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PROJECTOR

Abstract

A projector of the present disclosure includes a light source, a transmissive optical part, a rotating part, a light modulation device, and a control device. The light modulation device has an image forming region containing a plurality of pixels. The transmissive optical part rotates about a first rotational axis to scan the image forming region of the light modulation device with light emitted from the light source. The control device selects the light control target pixel based on image information, and performs light control.

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Background/Summary

[0001] The present application is based on, and claims priority from JP Application Serial Number 2024-023907, 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 a projector.

2. Related Art

[0003] In the past, there has been a projector that temporally scan a light modulation device such as a liquid crystal panel with light emitted from a light emitting part to thereby illuminate the light modulation device. JP-A-2007-225956 discloses a projector including a light source device including a light source lamp, a liquid crystal light valve, a polygonal mirror disposed between the light source device and the liquid crystal light valve, and a projection lens.

[0004] In this projector, the light source device emits light having an elliptical light flux cross section. The polygon mirror reflects the light emitted from the light source device to scan an image forming region of the liquid crystal light valve in a short-axis direction of the elliptical light flux cross section.

[0005] JP-A-2007-225956 is an example of the related art.

[0006] However, when the polygon mirror is used in the scan with the light as in the projector in JP-A-2007-225956, even when perfectly parallel light is made incident on the polygon mirror, the parallelism of the light is impaired by the polygon mirror. That is, since the polygon mirror reflects the light while rotating, the incidence angle ω f the light with respect to the reflecting surface of the polygon mirror changes with time, and the parallel light incident on the polygon mirror turns to light having a predetermined divergence angle to illuminate the image forming region of the liquid crystal light valve. As a result, there is a problem that the light emitted from the light source device cannot efficiently be used.

SUMMARY

[0007] In order to solve the problem described above, according to a first aspect of the present disclosure, there is provided a projector including [0008] a light source unit configured to emit light, [0009] a first transmissive optical part including a first plane of incidence on which the light emitted from the light source unit is incident, and a first exit surface configured to emit the light incident from the first plane of incidence, [0010] a first rotating part configured to rotate the first transmissive optical part, [0011] a light modulation device configured to modulate, based on image information, the light emitted from the first transmissive optical part to generate image light, and [0012] a control device configured to control an output of the light source unit, in which [0013] the light modulation device includes an image forming region containing a plurality of pixels, [0014] the first transmissive optical part is a light transmissive member having the first plane of incidence and the first exit surface parallel to each other, and rotates around a first rotational axis extending along a second direction crossing a first direction which is an incident direction of the light with respect to the first transmissive optical part to thereby scan the image forming region of the light modulation device with the light emitted from the light source unit, [0015] the control device performs light control of adjusting light intensity of the light to be incident on a target pixel in the image forming region by [0016] setting the light control reference value and the target pixel selected from among the plurality of pixels based on the image information, [0017] decreasing the output of the light source unit when a luminance value corresponding to the target pixel in the image light is smaller than a light control reference value, and [0018] increasing the output of the light source unit when the luminance value is larger than the light control reference value when the following formula is satisfied when defining a position coordinate of the target pixel in the image forming region as (px, py), a radius in a scanning direction of the light on the image forming region as r, and a position coordinate of the light on the image forming region at a time t as (dx(t), dy(t)).

√{square root over ({*p*.sub.x-*d*.sub.x(*t*)}.sup.2{*p*.sub.y−*d*.sub.y(*t*)}.sup.2)}≤*r*

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] FIG. **1** is a plan view showing a schematic configuration of a projector according to a first embodiment.

[0020] FIG. **2** is a block diagram showing an electrical configuration of the projector.

[0021] FIG. **3** is a perspective view showing a schematic configuration of a light source device.

[0022] FIG. **4**A is a schematic diagram illustrating a behavior of light during a rotation of a transmissive optical part.

[0023] FIG. **4**B is a schematic diagram showing the behavior subsequent to FIG. **4**A.

[0024] FIG. **4**C is a schematic diagram showing the behavior subsequent to FIG. **4**B.

[0025] FIG. **4**D is a schematic diagram showing the behavior subsequent to FIG. **4**C.

[0026] FIG. **4**E is a schematic diagram showing the behavior subsequent to FIG. **4**D.

