident green light GL in a peripheral region thereof and having an illuminance lower than a predetermined illuminance with one another in the plane that intersects with the optical axis of the green light GL to suppress a decrease in the amount of light in the peripheral region, and outputs the green light GL toward the light modulator **400**G. The field lens **300**B is disposed in the optical path of the blue light BL output from the total reflection mirror **250**. The field lens **300**B aligns the traveling directions of the incident blue light BL in a peripheral region thereof and having an illuminance lower than a predetermined illuminance with one another in the plane that intersects with the optical axis of the blue light BL to suppress a decrease in the amount of light in the peripheral region, and outputs the blue light BL toward the light modulator **400**B.

[0029] The light modulator **400**R is disposed in the optical path of the red light RL reflected off the total reflection mirror **230** and output from the field lens **300**R. The light modulator **400**R modulates the incident red light RL in accordance with image information input from an image output apparatus that is not shown to convert the red light RL into red image light and outputs the red image light toward the light combining system **500**. The image output apparatus is, for example, a personal computer or a portable terminal instrument.

[0030] The light modulator **400**G is disposed in the optical path of the green light GL reflected off the dichroic mirror **220** and output from the field lens **300**G. The light modulator **400**G modulates the incident green light GL in accordance with image information input from the image output apparatus, which is not shown, to convert the green light GL into green image light and outputs the green image light toward the light combining system **500**.

[0031] The light modulator **400**B is disposed in the optical path of the blue light BL reflected off the total reflection mirror **250** and output from the field lens **300**B. The light modulator **400**B modulates the incident blue light BL in accordance with image information input from the image output apparatus, which is not shown, to convert the blue light BL into blue image light and outputs the blue image light toward the light combining system **500**.

[0032] The light modulators **400**R, **400**G, and **400**B are each, for example, a transmissive liquid crystal panel. Polarizers are disposed at light-incident-side and light-exiting-side regions of each of the liquid crystal panels. That is, the light modulators **400**R, **400**G, and **400**B each include a light-incident-side polarizer, a liquid crystal panel, and a light-exiting-side polarizer that are sequentially arranged from the light incident side toward the light exiting side along the optical path of the incident color light.

[0033] The light-incident-side polarizers of the light modulators **400**B, **400**G, and **400**R are disposed in the optical paths of the red light RL, the green light GL, and the blue light BL output from the field lenses **300**R, **300**G, and **300**B. The light-incident-side polarizers each output a predetermined polarized component of the incident color light and blocks components of the color light other than the predetermined polarized component. The predetermined polarized light is, for example, P-polarized color light incident on the light-incident-side polarizer and having a vibration plane parallel to the light incident surface of the light-incident-side polarizer. The light-incident-side polarizer is an absorptive or reflective polarizer having a transmission axis corresponding to the predetermined polarized light. To suppress light returning from the light-incident-side polarizers to the field lenses **300**R, **300**G, and **300**B and stray light, the light-incident-side polarizers are each preferably an absorptive polarizer.

[0034] The liquid crystal panels of the light modulators **400**B, **400**G, and **400**R each have a display region and a peripheral region around the display region in a plane that intersects with the optical axis of the incident color light. The display region is provided with multiple pixels arranged two-dimensionally in a plane that intersects with the optical axis of the color light incident on the liquid crystal panel.

[0035] The liquid crystal panel of each of the light modulators **400**B, **400**G, and **400**R includes a counter substrate, a liquid crystal layer, and an element substrate that are not shown but are sequentially arranged along the traveling direction of the color light. Counter electrodes and various wires for the multiple pixels are formed at the plate surface of the counter substrate that faces the liquid crystal layer in the display region. Multiple element electrodes, switching elements, and various wires corresponding to the multiple counter electrodes are formed at the plate surface of the element substrate that faces the liquid crystal layer in the display region. The switching elements are each, for example, a polysilicon thin film transistor (TFT).

[0036] The pixels of the liquid crystal panel of each of the light modulators **400**B, **400**G, and **400**R each modulate the vibration direction of the corresponding one of the incident red light RL, green light GL, and blue light BL with the aid of the operation of the switching element according to an electric signal corresponding to the aforementioned image information on the color light. The light modulators **400**R, **400**G, and **400**B generate the red image light, the green image light, and the blue image light with the aid of the aforementioned operation of the switching elements.

[0037] The light-exiting-side polarizers of the light modulators **400**B, **400**G, and **400**R are disposed in optical paths of the red image light, the green image light, and the blue image light output from the liquid crystal panels disposed in correspondence with the respective multiple types of color light. The light-exiting-side polarizers each output a predetermined polarized component of the incident image light and blocks components of the image light other than the predetermined polarized component. The predetermined polarized light is, for example, P-polarized light having a vibration plane of the color light incident on the light-exiting-side polarizer is parallel to the light incident surface of the light-exiting-side polarizer. The light-exiting-side polarizer is an absorptive or reflective polarizer having a transmission axis corresponding to the predetermined polarized light. To suppress light returning from the light-exiting-side polarizers to the liquid crystal panels and stray light, the light-exiting-side polarizers are each preferably an absorptive polarizer.

[0038] The light combining system **500** is disposed in a region where the optical path of the red image light output from the light-exiting-side polarizer of the light modulator **400**R, the optical path of the green image light output from the light-exiting-side polarizer of the light modulator **400**G, and the optical path of the blue image light output from the light-exiting-side polarizer of the light modulator **400**B intersect with each other. The light combining system **500** combines the three types of incident color image light with one another and outputs the generated full-color image light toward the projection system **600**.

[0039] The light combining system **500** is configured, for example, with a cross dichroic prism. The cross dichroic prism includes four right-angle prisms and two reflection films, the reflection films not shown, and forms a cuboid. The reflection films are each configured, for example, with a dielectric multilayer film. The cross dichroic prism has three light incident surfaces on which the three types of color image light are incident, a light exiting surface via which the full-color image light exits, a first reflection surface, and a second reflection surface. The three light incident surfaces of the cross dichroic prism constitute three side surfaces of the cuboid and face the light exiting surfaces of the light-exiting-side polarizers of the light modulators **400**B, **400**G, and **400**R. The light exiting surface of the cross dichroic prism constitutes the remaining one side surface of the cuboid and faces the light incident surface of the projection system **600**. The first reflection surface is located along one diagonal line in the plan view of the cuboid, and is disposed so as to incline by an angle of 45° with respect to the light incident surface of the cross dichroic prism that faces the light exiting surface of the light-exiting-side polarizer of the light modulator **400**B, and the light exiting surface of the cross dichroic prism. The first reflection surface transmits the incident red image light and green image light and reflects the incident blue image light. The second reflection surface is located along the other diagonal line in the plan view of the cuboid, and is disposed so as to incline by the angle of 45° with respect to the light incident surface of the cross dichroic prism that faces the light exiting surface of the light-exiting-side polarizer of the light modulator **400**R, and the light exiting surface of the cross dichroic prism. The second reflection surface transmits the incident red image light and reflects the incident green image light and blue image light.

[0040] The red image light having exited via the light exiting surface of the light-exiting-side polarizer of the light modulator **400**R enters the cross dichroic prism, passes through a portion of the first reflection surface, and is reflected off the second reflection surface toward the light exiting surface. The green image light having exited via the light exiting surface of the light-exiting-side polarizer of the light modulator **400**G enters the cross dichroic prism, passes through the first and second reflection surfaces, and travels toward the light exiting surface. The blue image light having exited via the light exiting surface of the light-exiting-side polarizer of the light modulator **400**B enters the cross dichroic prism, passes through a portion of the second reflection surface, and is reflected off the first reflection surface toward the light exiting surface. The red image light having been reflected off the second reflection surface, the green image light having passed through the first and second reflection surfaces, and the blue image light having been reflected off the first reflection surface are combined with one another to generate the full-color image light.

[0041] The projection system **600** is disposed in the optical path of the image light output from the light combining system **500**. The projection system **600** projects the incident image light onto the screen SCR, enlarges images transmitted from an image forming apparatus that is not shown to the light modulators **400**B, **400**G, and **400**R, and displays the enlarged images on the screen SCR. The projection system **600** are configured with one or more optical lenses. Examples of the optical lenses may include a plano-convex lens, a plano-concave lens, a biconvex lens, a biconcave lens, a meniscus lens, an aspherical lens, and a freeform surface lens.

Illuminator

[0042] FIG. **2** is a schematic view showing the configuration of the illuminator **100** according to the first embodiment. The illuminator **100** includes a light source **40**, optical lenses **52**, **54**, and **56**, a light source **20**, optical lenses **32**, **34**, and **36**, a light combiner **60**, a light receiving sensor **90**, a first lens array **71**, a second lens array **76**, a polarization converter **80**, a superimposing lens **82**, and a controller **120**, as shown in FIG. **2**.

[0043] The light source **40** includes a light emitter **50**. The light emitter **50** is disposed at a position shifted toward the +X side and the −Y side from the light source **20** and the optical lenses **32**, **34**, and **36**, and overlaps with the light source **20** and the optical lenses **32**, **34**, and **36** in the Z direction. The light source **40** corresponds to a first light source.

[0044] The light emitter **50** emits the blue light BL via a light emitting surface **50***e* toward the +Y side along the Y direction and an optical axis AX**2**. The blue light BL emitted from the light emitter **50** corresponds to first light. The optical axis AX**2** of the blue light BL emitted from the light emitter **50** is perpendicular to an optical axis AX**1** of fluorescence FL output from the light source **20**. The light emitting surface **50***e* of the light emitter **50** is an end surface of the light emitter **50** that faces the +Y side and extends substantially parallel to the XZ plane. A lens, a diffuser, or any other optical element that is not shown may be disposed on the +Y side of the light emitter **50**. A blue wavelength band of the blue light BL emitted from the light emitter **50** differs from a yellow wavelength band and corresponds to a first wavelength band. The blue wavelength band of the blue light BL emitted from the light emitter **50** is the same blue wavelength band of the blue light BL that enters the color separation system **200** described with reference to FIG. **1**, for example, a wavelength band from 400 nm to 470 nm. The light emitter **50** is, for example, an LED that emits the blue light BL. The blue light BL emitted from the light emitter **50** is non-polarized light and randomly polarized light.

[0045] The light emitter **50** may be configured with multiple light emitters **50** the number of which is appropriately determined in accordance with the amount of the blue light BL required for the projector **1000**, the color balance of an image projected by the projector **1000**, and other factors. When the illuminator **100** includes multiple light emitters **50**, the multiple light emitters **50** are arranged, for example, at intervals in a region of an XZ plane that is not shown but spreads around the optical axis AX**2** of the blue light BL.

[0046] The optical lenses **52**, **54**, and **56** are disposed in the optical path of the blue light BL output from the light source **40**, are disposed at positions shifted toward the +Y side from the light source **40**, and overlap with the light source **40** in the X and Z directions, as shown in FIG. **2**. The optical lenses **52**, **54**, and **56** are sequentially arranged at intervals from the −Y side toward the +Y side along the Y direction. The optical axis of the blue light BL passing through the optical lenses **52**, **54**, and **56** is parallel to the optical axis AX**2** of the blue light BL output from the light source **40**, and coincides with the optical axis AX**2** in the form of a straight line. The optical lenses **52**, **54**, and **56** parallelize the blue light BL output from the light source **40** along the Y direction. That is, the blue light BL parallel to the Y direction exits via the +Y-side light exiting surface of the optical lens **56**.

[0047] The light incident surfaces of the optical lenses **52**, **54**, and **56** are each a planar surface parallel to the XZ plane. The light exiting surfaces of the optical lenses **52**, **54**, and **56** are each a convex curved surface protruding toward the +Y side. That is, the optical lenses **52**, **54**, and **56** are each a plano-convex lens having a +Y-side convex curved surface. At least one of the optical lenses **52**, **54**, and **56** may be any lens that is not a plano-convex lens but can parallelize the blue light BL along the Y direction, such as a biconvex lens, a biconcave lens, a meniscus lens, an aspherical lens, and a freeform surface lens. One or two of the optical lenses **52**, **54**, and **56** may be omitted, or other optical lenses may be added to the optical lenses **52**, **54**, and **56** as long as the blue light BL can be parallelized along the Y direction.

[0048] The light source **20** includes a wavelength converting member **22**, multiple light emitters **10**, mirrors **24** and **26**, and an angle converting member **28**. The light source **20** corresponds to a second light source.

[0049] The wavelength converting member **22** is formed in an elongated quadrangular columnar shape, and has four side surfaces including side surfaces **22***a* and **22***b*, and two end surfaces **22***c* and **22***d*. In the following description about the illuminator **100**, the direction in which the wavelength converting member **22** extends is called an X direction, one direction perpendicular to the X direction is called a Y direction, and the direction perpendicular to the X and Y directions is called a Z direction. One side in the X direction is called a −X side, and the other side in the X direction is called a +X side. One side in the Y direction is called a −Y side, and the other side in the Y direction is called a +Y side. One side in the Z direction is called a −Z side, and the other side in the Z direction is called a +Z side.

[0050] The edges of the wavelength converting member **22** that are parallel to the X direction are longer than the edges of the wavelength converting member **22** that are parallel to the Y direction and the edges thereof that are parallel to the Z direction. The edges parallel to the Y direction and the edges parallel to the Z direction of the wavelength converting member **22** have the same length. The side surfaces **22***a* and **22***b* of the wavelength converting member **22** extend in parallel to the XZ plane containing the X and Z directions, and each have a rectangular shape having long edges parallel to the X direction. The side surface **22***a* is located at a position shifted toward the −Y side from the side surface **22***b*. The end surfaces **22***c* and **22***d* of the wavelength converting member **22** extend in parallel to the YZ plane containing the Y and Z directions, and each have a square shape. The end surface **22***c* is located at a position shifted toward the −X side from the end surface **22***d*.

[0051] The wavelength converting member **22** contains a phosphor, and emits the fluorescence FL when irradiated with excitation light EL. That is, the wavelength converting member **22** converts the incident excitation light EL into the fluorescence FL having a wavelength band different from the wavelength band of the excitation light EL. In the present embodiment, the wavelength converting member **22** converts the excitation light EL having a blue wavelength band into the fluorescence FL having a yellow wavelength band. The yellow wavelength band corresponds to a second wavelength band and contains the same green wavelength band of the green light GL and the same red wavelength band of the red light RL, which enter the color separation system **200** described with reference to FIG. **1**. The green wavelength band is a wavelength band visually recognized as green in the visible wavelength band, and is, for example, a wavelength band from 490 nm to 600 nm. The red wavelength band is a wavelength band visually recognized as red in the visible wavelength band, and is, for example, a wavelength band from 600 nm to 740 nm.

[0052] The wavelength converting member **22** contains a ceramic phosphor configured with a polycrystalline phosphor that converts the excitation light EL in terms of wavelength into the fluorescence FL. Specifically, the material of the wavelength converting member **22** is, for example, YAG: Ce containing an yttrium-aluminum-garnet-based (YAG-based) phosphor and cerium (Ce) as an activator. The wavelength converting member **22** is made, for example, of a material produced by mixing raw powder materials containing yttrium oxide (Y_2O_3), aluminum oxide (Al_2O_3), cerium oxide (CeO_3), and other constituent elements with one another and causing the mixture to go through a solid-phase reaction, Y—Al—O amorphous particles produced by using a coprecipitation method, a sol-gel method, or any other wet method, or YAG particles produced by using a spray-drying method, a flame-based thermal decomposition method, a thermal plasma method, or any other gas-phase method.

[0053] Note that the wavelength converting member **22** may contain a single crystal phosphor that converts the excitation light EL in terms of wavelength into the fluorescence FL in place of the polycrystalline phosphor described above. The wavelength converting member **22** may instead be made of fluorescent glass that converts the excitation light EL in terms of wavelength into the fluorescence FL. The wavelength converting member **22** may still instead be configured with a binder which is made of glass or resin and in which a large number of phosphor particles are dispersed, and may convert the excitation light EL in terms of wavelength into the fluorescence FL.

[0054] The multiple light emitters **10** are disposed at the same position in the Y direction along an XZ plane shifted toward the −Y side from the side surface **22***a* of the wavelength converting member **22**, are disposed at intervals in the X direction in the XZ plane but at the same position in the Z direction, as shown in FIG. **2**. The multiple light emitters **10** are supported by a substrate, a support member, or any other element that is not shown but is provided, for example, with wires that supply the light emitters **10**, for example, with electric signals.

[0055] The light emitters **10** each emit the excitation light EL via a light emitting surface **10***e* toward the +Y side along the Y direction. The light emitting surface **10***e* of each of the light emitters **10** is a +Y-side end surface extending substantially in parallel to the XZ plane, and faces the side surface **22***a* of the wavelength converting member **22**. A lens, a diffuser, or any other optical element that is not shown may be disposed between the light emitters **10** and the wavelength converting member **22** in the Y direction. The blue wavelength band of the excitation light EL is a wavelength band over which the wavelength converting member **22** can be excited to emit the fluorescence FL as described above, and is, for example, a wavelength band from 400 nm to 480 nm. The peak wavelength of the excitation light EL is, for example, 445 nm, and is equal to the wavelength at which the wavelength converting member **22** is excited. The light emitters **10** are each, for example, an LED that emits the excitation light EL. The excitation light EL emitted from each of the light emitters **10** is non-polarized light and randomly polarized light.

[0056] When the excitation light EL emitted from each of the light emitters **10** enters the wavelength converting member **22** via the side surface **22***a* thereof, the phosphor in the wavelength converting member **22** is excited, and the fluorescence FL is emitted in many directions from light emitting points created in the wavelength converting member **22**. The fluorescence FL emitted from the phosphor in the wavelength converting member **22** is repeatedly totally reflected off the side surfaces **22***a* and **22***b* and the side surfaces extending in parallel to the XY plane containing the X and Y directions, and travels toward the end surfaces **22***c* and **22***d*. The wavelength converting member **22** functions as a light guide member that guides the fluorescence FL. The mirror **24** is disposed on the +Y side of the side surface **22***b* of the wavelength converting member **22** and is in contact with the side surface **22***b*. The mirror **24** reflects part of the excitation light EL which enters the wavelength converting member **22** via the side surface **22***a*, and which travels through the interior of the wavelength converting member **22** and reaches the end surface **22***c* from the −Y side. The excitation light EL reflected off the mirror **24** at the side surface **22***b* is reused to excite the wavelength converting member **22**. The mirror **24** may reflect the fluorescence FL guided through the interior of the wavelength converting member **22** and incident on the side surface **22***b* from the −Y side. The mirror **24** is configured, for example, with a dielectric multilayer film or a metal thin film formed separately from the wavelength converting member **22**, and is directly formed on the +Y side of the side surface **22***b*.

[0057] Note that when the amount of the excitation light EL that enters the wavelength converting member **22** via the side surface **22***a* and can exit via the side surface **22***b* toward the +Y side is small, the mirror **24** may be omitted.

[0058] The mirror **26** is disposed on the −X side of the end surface **22***c* of the wavelength converting member **22** and is in contact with the end surface **22***c*. The mirror **26** reflects the fluorescence FL guided through the interior of the wavelength converting member **22** and reaching the end surface **22***c* from the +X side. The fluorescence FL reflected off the mirror **26** at the end surface **22***c* is guided again through the interior of the wavelength converting member **22** and travels toward the end surface **22***d*. The mirror **26** is configured, for example, with a dielectric multilayer film or a metal thin film formed separately from the wavelength converting member **22**, and is directly formed on the −X side of the end surface **22***c*. Note that the mirror **26** may include a substrate made, for example, of glass and a reflection film such as a dielectric multilayer film or a metal film formed at one surface of the substrate.