[0027] FIG. **4**F is a schematic diagram showing the behavior subsequent to FIG. **4**E.

[0028] FIG. **5** is a schematic diagram showing a transmissive optical part as a simulation model.

[0029] FIG. **6** is a diagram showing a periodic function representing a relationship between a rotation angle and a displacement amount.

[0030] FIG. **7** is a flowchart representing a flow of processing in light control.

[0031] FIG. **8** is a diagram showing a configuration of a principal portion of an image forming region of a first light modulation part.

[0032] FIG. **9** is an image diagram showing a locus of scanning light on the image forming region.

[0033] FIG. **10** is a diagram illustrating the light control when displaying characters shown in FIG. **8**.

[0034] FIG. **11** is a diagram showing a change in a displacement amount of a spot of blue light.

[0035] FIG. **12** is a diagram illustrating the light control in a second modified example.

[0036] FIG. **13** is a plan view showing a schematic configuration of a projector according to a second embodiment.

[0037] FIG. **14** is a side view illustrating a configuration of a second light source unit.

[0038] FIG. **15** is a diagram showing a state of scanning light on a light modulation device.

[0039] FIG. **16** is a cross-sectional view showing a configuration of an essential part of the light modulation device.

DESCRIPTION OF EMBODIMENTS

First Embodiment

[0040] A first embodiment of the present disclosure will hereinafter be described using the drawings.

[0041] A projector according to the present embodiment is an example of a liquid crystal projector using liquid crystal panels as light modulation devices.

[0042] In the following drawings, parts are drawn at different dimensional scales in some cases in order to make the parts eye-friendly.

[0043] FIG. **1** is a plan view showing a schematic configuration of a projector **200** according to the present embodiment.

[0044] As shown in FIG. **1**, the projector **200** according to the present embodiment includes a light source device **1**, a magnifying optical system **2**, a color separation optical system **3**, a light modulation device **30**, an image light combining part **24**, a projection optical device **23**, and a control device CONT.

[0045] The light source device **1** in the present embodiment includes a light source unit **10**, a first

transmissive optical part **13**, a second transmissive optical part **14**, a first rotating part **15**, and a second rotating part **16**. The light source unit **10** includes a first light source unit **101**, a second light source unit **102**, a third light source unit **103**, and a light combining optical system **104**. The control device CONT controls drive of each of the light source unit **10**, the first rotating part **15**, and the second rotating part **16**.
[0046] FIG. **2** is a block diagram showing an electrical configuration of the projector **200**.
[0047] As shown in FIG. **2**, the control device CONT is configured with a computer or an integrated circuit which incorporates processing in each of drive devices for driving the light source device **1** and the light modulation device **30** as a program. That is, the control device CONT is, for example, a processor. The control device CONT is coupled to the light source device **1** and the light modulation device **30** wirelessly or by wire (not shown).
[0048] The control device CONT includes a first light source drive unit CON**1** that controls drive of the first light source unit **101**, a second light source drive unit CON**2** that controls drive of the second light source unit **102**, a third light source drive unit CON**3** that controls drive of the third light source unit **103**, a first rotation drive unit CON**4** that controls drive of the first rotating part **15**, a second rotation drive unit CON**5** that controls drive of the second rotating part **16**, and a panel drive unit CON**6** that controls drive of the light modulation device **30**.
[0049] Since the control device CONT in the present embodiment collectively performs the light control of the light source unit **10**, the drive control of the rotating parts **15**, **16**, and the drive control of the light modulation device **30**, simple and accurate control becomes possible.
[0050] In the following descriptions, an X-Y−Z orthogonal coordinate system will be used as needed in the drawings. The X axis is an axis parallel to the optical axis AX of the light source unit **10**. The optical axis AX of the light source unit **10** is defined as an axis along a principal ray of illumination light WL described later that is emitted from the light source unit **10**. An optical axis AX**2** of the second light source unit **102** coincides with the optical axis AX of the light source unit **10**. The optical axis AX**2** of the second light source unit **102** is defined as an axis along a principal ray of green light LG described later and emitted from the second light source unit **102**. The Y axis is an axis which is perpendicular to the X axis and extends along a rotational axis of the first transmissive optical part **13**. The Z axis is an axis perpendicular to the X axis and the Y axis. The optical axis AX**1** of the first light source unit **101** is defined as an axis along a principal ray of blue light LB described later and emitted from the first light source unit **101**. An optical axis AX**3** of the third light source unit **103** is defined as an axis along a principal ray of red light LR described later and emitted from the third light source unit **103**. An X-axis direction in the present embodiment corresponds to a “first direction” in the appended claims. A Y-axis direction in the present embodiment corresponds to a “second direction” in the appended claims. A Z-axis direction in the present embodiment corresponds to a “third direction” in the appended claims.
[0051] The first light source unit **101** is arranged such that the optical axis AX**1** of the first light source unit **101** is orthogonal to the optical axis AX**2** of the second light source unit **102**. The third light source unit **103** is arranged such that the optical axis AX**3** of the third light source unit **103** is orthogonal to the optical axis AX**2** of the second light source unit **102**. The first light source unit **101** emits the blue light (first light) LB toward the −Z side. The third light source unit **103** emits the red light (third light) LR toward the −Z side. The second light source unit **102** emits the green light (second light) LG toward the +X side. In this example, the first light source unit **101** is disposed at a side closer to the second light source unit **102**, and the third light source unit **103** is disposed at a side farther from the second light source unit **102**, but this arrangement may be reversed.
[0052] The first light source unit **101** includes a first light emitting part **25** and a substrate **29**. The first light emitting part **25** is formed of a laser diode that emits a light beam in a first wavelength band. Therefore, the light beam emitted from the first light emitting part **25** is linearly-polarized light having coherency, and is a laser beam narrow in light flux width and high in parallelism. The first wavelength band is, for example, a blue wavelength band in a range of 450 nm±5 nm. That is,