[0059] The angle converting member **28** is disposed on the +X side of the end surface **22***d* of the wavelength converting member **22**. The angle converting member **28** is formed, for example, in a truncated quadrangular pyramidal shape. The angle converting member **28** has a −X-side end surface, a +X-side end surface, and four side surfaces. The fluorescence FL guided from the −X side to the end surface **22***d* of the wavelength converting member **22** and exiting via the end surface **22***d* is incident on the −X-side end surface of the angle converting member **28**. The fluorescence FL exits as yellow light YL via the +X-side end surface of the angle converting member **28**.

[0060] At least part of the fluorescence FL output via the end surface **22***d* of the wavelength converting member **22** toward +X side at a wide angle around the X direction is totally reflected off the four side surfaces of the angle converting member **28** toward the +X-side end surface of the angle converting member **28**. The optical axis AX**1** of the fluorescence FL in the angle converting member **28** is parallel to the X direction. The cross section of the angle converting member **28** that is perpendicular to the optical axis AX**1** widens as the angle converting member **28** extends from the −X-side end surface toward the +X-side end surface. That is, the +X-side end surface of the angle converting member **28** is larger than the −X side-end surface thereof.

[0061] The fluorescence FL having entered the angle converting member **28** changes its orientation while propagating through the interior of the angle converting member **28** in such a way that the orientation of the fluorescence FL approaches the direction parallel to the optical axis AX**1** whenever the fluorescence FL is totally reflected off the side surfaces as described above. The angle converting member **28** converts the exiting angle distribution of the fluorescence FL output via the end surface **22***d* of the wavelength converting member **22**. Specifically, since the etendue of light specified by the product of the area of a region from which light exits and the solid angle, that is, the largest exiting angle of the light is preserved, the etendue of the fluorescence FL is preserved before the fluorescence FL enters the angle converting member **28** and after the fluorescence FL exits out of the angle converting member **28**. As described above, since the area of the +X-side end surface of the angle converting member **28** is greater than the area of the −X-side end surface thereof, the angle converting member **28** causes the largest exiting angle of the fluorescence FL exiting via the +X-side end surface to be smaller than the largest incident angle of the fluorescence FL incident on the −X-side end surface to preserve the etendue.

[0062] The −X-side end surface of the angle converting member **28** faces the end surface **22***d* of the wavelength converting member **22** and is fixed to the wavelength converting member **22** via an optical adhesive that is not shown. That is, the angle converting member **28** and the wavelength converting member **22** are coupled to each other in the X direction via the optical adhesive, and no gap is provided between the wavelength converting member **22** and the angle converting member **28**. The angle converting member **28** is made of a transparent material such as optical glass. The refractive index of the angle converting member **28** is preferably close to the refractive index of the wavelength converting member **22**.

[0063] Noted that the angle converting member **28** may be configured with a compound parabolic concentrator (CPC) in place of the truncated quadrangular pyramidal member described above and shown in FIG. **2**. The angle converting member **28** may be omitted as long as the etendue of the fluorescence FL output from the wavelength converting member **22** falls within a certain condition.

[0064] The fluorescence FL exits along the +X direction as the yellow light YL via the +X-side end surface of the angle converting member **28**. The yellow light YL output from the light source **20** is non-polarized light, for example, randomly polarized light, and corresponds to second light.

[0065] The optical lenses **32**, **34**, and **36** are disposed in the optical path of the fluorescence FL output from the light source **20**, are disposed at positions shifted toward the +X side from the light source **20**, and overlap with the light source **20** in the Y and Z directions. The optical lenses **32**, **34**, and **36** are sequentially arranged at intervals from the −X side toward the +X side along the X direction. The optical axis of the fluorescence FL passing through the optical lenses **32**, **34**, and **36** is parallel to the optical axis AX**1** of the fluorescence FL output from the light source **20**, and coincides with the optical axis AX**1** in the form of a straight line. The optical lenses **32**, **34**, and **36** parallelize the fluorescence FL output from the light source **20** along the X direction. That is, the fluorescence FL, that is, the yellow light YL, which are parallel to the X direction, exits via the +X-side light exiting surface of the optical lens **36**.

[0066] The light incident surface of each of the optical lenses **32**, **34**, and **36** is a planar surface parallel to the YZ plane. The light exiting surfaces of the optical lenses **32**, **34**, and **36** are each a convex curved surface protruding toward the +X side. That is, the optical lenses **32**, **34**, and **36** are each a plano-convex lens having a +X-side convex curved surface. At least one of the optical lenses **32**, **34**, and **36** may be any lens that is not a plano-convex lens but can parallelize the fluorescence FL along the X direction, such as a biconvex lens, a biconcave lens, a meniscus lens, an aspherical lens, and a freeform surface lens. One or two of the optical lenses **32**, **34**, and **36** may be omitted, or other optical lenses may be added to the optical lenses **32**, **34**, and **36** as long as the fluorescence FL can be parallelized along the X direction.

[0067] The optical axes AX**1** and AX**2** intersect with each other at a predetermined position shifted toward the +X side from the optical lens **36** and toward the +Y side from the optical lens **56**. The light combiner **60** contains the predetermined position, where the optical axes AX**1** and AX**2** intersect with each other, and is disposed in a region where the yellow light YL output from the optical lens **36** toward the +X side along the X direction and the blue light BL output from the optical lens **56** toward the +Y side along the Y direction are superimposed on each other. The light combiner **60** includes a substrate **62** and a reflection film **64**, and has reflection surfaces **60***a* and **60***b*.

[0068] The substrate **62** is made of a material that transmits light having the visible wavelength band and is transparent to the light having the visible wavelength band. The plate surfaces of the substrate **62** incline by 45° with respect to the Y and X directions and incline by 45° with respect to the YZ and XZ planes when viewed along the Z direction. The plate surfaces of the substrate **62** extend from the −Y side toward the +Y side as they extend from the −X side toward the +X side. The substrate **62** and the reflection film **64** have sizes in the X direction that are approximately equal to the size of the blue light BL in the X direction, which is incident on the reflection film **64** from the −Y side through the substrate **62**, and each have an appropriate margin at the outer circumference. Similarly, the substrate **62** and the reflection film **64** have sizes in the Y direction that are approximately equal to the size of the yellow light YL in the Y direction, which is incident on the reflection film **64** from the −X side, and each have an appropriate margin at the outer circumference. The substrate **62** and the reflection film **64** have sizes in the Z direction that are approximately equal to the size of the larger one of the yellow light YL in the Z direction, which is incident on the reflection film **64** from the −X side, and the blue light BL in the Z direction, which is incident on the reflection film **64** from the −Y side through the substrate **62**, and each have an appropriate margin at the outer circumference.

[0069] The reflection film **64** is disposed at the +Y-side surface of the substrate **62** of the light combiner **60**, and is in contact with the +Y-side plate surface of the substrate **62**. The reflection film **64** reflects part of the yellow light YL incident from the −X side along the X direction at the reflection surface **60***b* toward the +Y side along the Y direction, and transmits at least part of the remainder of the yellow light YL. The reflection film **64** transmits part of the blue light BL incident from the −Y side along the Y direction, and reflects at least part of the remainder of the blue light BL at the reflection surface **60***a* toward the +X side along the X direction. The light combiner **60** combines the blue light BL passing through the reflection film **64** and the yellow light YL reflected off the reflection film **64** with each other to generate the white light WL, that is, the illumination light.

[0070] The reflection film **64** is, for example, a yellow reflective dichroic mirror (YDM), and is configured with a dielectric multilayer film. The transmittance and reflectance of the reflection film **64** in each of the blue wavelength band and the yellow wavelength band are controlled with high precision by adjusting conditions such as a difference in refractive index between low-refractive-index layers and high-refractive-index layers that constitute the dielectric multilayer film, the layer thickness of each of the low-refractive-index layers, the layer thickness of each of the high-refractive-index layers, and the number of layers.

[0071] The reflectance of the reflection film **64** in the blue wavelength band is at least higher than 0%, but is lower than the transmittance of the reflection film **64** in the blue wavelength band. The reflectance of the reflection film **64** in the blue wavelength band is preferably higher than or equal to 0.01% but lower than or equal to 10.00%, more preferably, higher than or equal to 1.0% but lower than or equal to 5.0%. In the case described above, the transmittance of the reflection film in the blue wavelength band is higher than or equal to about 90.0% but lower than or equal to about 99.0%. The transmittance of the reflection film **64** in the yellow wavelength band is at least higher than 0%, but is lower than the reflectance of the reflection film **64** in the yellow wavelength band. The transmittance of the reflection film **64** in the yellow wavelength band is preferably higher than or equal to 0.01% but lower than or equal to 10.00%, more preferably, higher than or equal to 1.0% but lower than or equal to 5.0%. In the case described above, the reflectance of the reflection film in the yellow wavelength band is higher than or equal to about 90.0% but lower than or equal to about 99.0%. Accordingly, the amount of the white light WL output from the illuminator **100**, that is, the illumination light is secured, and the light receiving sensor **90** sufficiently receives information on the amount of each of the blue light BL and the yellow light YL in the white light WL.

[0072] The lower limit of the reflectance of the reflection film **64** in the blue wavelength band is determined by the minimum ratio of the amount of the blue light BL that can be detected by a detector **91** of the light receiving sensor **90** and clearly distinguished from the background and noise to the amount of the blue light BL that enters the light combiner **60**. Similarly, the lower limit of the transmittance of the reflection film **64** in the yellow wavelength band is determined by the minimum ratio of the amount of the yellow light YL that can be detected by the detector **91** of the light receiving sensor **90** and clearly distinguished from the background and noise to the amount of the yellow light YL that enters the light combiner **60**. Note that when the reflectance of the reflection film **64** in the blue wavelength band exceeds the upper limit, the white light WL output from the illuminator **100** is lost by an excessively large amount. When the transmittance of the reflection film **64** in the yellow wavelength band exceeds the upper limit, the white light WL output from the illuminator **100** is also lost by an excessively large amount.