the first light emitting part **25** emits the blue light LB as the first light.

[0053] The second light source unit **102** includes a second light emitting part **26** and a substrate **29**. The second light emitting part **26** is formed of a laser diode that emits a light beam in a second wavelength band different from the first wavelength band. The light beam emitted from the second light emitting part **26** is linearly-polarized light having coherency, and is a laser beam narrow in light flux width and high in parallelism. The second wavelength band is, for example, a green wavelength band in a range of 530 nm±5 nm. That is, the second light emitting part **26** emits the green light LG as the second light.

[0054] The third light source unit **103** includes a third light emitting part **27** and a substrate **29**. The third light emitting part **27** is formed of a laser diode that emits a light beam in a third wavelength band different from the first wavelength band and the second wavelength band. The light beam emitted from the third light emitting part **27** is linearly-polarized light having coherency, and is a laser beam narrow in light flux width and high in parallelism. The third wavelength band is, for example, a red wavelength band in a range of 650 nm±5 nm. That is, the third light emitting part **27** emits the red light LR as the third light.

[0055] Note that in the present embodiment, the laser diodes are cited as the light emitting parts **25**, **26**, and **27**, but this is not a limitation, and it is possible to use a light source such as an LED or a lamp, and an optical system for adjusting the polarization direction of the light, an optical system for adjusting the light flux width, a color wheel, and so on in combination with each other.

[0056] The light combining optical system **104** includes a first light combining part **105** and a second light combining part **106**. The first light combining part **105** is disposed at a position where the optical axes AX**1**, AX**2** cross each other. The first light combining part **105** includes a dichroic mirror that transmits green light and reflects blue light. The second light combining part **106** is provided at a position where the optical axes AX**2**, AX**3** cross each other. The second light combining part **106** is formed of a dichroic mirror that transmits the green light LG and the blue light LB and reflects the red light LR. The light combining optical system **104** combines the blue light LB emitted from the first light source unit **101**, the green light LG emitted from the second light source unit **102**, and the red light LR emitted from the third light source unit **103** with each other to generate white light LW. Thus, the light source unit **10** emits the white light LW. The white light LW enters the first transmissive optical part **13** without being separated according to the wavelength band.