[0073] FIG. **3** is a diagrammatic view showing the dependence of the color light transmittance and reflectance of the reflection film **64**, which is configured with a YDM, on the wavelength. There is almost no internal absorption in the substrate **62** and the reflection film **64**, so that the sum of the color light transmittance and the reflectance of the reflection film **64** can be regarded as one, that is, 100%, as shown in FIG. **3**. The transmittance of the reflection film **64** for the blue light BL and the reflectance of the reflection film **64** for the yellow light YL are controlled with high precision when the reflection film **64** is manufactured. That is, since the reflection film **64** is configured with a YDM, the color light transmittance proportional to the thickness of each layer that constitutes the dielectric multilayer film as the YDM is controlled with high precision when the reflection film **64** is manufactured. The thus configured reflection film **64** prevents the amounts of the blue light BL and the yellow light YL output from the reflection film **64** toward the light receiving sensor **90** from not falling within a predetermined range, so that the light receiving sensor **90** is produced at an improved yield. Furthermore, the reflectance of the +Y-side surface of the reflection film **64**, that is, the reflection surface **60***b* for the yellow light YL or the blue light BL is measured to accurately determine the transmittance of the −Y-side surface of the substrate **62**, that is, the reflection surface **60***b* for the blue light BL or the yellow light YL by calculation without measurement.

[0074] As described above, since there is no internal absorption in the dielectric multilayer film as a YDM, the yellow light YL passes through the dielectric multilayer film by a large amount, that is, a large amount of yellow light YL is incident on the light receiving sensor **90**, so that the light receiving sensor **90** outputs a signal having an improved signal-to-noise ratio. The stray light in the illuminator **100** is thus suppressed in a simplified manner.

[0075] FIG. **4** is a diagrammatic view showing the dependence of color light transmittance and reflectance on the wavelength in a case where a metal thin film is disposed at the +Y-side plate surface of the substrate **62**. In this case, the color light reflectance does not depend on the wavelength but is substantially constant. Even when the thickness of the metal thin film varies, the color light reflectance is constant, but the color light transmittance significantly varies. Within a predetermined range of the thickness of the metal thin film, the color light transmittance drastically as decreases the thickness increases. Therefore, when the metal thin film is disposed at the +Y-side plate surface of the substrate **62**, it is difficult to control the thickness of the metal thin film being manufactured and hence the color light transmittance, so that the light receiving sensor is produced at a reduced yield.

[0076] The −Y-side surface of the reflection film **64** faces the light exiting surface of the optical lens **56** and the light receiving surface of the light receiving sensor **90**, constitutes the reflection surface **60***a* of the light combiner **60**, and corresponds to a first surface. The +Y-side surface of the reflection film **64** faces the light exiting surface of the optical lens **36** and the light incident surface of the first lens array **71**, constitutes the reflection surface **60***b* of the light combiner **60**, and corresponds to a second surface.

[0077] The light receiving sensor **90** is disposed on the optical axis AX**1** and shifted toward the +X side from the light combiner **60**, and overlaps with the light source **20** and the light combiner **60** in the Y and Z directions. The light receiving sensor **90** is disposed in the optical path of the blue light BL and the yellow light YL output from the light combiner **60** toward the +X side along the X direction and the optical axis AX**1**.

[0078] The light receiving sensor **90** includes a single multicolor sensor capable of measuring the amounts of multiple kinds of color light, that is, multiple kinds of light having multiple wavelength bands. Specifically, the light receiving sensor **90** includes detectors **91**, **92**, and **93** capable of detecting multiple kinds of color light having wavelength bands different from each other. The detector **91** detects the optical intensity or the amount of the incident blue light BL. The detector **92** detects the optical intensity or the amount of the green light GL out of the incident yellow light YL. The detector **93** detects the optical intensity or the amount of the red light RL out of the incident yellow light YL. That is, in the illuminator **100**, the amount of the blue light BL and the amounts of the green light GL and the red light RL contained in the yellow light YL are measured with the single multicolor sensor.

[0079] The light receiving sensor **90** in the present embodiment detects the blue light BL having the blue wavelength band with the single detector **91**, and detects the yellow light YL having the yellow wavelength band with the two detectors **92** and **93**, as described above. Note that the light receiving sensor **90** may detect the blue light BL with multiple detectors capable of detecting blue light having wavelength bands contained in the blue wavelength band but different from each other. That is, the light receiving sensor **90** may include multiple detectors capable of detecting color light having wavelength bands contained in a single wavelength band but different from each other. A complicated variation in the spectrum of the color light containing the blue light BL and the yellow light YL can thus be detected in the form of a change in an integral value. A multicolor sensor can detect two integral values separately, for example, a result of integration of the optical output over the measurement range of the green light GL, that is, a green light integral value, and a result of integration of the optical output over the measurement range of the red light RL, that is, a red light integral value with the aid, for example, of color filters.

[0080] FIG. **5** is a diagrammatic view showing an example of an electric signal, that is, data output from the light receiving sensor **90**. In the light receiving sensor **90**, an electric signal SB relating to the amount of the blue light BL detected with the detector **91**, an electric signal SG relating to the amount of the green light GL detected with the detector **92**, and an electric signal SR relating to the amount of the red light RL detected with the detector **93** are continuously output in time series toward the controller **120**. In the light receiving sensor **90**, there is no waiting period between the electric signals SB and SG output in a single set and between the electric signals SG and SR output in the single set, as shown in FIG. **5**. Assuming that brightness CL**1** of the blue light BL and the yellow light YL in a certain set is 100%, brightness CL**2** of the blue light BL and the yellow light YL in the next set changes from 100%, for example, to 85%. A data transfer period IT**1** and a waiting period IT**2**, for which the detector is switched to another, occur for the first time between the timing at which the electric signal SR is output and the timing at which the electric signal SB in the next set is output. The period for which the electric signals SB, SG, and SR are transferred in time series is thus minimized.

[0081] FIG. **6** is a diagrammatic view showing an example of electric signals, that is, data output from a light receiving sensor of related art. The light receiving sensor of related art includes two sensors configured separately from each other. The two sensors include a first sensor that acquires an electric signal relating to the amount of blue light and a second sensor that acquires an electric signal relating to the amount of red light. When the light receiving sensor of related art is used, the period for which the electric signals SB, SG, and SR are transferred in time series is longer than the period required when the light receiving sensor **90** in the present embodiment is used due to the sum of the time difference in the time series between the first sensor and the second sensor shifted from each other, and the transfer period IT**1** and the waiting period IT**2** in each of the sensors, as shown in FIG. **6**.

[0082] The first lens array **71** is disposed on the optical axis AX**2** at a position shifted toward the +Y side from the light combiner **60**, and overlaps with the light source **20** and the light combiner **60** in the X and Z directions. The first lens array **71** is disposed in the optical path of the blue light BL and the yellow light YL output from the light combiner **60** toward the +Y side along the Y direction and the optical axis AX**2**.

[0083] The first: lens array **71** includes multiple microlenses **72**. The multiple microlenses **72** are arranged in a matrix in a region of an XZ plane around the optical axis AX**2**. The multiple microlenses **72** divide the white light WL output from the light combiner **60** and incident from the −Y side into multiple sub-luminous fluxes in the XZ plane. The microlenses **72** viewed along the Y direction each have a quadrangular shape substantially similar to the shape of an image formation region in which the multiple pixels of each of the light modulators **400**B, **400**R, and **400**G are arranged. The sub-luminous fluxes output from the first lens array **71** are thus efficiently incident on the image formation region of each of the light modulators **400**B, **400**G, and **400**R. The microlenses **72** are each, for example, a plano-convex lens having a +Y-side convex curved surface.

[0084] The second lens array **76** is disposed at a position shifted toward the +Y side from the first lens array **71** and overlaps with the first lens array **71** in the X and Z directions. The second lens array **76** is disposed in the optical path of the white light WL containing the blue light BL and the yellow light YL output from the first lens array **71** toward the +Y side along the Y direction and the optical axis AX**2**.

[0085] The second lens array **76** includes multiple microlenses **77**. The multiple microlenses **77** are arranged in a matrix in a region of an XZ plane around the optical axis AX**2**, and face the multiple microlenses **72**. The multiple microlenses **77** correspond to the multiple microlenses **72** of the first lens array **71**. The second lens array **76** cooperates with the superimposing lens **82** to form images of the multiple microlenses **72** of the first lens array **71** in the vicinity of each of the image formation regions of the light modulators **400**R, **400**G, **400**B. The microlenses **77** are each, for example, a plano-convex lens having a −Y-side convex curved surface.

[0086] The microlenses **77** of the second lens array **76** each have the same size as each of the microlenses **72** of the first lens array **71** in an XZ plane. The sizes of the microlenses **72** and **77** in the XZ plane may, however, differ from each other. The microlenses **72** of the first lens array **71** and the microlenses **77** of the second lens array **76**, which correspond to the microlenses **72**, are so located that the optical axes of the color light that enter the two types of microlenses coincide with each other, but may instead be so located that the optical axes deviate from each other.

[0087] The polarization converter **80** is disposed at a position shifted toward the +Y side from the second lens array **76** and overlaps with the second lens array **76** in the X and Z directions. The polarization converter **80** is disposed in the optical path of the white light WL output from the second lens array **76** toward the +Y side along the Y direction and the optical axis AX**2**. The polarization converter **80** converts the polarization direction of the white light WL output from the second lens array **76**. Specifically, the polarization converter **80** converts the sub-luminous fluxes that form the white light WL output from the second lens array **76** into linearly polarized light.

[0088] The polarization converter **80** includes polarization separating layers, reflection layers, and phase retarding layers, none of which is shown. The polarization separating layers transmit one linearly polarized component of the polarized components contained in the white light WL output from the second lens array **76**, and reflect the other linearly polarized component in a direction perpendicular to the optical axis AX**2**. The reflection layers reflect the other linearly polarized component reflected off the polarization separating layers in the direction parallel to the optical axis AX**2**. The phase retarding layers convert the other linearly polarized component reflected off the reflection layers into the one linearly polarized component.

[0089] The superimposing lens **82** is disposed at a position shifted toward the +Y side from the polarization converter **80** and overlaps with the polarization converter **80** in the X and Z directions. The superimposing lens **82** is, for example, a biconvex lens having-Y-side and the +Y-side convex curved surfaces. Note that the superimposing lens **82** may not be a biconvex lens but may, for example, be a plano-convex lens, a meniscus lens, an aspherical lens, a freeform surface lens.

[0090] The first lens array **71**, the second lens array **76**, and the superimposing lens **82** constitute an optical integration system. The optical integration system functions as a uniform illumination system that homogenizes the optical intensity distribution of the yellow light YL output from the light source **20** and the optical intensity distribution of the blue light BL output from the light source **40** in a plane perpendicular to the optical axis passing through each of the light modulators **400**B, **400**G, and **400**R, which are each an illumination receiving region.

[0091] The white light WL output from the superimposing lens **82** travels toward the +Y side along the optical axis AX**2** and enters the color separation system **200** shown in FIG. **1**.

[0092] The controller **120** is electrically coupled to the light receiving sensor **90**, and receives the electric signals output from the light receiving sensor **90** in a wired or wireless manner. The controller **120** adjusts the voltage or current supplied to the light emitter **50** of the light source **40** and the voltage or current supplied to the multiple light emitters **10** of the light source **20** in accordance with the intensities of the electric signals output from the light receiving sensor **90** and the relative relationship between the intensities.

[0093] Specifically, the controller **120** receives the electric signal SB relating to the optical intensity or the amount of the blue light BL incident on the detector **91** of the light receiving sensor **90**, and an electric signal SY relating to the optical intensity or the amount of the yellow light YL incident on the detectors **92** and **93** of the light receiving sensor **90**. The controller **120** supplies the light emitter **50** with an electric signal S1 relating to a voltage or a current that realizes an optical intensity or amount required for the blue light BL. The controller **120** supplies the multiple light emitters **10** with the electric signal S**1** relating to a voltage or a current that realizes an optical intensity or amount required for the yellow light YL.

[0094] For example, when the intensity of the electric signal SB is smaller than a predetermined value, the controller **120** increases the intensity of the electric signal S**1** to increase the voltage or current supplied to the light emitter **50** of the light source **40**. When the intensity of the electric signal SB is greater than a predetermined value, the controller **120** reduces the intensity of the electric signal S**1** to reduce the voltage or current supplied to the light emitter **50** of the light source **40**. Similarly, when the intensity of the electric signal SY is smaller than a predetermined value, the controller **120** increases the intensity of an electric signal S**2** to increase the voltage or current supplied to the light emitters **10** of the light source **20**. When the intensity of the electric signal SY is greater than a predetermined value, the controller **120** reduces the intensity of the electric signal S**2** to reduce the voltage or current supplied to the light emitters **10** of the light source **20**. The range of the predetermined value of the intensity of the electric signal SB relating to the blue light BL and the range of the predetermined value of the intensity of the electric signal SY relating to the yellow light YL are set in accordance with the color balance of the white light WL, that is, the illumination light, and desired color balance required for an image projected from the projection system **600** of the projector **1000**.

[0095] The spectrum of the yellow light YL output from the light source **20** varies depending on the period for which and the environment in which the illuminator **100** is used. The yellow light YL contains the green light GL having the green wavelength band contained in the yellow wavelength band and red light RL having the red wavelength band contained in the yellow wavelength band but different from the green wavelength band. The green wavelength band corresponds to a third wavelength band. The green light GL corresponds to third light. The red wavelength band corresponds to a fourth wavelength band. The red light RL corresponds to fourth light.

[0096] FIG. **7** is a diagrammatic view of the spectrum of the yellow light YL output from the light source **20**. For example, out of the green light GL and the red light RL contained in the yellow light YL, only the spectrum of the green light GL within the wavelength range over which the green light GL is measured may change, and the spectrum the red light RL within the wavelength range over which the red light RL is measured may not substantially change, as shown in FIG. **7**. The change in the spectrum of the green light GL is detected in the form of an integral value by the detector **92** of the light receiving sensor **90**. The light source **20** uses the multiple light emitters **10**, which are configured with LEDs arranged along the X direction, as described above. Therefore, the spectrum of the yellow light YL output from the light source **20** is more likely to vary depending on the period for which and the environment in which the illuminator **100** is used than the spectrum of the yellow light YL output from a light source including a fixed or wheel-shaped wavelength converter using laser diodes (LDs) as the light source of the excitation light.

[0097] To control the color balance of the illumination light from the illuminator **100** by using the controller **120**, the ratio among the optical intensity or the amount of the blue light BL emitted from the light emitter **50** of the light source **40**, the optical intensity or the amount of the green light GL output from the light source **20**, and the optical intensity or the amount of the red light RL output from the light source **20** is maintained within a fixed range. For example, in related-art control of the color balance of the illumination light, the integration of the optical output within the range over which the yellow light YL is measured, that is, a yellow light integral value is estimated from a red light integral value, and the estimated yellow light integral value and a measured blue light integral value are used in some cases. In this case, when the spectrum of the yellow light YL varies in a complicated manner as shown in FIG. **7**, an erroneous estimated yellow light integral value may be provided, so that illumination light having erroneous color balance, that is, unexpected color balance may be output from the illuminator. In contrast, in the illuminator **100** according to the present embodiment, the green light integral value and the red light integral value are separately determined by the detectors **92** and **93**. As a result, the color balance of the white light WL output from the superimposing lens **82** disposed as the last element, that is, the illumination light can be accurately adjusted.

[0098] The controller **120** is, for example, a computer or a tablet terminal, and is configured with a processor including a built-in program that carries the processes described above. The controller **120** may further have the function of outputting electric signals relating to images to be projected to the light modulators **400**B, **400**G, and **400**R of the projector **1000**.

[0099] The illuminator **100** according to the first embodiment described above includes the light source (first light source) **40**, the light source (second light source) **20**, the light combiner **60**, and the light receiving sensor **90**. The light source **40** outputs the blue light (first light) BL having the blue wavelength band (first wavelength band). The light source **20** outputs the yellow light (second light) YL having the yellow wavelength band (second wavelength band) different from the blue wavelength band. The light combiner **60** has the +Y-side reflection surface (first surface) **60***a* and the −Y-side reflection surface (second surface) **60***b* different from the reflection surface **60***a*. The light receiving sensor **90** receives at least part of the yellow light YL and at least part of the blue light BL. The light combiner **60** includes the substrate **62** and the reflection film **64** configured with a dielectric multilayer film layered on the substrate. The transmittance of the reflection film **64** for the blue light BL having the blue wavelength band is higher than the reflectance of the reflection film **64** for the blue light BL. The reflectance of the reflection film **64** for the blue light BL is greater than 0%. The transmittance of the reflection film **64** for the yellow light YL having the yellow wavelength band is lower than the reflectance of the reflection film **64** for the yellow light YL. The transmittance and reflectance of the reflection film **64** for the blue light BL are greater than 0%. In the illuminator **100** according to the first embodiment, the blue light BL output from the light source **40** is incident on the reflection surface **60***a*. The yellow light YL output from the light source **20** is incident on the reflection surface **60***b*. The light receiving sensor **90** receives the blue light (light) BL reflected off the reflection surface **60***a* out of the blue light BL that enters the light combiner **60**, and the yellow light (light) YL having passed through the reflection surface **60***b* of the light combiner **60** out of the yellow light YL that enters the light combiner **60**.

[0100] In the illuminator **100** according to the first embodiment, it is not necessary to dispose the light receiving sensor **90** in correspondence with each of the blue light BL and the yellow light YL, so that the illuminator **100** can be reduced in size, configured in a simple manner, and reduced in cost. In addition, in the illuminator **100** according to the first embodiment, it is not necessary to dispose a reflector or a light guide that guides part of the illumination light to the light receiving sensor **90** in the optical path of the white light WL output from the superimposing lens **82** disposed as the last element in the optical path of the color light in the illuminator **100**, that is, the illumination light. The illuminator **100** according to the first embodiment can therefore prevent the illumination light from being partially blocked when a reflector or a light guide is disposed.

[0101] The illuminator **100** according to the first embodiment further includes the controller **120**, which controls the color balance of the white light (light) WL, which is the combination of the blue light BL having been reflected off the reflection film **64** and the yellow light YL having passed through the reflective film **64**. The controller **120** is coupled to the light receiving sensor **90** and receives the electric signal relating to the intensity of the blue light BL output from the light receiving sensor **90** and the electric signal relating to the intensity of the yellow light YL output from the light receiving sensor **90**.

[0102] The illuminator **100** according to the first embodiment can control the color balance of the white light WL, which is the combined light, that is, the illumination light, in accordance with the result of the detection, performed by the light receiving sensor **90**, of the intensity of the blue light BL and the intensity of the yellow light YL.

[0103] In the illuminator **100** according to the first embodiment, the blue light BL incident on the reflection surface **60***a* of the light combiner **60** and the yellow light YL incident on the reflection surface **60***b* of the light combiner **60** each randomly polarized light. The reflection film **64** is a YDM (dichroic mirror).

[0104] In the illuminator **100** according to the first embodiment, the white light WL output from the illuminator **100**, that is, the illumination light is color light that is the combination of the blue light BL and the yellow light YL, and is randomly polarized light, so that interference noise produced by the illumination light can be reduced.

[0105] In the illuminator **100** according to the first embodiment, the light source **40** includes an LED as the light emitter **50**. The light source **20** includes LEDs as the light emitters **10**.

[0106] The illuminator **100** according to the first embodiment can readily produce randomly polarized light in the form of the blue light BL and the yellow light YL.

[0107] In the illuminator **100** according to the first embodiment, the reflectance of the reflection film **64** in the blue wavelength band is greater than or equal to 0.01% but smaller than or equal to 10.0%, and the transmittance of the reflection film **64** in the yellow wavelength band greater than or equal to 0.01% but smaller than or equal to 10.0%.

[0108] The illuminator **100** according to the first embodiment can secure the amount of the white light WL output from the illuminator **100**, that is, the illumination light, and acquire information on the amounts of the blue light BL and the yellow light YL with the light receiving sensor **90**.

[0109] In the illuminator **100** according to the first embodiment, the light source **20** includes the light emitters **10** and the wavelength conversion member **22**. The light emitters **10** each emit the excitation light EL having the blue wavelength band toward the wavelength converting member **22**. The wavelength converting member **22** contains a phosphor, and converts the excitation light EL into the fluorescence FL, which is the yellow light YL having the yellow wavelength band. The wavelength converting member **22** has the end surface (first end surface) **22***c* and the end surface (second end surface) **22***d*, which are located at sides opposite each other in the X direction (longitudinal direction), and the side surfaces that couple the end surfaces **22***c* and **22***d* to each other along the X direction. The end surface **22***c* is the −X-side end surface of the wavelength converting member **22**. The end surface **22***d* is the +X-side end surface of the wavelength converting member **22**. The end surface **22***d* is disposed at a position closer to the reflection surface **60***b* of the light combiner **60** than the end surface **22***c* in the X direction. The yellow light YL exits via the end surface **22***d* of the wavelength converting member **22**.

[0110] The illuminator **100** according to the first embodiment can reduce a heat load generated in the wavelength converting member **22**, which is elongated along the X direction, when the excitation light EL enters the wavelength converting member **22**, so that the durability of the light source **20** can be improved.

[0111] In the illuminator **100** according to the first embodiment, the light receiving sensor **90** separately receives the green light (third light) GL having the green wavelength band (third wavelength band) contained in the yellow wavelength band, and the red light (fourth light) RL having the red wavelength band (fourth wavelength band) contained in the yellow wavelength band but different from the green wavelength band.

[0112] The illuminator **100** according to the first embodiment can detect a complex variation in the spectrum of at least one of the green light GL and the red light RL contained in the yellow light YL output from the light source **20**. As a result, the color balance and other factors of the white light WL output from the illuminator **100**, that is, the illumination light can be controlled with high precision in accordance with the variation in the spectrum of at least one of the green light GL and the red light RL.

[0113] In the illuminator **100** according to the first embodiment, the light receiving sensor **90** includes the multiple detectors **91**, **92**, and **93**. The multiple detectors **91**, **92**, and **93** can detect the blue light BL having the blue wavelength band, the green light GL having the green wavelength band, and the red light RL having the red wavelength band, which have colors different from each other. The multiple detectors **91**, **92**, and **93** continuously output in time series electric signals (data) relating to the amount of the blue light BL, the amount of the green light GL, and the amount of the red light RL detected by the respective detectors.

[0114] In the illuminator **100** according to the first embodiment, electric signals relating to the amounts of the multiple types of color light, that is, the amount of the blue light BL, the amount of the green light GL, and the amount of the red light RL are continuously output from an interface in the light receiving sensor **90** configured as a single multicolor sensor. The illuminator **100** according to the first embodiment, which eliminates the need to secure a waiting period required to switch the detector from one of detectors **91**, **92**, and **93** to another in time series, can shorten the period for which the electric signal relating to the amount of the multiple types of color light is transferred. As a result, the information on the ratio among the amounts of the blue light BL, the green light GL, and the red light RL of the illumination light in the illuminator **100** can be acquired quickly and accurately as compared with the illuminator of related art.

[0115] Although not shown, the light source **40** and the light source **20** may be swapped as a variation of the illuminator **100** according to the first embodiment. That is, the light source **40** may output the blue light BL toward the +X side along the X direction and the optical axis AX**1**. The light source **20** may output the yellow light YL toward the +Y side along the Y direction and the optical axis AX**2**. In the arrangement and configuration described above, the light source **20** corresponds to the first light source, the yellow light YL corresponds to the first light, and the yellow wavelength band corresponds to the first wavelength band. The light source **40** corresponds to the second light source, the blue light BL corresponds to the second light, and the blue wavelength band corresponds to the second wavelength band. The +Y-side surface of the reflection film **64** of the light combiner **60** constitutes the reflection surface **60***a* and corresponds to the first surface. The −Y-side surface of the reflection film **64** of the light combiner **60** constitutes the reflection surface **60***b* and corresponds to the second surface. Even in the apparatus configuration described above, the same effects as those provided by the illuminator **100** according to the first embodiment can be provided.

[0116] The projector **1000** according to the first embodiment includes the illuminator **100** described above, the light modulators **400**B, **400**G, and **400**R, and the projection system **600**. The light modulators **400**B, **400**G, and **400**R modulate the blue light (color light) BL, the green light (color light) GL, and the red light (color light) RL output from the illuminator **100** in accordance with image information, and output the blue image light, the green image light, and the red image light. The projection system **600** projects the blue image light, the green image light, and the red image light output from the light modulators **400**B, **400**G, and **400**R onto the screen SCR.

[0117] The projector **1000** according to the first embodiment can provide a projector including the illuminator **100**, which can have a smaller, simpler configuration than the illuminator of related art. In addition, the projector **1000** according to the first embodiment can acquire the information on the intensity and the amount of each of the blue light BL and the yellow light YL contained in the white light WL output from the illuminator **100**, that is, the illumination light with high precision.

Second Embodiment

[0118] A second embodiment of the present disclosure will next be described with reference to FIG. **8**. Note in the second embodiment that the contents common to those in the first embodiment will be omitted, and only contents different from those in the first embodiment will be described. Out of the elements of a projector and an illuminator **102** according to the second embodiment, the elements common to those of the projector **1000** and the illuminator **100** according to the first embodiment have the same reference characters as the elements of the projector **1000** and the illuminator **100**, and will not be described in detail.

[0119] Although not shown, the projector according to the second embodiment includes the illuminator **102** according to the second embodiment in place of the illuminator **100** according to the first embodiment, and further includes the same configuration as the projector **1000** according to the first embodiment except the illuminator **100**.

[0120] FIG. **8** schematic is a view showing the configuration of the illuminator **102** according to the second embodiment. The illuminator **102** includes light sources **43** and **44**, a dichroic mirror **38**, the light combiner **60**, the light receiving sensor **90**, the first lens array **71**, the second lens array **76**, the polarization converter **80**, the superimposing lens **82**, and the controller **120**, as shown in FIG. **8**. In FIG. **8**, the optical lenses **52**, **54**, and **56** are omitted.

[0121] The light sources **43** and **44** and the dichroic mirror **38** in the illuminator **102** constitute a light source that outputs the yellow light YL, as the light source **20** in the illuminator **100**.

[0122] The light source **43** includes a light emitter **14**. The light emitter **14** is disposed at a position shifted toward the −X side from the light source **40** and the optical lenses **52**, **54**, and **56**, and overlaps with the light source **40** in the Y and Z directions. The light source **43** corresponds to a first sub-light source. The light emitter **14** emits the green light GL via a light emitting surface **14***e* toward the +Y side along the Y direction and an optical axis AX**3**. The optical axis AX**3** is parallel to the optical axis AX**2** and is shifted toward the −X side from the optical axis AX**2**.

[0123] The green light GL emitted from the light emitter **14** corresponds to the third light. The light emitting surface **14***e* of the light emitter **14** is the +Y-side end surface of the light emitter **14** that extends substantially in parallel to the XZ plane. A lens, a diffuser, or any other optical element that is not shown may be disposed on the +Y side of the light emitter **14**. The green wavelength band of the green light GL emitted from the light emitter **14** is contained in the yellow wavelength band, is a portion of the yellow wavelength band, and corresponds to the third wavelength band. The green wavelength band of the green light GL emitted from the light emitter **14** is the same green wavelength band of the green light GL that enters the color separation system **200** described with reference to FIG. **1**. The light emitter **14** is, for example, an LED that emits the green light GL. The green light GL emitted from the light emitter **14** is non-polarized light and randomly polarized light.

[0124] The light emitter **14** may be configured with multiple light emitters **14** the number of which is appropriately determined in accordance with the amount of the green light GL required for the projector **1000**, the color balance of an image projected by the projector **1000**, and other factors. When the illuminator **102** includes multiple light emitters **14**, the multiple light emitters **14** are disposed, for example, at intervals in a region of an XZ plane that is not shown but spreads around the optical axis AX**3** of the green light GL.

[0125] The light source **44** includes a light emitter **12**, as shown in FIG. **8**. The light emitter **12** is disposed at a position shifted toward the −X side and the +Y side from the light emitter **14** of the light source **43**, is disposed on the optical axis AX**1**, and overlaps with the light source **43** in the Z direction. The light source **44** corresponds to a second sub-light source. The light emitter **12** emits the red light RL via a light emitting surface **12***e* toward the +X side along the X direction and the optical axis AX**1**.

[0126] The red light RL emitted from the light emitter **12** corresponds to the fourth light. The light emitting surface **12***e* of the light emitter **12** is the +X-side end surface of the light emitter **12** that extends substantially in parallel to the YZ plane. A lens, a diffuser, or any other optical element that is not shown may be disposed on the +X side of the light emitter **12**. The red wavelength band of the red light RL emitted from the light emitter **12** is contained in the yellow wavelength band, is a portion of the yellow wavelength band, differs from the green wavelength band, and corresponds to the fourth wavelength band. The red wavelength band of the red light RL emitted from the light emitter **12** is the same red wavelength band of the red light RL that enters the color separation system **200** described with reference to FIG. **1**. The light emitter **12** is, for example, an LED that emits the red light RL. The red light RL emitted from the light emitter **12** is non-polarized light and randomly polarized light.

[0127] The light emitter **12** may be configured with multiple light emitters **12** the number of which is appropriately determined in accordance with the amount of the red light RL required for the projector **1000**, the color balance of an image projected by the projector **1000**, and other factors. When the illuminator **102** includes multiple light emitters **12**, the multiple light emitters **12** are disposed, for example, at intervals in a region of an YZ plane that is not shown but spreads around the optical axis AX**1** of the red light RL.

[0128] The optical axis AX**1** of the red light RL emitted from the light emitter **12** of the light source **44** is perpendicular to the optical axis AX**3** of the green light GL, which is emitted from the light emitter **14** of the light source **43**, at a predetermined position. The predetermined position is shifted toward the −X side from the position where the optical axes AX**1** and AX**2** intersect with each other.

[0129] The dichroic mirror **38** contains the predetermined position, where the optical axes AX**1** and AX**3** intersect with each other, and is disposed in a region where the red light RL output from the light source **44** toward the +X side along the X direction and the green light GL output from the light source **43** toward the +Y side along the Y direction are superimposed on each other. The dichroic mirror **38** is a green reflective dichroic mirror (GDM), has a reflection surface, and is configured with a dielectric multilayer film.

[0130] The reflection surface of the dichroic mirror **38** transmits the red light RL incident from the −X side along the X direction toward the +X side, and reflects the green light GL incident from the −Y side along the Y direction toward the +X side along the X direction. The reflection surface of the dichroic mirror **38** extends from the −Y side toward the +Y side as it extends from the −X side toward the +X side. The dichroic mirror **38** combines the green light GL reflected thereby and the red light RL passing therethrough with each other to generate the yellow light YL.

[0131] In the illuminator **102**, the controller **120** supplies the light emitter **14** with an electric signal S**3** relating to a voltage or a current that realizes an optical intensity or amount required for the green light GL in place of the electric signal S**2**, and supplies the light emitter **12** with an electric signal S**4** relating to a voltage or a current that realizes an optical intensity or amount required for the red light RL.

[0132] In the illuminator **102** according to the second embodiment described above, the light source (second light source) **20** includes the light source (first sub-light source) **43** and the light source (second sub-light source) **44**. The light source **43** outputs the green light (third light) GL having the green wavelength band (third wavelength band) contained in the yellow wavelength band. The light source **44** outputs the red light (fourth light) RL having the red wavelength band (fourth wavelength band) contained in the yellow wavelength band but different from the green wavelength band.

[0133] In the illuminator **102** according to the second embodiment, in which the three light sources **40**, **43**, and **44** generate the three types of color light including the blue light BL, the green light GL, and the red light RL, the color gamut of the white light WL output from the superimposing lens **82** disposed as the last element, that is, the illumination light can be expanded.

[0134] The illuminator **102** according to the second embodiment can provide the same effects and advantages as those provided by the arrangement and configuration common to those of the illuminator **100** according to the first embodiment.

[0135] Although not shown, the light source **43** and the light source **44** may be swapped as a variation of the illuminator **102** according to the second embodiment. That is, the light source **43** may output the green light GL toward the +X side along the X direction and the optical axis AX**1**. The light source **44** may output the red light RL toward the +Y side along the Y direction and the optical axis AX**3**. In the arrangement and configuration described above, the reflection surface of the dichroic mirror **38** transmits the green light GL incident from the −X side along the X direction toward the +X side, and reflects the red light RL incident from the −Y side along the Y direction toward the +X side along the X direction. The dichroic mirror **38** combines the green light GL passing therethrough and the red light RL reflected thereby with each other to generate the yellow light YL. According to the arrangement and configuration described above, the same effects and advantages as those provided by the illuminator **102** according to the second embodiment can be provided.

Third Embodiment

[0136] A third embodiment of the present disclosure will next be described with reference to FIG. **9**. In the third embodiment, the contents common to those in the first and second embodiments will be omitted, and only contents different from those in the first and second embodiments will be described. Out of the elements of a projector and an illuminator **104** according to the third embodiment, the elements common to those of the projector **1000** and the illuminator **100** according to the first embodiment have the same reference characters as the elements of the projector **1000** and the illuminator **100**, and will not be described in detail.

[0137] Although not shown, the projector according to the third embodiment includes the illuminator **104** according to the third embodiment in place of the illuminator **100** according to the first embodiment, and further includes the same configuration as the projector **1000** according to the first embodiment except the illuminator **100**.

[0138] FIG. **9** is a schematic view showing the configuration of the illuminator **104** according to the third embodiment. The illuminator **104** includes the light sources **43** and **44**, the dichroic mirror **38**, the light combiner **60**, the light receiving sensor **90**, the first lens array **71**, the second lens array **76**, the polarization converter **80**, the superimposing lens **82**, and the controller **120**, as the illuminator **102** according to the second embodiment, as shown in FIG. **9**. Also in FIG. **9**, the optical lenses **52**, **54**, and **56** are omitted.

[0139] The light source **40** includes a light emitter **58** in place of the light emitter **50**. The light emitter **58** emits the blue light BL via a light emitting surface **58***e* toward the +X side along the Y direction and an optical axis AX**2**. The light emitter **58** is, for example, an LD that emits the blue light BL. The blue light BL emitted from the light emitter **58** is linearly polarized light, for example, P-polarized light. The polarization direction of the blue light BL is parallel to the X direction.

[0140] The light source **43** includes a light emitter **16** in place of the light emitter **14**. The light emitter **16** emits the green light GL via a light emitting surface **16***e* toward the +Y side along the Y direction and an optical axis AX**3**. The light emitter **16** is an LD that emits the green light GL. The light source **44** includes a light emitter **18** in place of the light emitter **12**. The light emitter **18** outputs the red light RL via a light emitting surface **18***e* toward the +X side along the X direction and the optical axis AX**1**. The light emitter **18** is an LD that emits the red light RL. The green light GL emitted from the light emitter **16** and the red light RL emitted from the light emitter **18** are each linearly polarized light. The yellow light YL as a result of the combination performed by the dichroic mirror **38** is, for example, S-polarized light. The polarization direction of the blue light BL is parallel to the X direction.

[0141] The light combiner **60** is, for example, a cube-shaped polarizing beam splitter, and includes two right-angle prisms **62**A and **62**B and the reflection film **64**. The reflection film **64** is disposed at the bonding surface between the inclining surfaces of the two right-angle prisms **62**A and **62**B. The reflection film **64** is provided at the inclining surface of the right-angle prism **62**A, and the right-angle prism **62**A functions as a substrate in the light combiner **60**.

[0142] The right-angle prisms **62**A and **62**B are made of a material that transmits light having the visible wavelength band and is transparent to the light having the visible wavelength band. The inclining surfaces of the right-angle prisms **62**A and **62**B each incline by 45° with respect to the Y and X directions and incline by 45° with respect to the YZ and XZ planes when viewed along the Z direction. The inclining surfaces of the right-angle prisms **62**A and **62**B extend from the −Y side toward the +Y side as they extend from the −X side toward the +X side.

[0143] The right-angle prisms **62**A and **62**B and the reflection film **64** have sizes in the X direction that are approximately equal to the size of the blue light BL in the X direction, which is incident on the reflection film **64** from the −Y side through the right-angle prism **62**A, and each have an appropriate margin at the outer circumference. Similarly, the right-angle prisms **62**A and **62**B and the reflection film **64** have sizes in the Y direction that are approximately equal to the size of the yellow light YL in the Y direction, which is incident on the reflection film **64** from the −X side through the right-angle prism **62**B, and each have an appropriate margin at the outer circumference. The right-angle prisms **62**A and **62**B and the reflection film **64** have sizes in the Z direction that are approximately equal to the size of the larger one of the yellow light YL in the Z direction, which is incident on the reflection film **64** from the −X side through the right-angle prism **62**B, and the blue light BL in the Z direction, which is incident on the reflection film **64** from the −Y side through the right-angle prism **62**A, and each have an appropriate margin at the outer circumference.

[0144] The white light WL as a result of the combination performed by the light combiner **60**, that is, the illumination light contains the P-polarized blue light BL and the S-polarized yellow light YL, and enters the first lens array **71** as non-polarize or randomly polarized light. The white light WL converted into linearly polarized light by the polarization converter **80** of the illuminator **104** exits out of the superimposing lens **82**, as in the illuminator **100** according to the first embodiment and the illuminator **102** according to the second embodiment.

[0145] In the illuminator **104** according to the third embodiment described above, the blue light BL incident on the reflection surface **60***a* of the light combiner **60** and the yellow light YL incident on the reflection surface **60***b* are each linearly polarized light. The light combiner **60** is configured, for example, with a cube-shaped polarizing beam splitter. The reflection film **64** of the light combiner **60** is configured with a dielectric multilayer film disposed between the two right-angle prisms **62**A and **62**B of the cube-shaped polarizing beam splitter.

[0146] In the illuminator **104** according to the third embodiment, in accordance with the amounts of shift of the polarization axes of the blue light BL, the green light GL, and the red light RL, which are linearly polarized light, with respect to the orientations of the S-polarization and the P-polarization axes in the polarizing beam splitter, the optical intensities of the multiple types of color light incident on the detectors **91**, **92**, and **93** of the light receiving sensor **90** can be readily adjusted.

[0147] The illuminator **104** according to the third embodiment can provide the same effects and advantages as those provided by the arrangements and configurations common to those of the illuminator **100** according to the first embodiment and the illuminator **102** according to the second embodiment. Furthermore, the variation described with reference to the illuminator **102** according to the second embodiment may be applied to the illuminator **104** according to the third embodiment.

[0148] A cube-shaped polarizing beam splitter is presented by way of example as the light combiner **60** in the illuminator **104** according to the third embodiment, and a plate-shaped polarizing beam splitter having a substrate and the reflection film **64** may be used in place of the cube-shaped polarizing beam splitter.

[0149] Although not shown, the polarizing beam splitter may be made of a nonlinear optical crystal. A prism made of a birefringent material or a combination of a Glan Taylor prism and a wedge prism may, for example, be used as the light combiner **60** in the illuminator **104** according to the third embodiment. Even when the configuration described above is used, the optical intensities of the multiple types of color light incident on the detectors **91**, **92**, and **93** of the light receiving sensor **90** can be readily adjusted in accordance with the amounts of shift of the polarization axes of the multiple types of color light with respect to the orientations of the S-polarization and the P-polarization axes in the polarizing beam splitter and the light combiner **60**.

[0150] Preferable embodiments of the present disclosure have been described above in detail. The present disclosure is, however, not limited to a specific embodiment, and various modifications and changes can be made to the embodiments within the scope of the gist of the present disclosure described in the claims. The configurations of the multiple embodiments and variations of the embodiments may be combined with each other as appropriate.

Summary of Present Disclosure

[0151] The present disclosure will be summarized below in the form of additional remarks.

[0152] (Additional remark **1**) An illuminator including a first light source configured to output first light having a first wavelength band; a second light source configured to output second light having a second wavelength band different from the first wavelength band; a light combiner having a first surface and a second surface different from the first surface; and a light receiving sensor configured to receive the first light and the second light, wherein the light combiner includes a substrate, and a reflection film layered on the substrate, the reflection film has transmittance higher than reflectance in the first wavelength band, and the reflectance is higher than 0% in the first wavelength band, the reflection film has transmittance lower than the reflectance in the second wavelength band, and the transmittance is higher than 0% in the second wavelength band, the first light is incident on the first surface, the second light is incident on the second surface, and the light receiving sensor is configured to receive the first light reflected off the first surface and the second light passing through the second surface.

[0153] The configuration described in Additional remark **1** allows reduction in the size of the illuminator, a simple configuration of the illuminator, and reduction in the overall cost including the manufacturing cost and the installation cost. The configuration according to Additional remark **1** can further prevent the illumination light from being partially blocked when a reflector or a light guide is disposed as in the illuminator or related art.

[0154] (Additional remark **2**) The illuminator according to Additional remark **1**, further including a controller configured to control color balance of combined light containing the first light reflected off the reflection film and the second light passing through the reflection film.

[0155] According to the configuration described in Additional remark **2**, the color balance of illumination light that is the combined light output from the illuminator can be controlled in accordance with the result of detection, performed by the light receiving sensor, of the intensity of the first light and the intensity of the second light.

[0156] (Additional remark **3**) The illuminator according to Additional remark **1** or **2**, wherein the first light incident on the first surface and the second light incident on the second surface are each randomly polarized light, and the reflection film is a dichroic mirror.

[0157] The configuration described in the Additional remark **3** can reduce interference noise produced by illumination light output from the illuminator.

[0158] (Additional remark **4**) The illuminator according to any of Additional remark **1** to **3**, wherein the first and second light sources each include an LED.

[0159] According to the configuration described in Additional remark **4**, the first and second randomly polarized light can be readily generated.

[0160] (Additional remark **5**) The illuminator according to any of Additional remarks **1** to **4**, wherein the reflectance of the reflection film in the first wavelength band is higher than or equal to 0.01% but lower than or equal to 10.00%, and the transmittance of the reflection film in the second wavelength band is higher than or equal to 0.01% but lower than or equal to 10.00%.

[0161] According to the configuration described in Additional remark **5**, the amount of the illumination light output from the illuminator can be secured, and information on the intensities or the amounts of the first light and the second light can be acquired by the light receiving sensor.

[0162] (Additional remark **6**) The illuminator according to any of Additional remarks **1** to **5**, wherein the second light source includes a light emitter configured to emit excitation light, and a wavelength converting member containing a phosphor and configured to convert the excitation light into the second light, the wavelength converting member has a first end surface and a second end surface that are located at sides opposite each other in a longitudinal direction, and a side surface configured to couple the first end surface and the second end surface to each other along the longitudinal direction, the second end surface is disposed at a position closer to the second surface than the first end surface in the longitudinal direction, and the second light exits via the second end surface.

[0163] According to the configuration described in Additional remark **6**, a heat load generated in the elongated wavelength converting member when the excitation light enters the wavelength converting member, so that the durability of the light source can be improved.

[0164] (Additional remark **7**) The illuminator according to Additional remark **6**, wherein the light receiving sensor is configured to receive third light having a third wavelength band contained in the second wavelength band, and fourth light having a fourth wavelength band contained in the second wavelength band but different from the third wavelength band.

[0165] According to the configuration described in Additional remark **7**, a complicated variation in the spectrum of at least one of the third light and the fourth light contained in the second light output from the second light source can be detected. As a result, the color balance and other factors of the illumination light output from the illuminator can be controlled with high precision in accordance with the variation in the spectrum of at least one of the third light and the fourth light.

[0166] (Additional remark **8**) The illuminator according to any of Additional remarks **1** to **7**, wherein the light receiving sensor includes multiple detectors configured to detect multiple types of color light having wavelength bands different from each other, and the multiple detectors are configured to continuously detect amounts of the multiple types of color light in time series and output data on the detected amounts.

[0167] The configuration described in Additional remark **8**, which eliminates the need to secure a waiting period required to switch the detector from one of multiple detectors to another, can shorten the period for which an electric signal relating to the intensities of amounts of the multiple types of color light is transferred. As a result, information on the ratio among the amounts of the multiple types of color light contained in the illumination light in the illuminator can be acquired quickly and accurately as compared with the illuminator of related art.

[0168] (Additional remark **9**) The illuminator according to any of Additional remarks **1** to **8**, wherein the second light source includes a first sub-light source configured to output third light having a third wavelength band contained in the second wavelength band, and a second sub-light source configured to output fourth light having a fourth wavelength band contained in the second wavelength band but different from the third wavelength band. According to the configuration described in Additional remark **9**, the first light source, the first sub-light source, and the second sub-light source separately produce three types of color light to be combined with one another into the illumination light, the color gamut of the illumination light output from the illuminator can be expanded as compared with a case where only the first and second light sources are used.

[0169] (Additional remark **10**) A projector including:

[0170] the illuminator according to any of Additional remarks **1** to **9**; a light modulator configured to modulate color light output from the illuminator in accordance with image information; and a projection system configured to project image light output from the light modulator.

[0171] According to the configuration described in Additional remark **10**, a projector including an illuminator that can have a smaller, simpler configuration than the illuminator of related art can be provided.

What is claimed is:

1. An illuminator comprising:

a first light source configured to output first light having a first wavelength band;

a second light source configured to output second light having a second wavelength band different from the first wavelength band;

a light combiner having a first surface and a second surface different from the first surface; and

a light receiving sensor configured to receive the first light and the second light,

wherein the light combiner includes

a substrate, and

a reflection film layered on the substrate,

the reflection film has transmittance higher than reflectance in the first wavelength band, and the reflectance is higher than 0% in the first wavelength band,

the reflection film has transmittance lower than the reflectance in the second wavelength band, and the transmittance is higher than 0% in the second wavelength band,

the first light is incident on the first surface,

the second light is incident on the second surface, and

the light receiving sensor is configured to receive the first light reflected off the first surface and the second light passing through the second surface.

2. The illuminator according to claim **1**, further comprising

a controller configured to control color balance of combined light containing the first light reflected off the reflection film and the second light passing through the reflection film.

3. The illuminator according to claim **1**, wherein

the first light incident on the first surface and the second light incident on the second surface are each randomly polarized light, and

the reflection film is a dichroic mirror.

4. The illuminator according to claim **1**, wherein

the first and second light sources each include a light emitting diode.

5. The illuminator according to claim **1**, wherein

the reflectance of the reflection film in the first wavelength band is higher than or equal to 0.01% but lower than or equal to 10.00%, and

the transmittance of the reflection film in the second wavelength band is higher than or equal to 0.01% but lower than or equal to 10.00%.

6. The illuminator according to claim **1**, wherein

the second light source includes a light emitter configured to emit excitation light, and

a wavelength converting member containing a phosphor and configured to convert the excitation light into the second light,

the wavelength converting member has a first end surface and a second end surface that are located at sides opposite each other in a longitudinal direction, and a side surface configured to couple the first end surface and the second end surface to each other along the longitudinal direction,

the second end surface is disposed at a position closer to the second surface than the first end surface in the longitudinal direction, and

the second light exits via the second end surface.

7. The illuminator according to claim **6**, wherein

the light receiving sensor is configured to receive third light having a third wavelength band contained in the second wavelength band, and fourth light having a fourth wavelength band contained in the second wavelength band but different from the third wavelength band.

8. The illuminator according to claim **1**, wherein

the light receiving sensor includes multiple detectors configured to detect multiple types of color light having wavelength bands different from each other, and

the multiple detectors are configured to continuously detect amounts of the multiple types of color light in time series and output data on the detected amounts.

9. The illuminator according to claim **1**, wherein

the second light source includes a first sub-light source configured to output third light having a third wavelength band contained in the second wavelength band, and a second sub-light source configured to output fourth light having a fourth wavelength band contained in the second wavelength band but different from the third wavelength band.

10. A projector comprising:

the illuminator according to claim **1**;

a light modulator configured to modulate color light output from the illuminator in accordance with image information; and

a projection system configured to project image light output from the light modulator.

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