[0057] The first transmissive optical part **13** is disposed between the light source unit **10** and the second transmissive optical part **14** on the optical axis of the light source unit **10**. The first transmissive optical part **13** is formed of a light transmissive member that is rotatably supported. The first transmissive optical part **13** is made rotatable around the first rotational axis C**1** extending along the Y-axis direction. The first rotational axis C**1** is coupled to the first rotating part **15** formed of a motor or the like. The first transmissive optical part **13** rotates about the first rotational axis C**1** by the drive of the first rotating part **15**.

[0058] FIG. **3** is a perspective view showing a schematic configuration of the light source device **1**. In FIG. **3**, in order to make the drawing eye-friendly, illustration of the light source unit **10** is omitted.

[0059] As shown in FIG. **3**, as the glass material of the light transmissive member constituting the first transmissive optical part **13**, there is used a light transmissive material such as optical glass such as BK**7**, quartz, or resin. The first transmissive optical part **13** includes a first surface **13**_a_ and a second surface **13**_b_ crossing the first rotational axis C**1**, and four first side surfaces **13**_c_ having perpendicular contact with the first surface **13**_a_ and the second surface **13**_b_. That is, the first transmissive optical part **13** has a square prismatic shape having six planar surfaces including the first surface **13**_a_, the second surface **13**_b_, and the four first side surfaces **13**_c_. A cross-sectional shape of the first transmissive optical part **13** cut by a plane perpendicular to the first rotational axis C**1** is a square shape. That is, the four first side surfaces **13**_c_ have the same area as each other, and any pair of first side surfaces **13***c* opposed to each other are parallel to each other.

[0060] The first transmissive optical part **13** transmits the illumination light WL as white light emitted from the light source unit **10** while rotating about the first rotational axis C**1**. Therefore, the first side surface **13***c*, from which the illumination light WL emitted from the light source unit **10** enters the first transmissive optical part **13**, is not uniquely determined, but changes with time. Similarly, the first side surface **13***c*, from which the illumination light WL having entered the first transmissive optical part **13** is emitted to an outside space, is not uniquely determined, but changes with time. In the first transmissive optical part **13**, the first side surface **13***c* on which the illumination light WL emitted from the light source unit **10** is incident is referred to as a first plane of incidence. The first side surface **13***c*, from which the illumination light WL incident on the first plane of incidence is emitted, is referred to as a first exit surface. The first plane of incidence and the first exit surface change with time, and are any of the pair of first side surfaces **13***c* parallel to each other out of the four first side surfaces **13***c*.

[0061] In the present specification, when two surfaces of the light transmissive member are referred to as surfaces parallel to each other, when an angle between the two surfaces falls within a range of 0±5 degrees is referred to as “parallel” in consideration of the processing accuracy of the glass material constituting the light transmissive member, an allowable range of the parallelism of the light, and so on.

[0062] In the case of the present embodiment, the first transmissive optical part **13** has the four first side surfaces **13***c*, but the number of first side surfaces **13***c* is not necessarily four, but is desirably 2×m (m is a natural number no smaller than 2). That is, the number of first side surfaces **13***c* is preferably an even number no smaller than 4 such as 6 or 8. When the number of first side surfaces **13***c* is the even number no smaller than 4, all the first side surfaces **13***c* each become parallel to the first side surface **13***c* opposed to that first side surface **13***c*, and there is no first side surface **13***c* which fails to have a counterpart parallel thereto. Thus, the stray light rarely occurs in the first transmissive optical part **13**, and it is possible to increase the light use efficiency.

[0063] The second transmissive optical part **14** is disposed at the light exit side of the first transmissive optical part **13** on the optical axis AX of the light source unit **10**. The second transmissive optical part **14** is formed of a light transmissive member that is rotatably supported. The second transmissive optical part **14** is made rotatable around the second rotational axis C**2** extending along the Z-axis direction. That is, the first rotational axis C**1** and the second rotational axis C**2** extend in directions perpendicular to each other in an imaginary plane perpendicular to the optical axis AX. The second rotational axis C**2** is coupled to the second rotating part **16** formed of a motor or the like. The second transmissive optical part **14** rotates about the second rotational axis C**2** by the drive the second rotating part **16**.

[0064] The light transmissive member that constitutes the second transmissive optical part **14** is substantially the same as the light transmissive member that constitutes the first transmissive optical part **13**. As the glass material of the light transmissive member, a light transmissive material such as optical glass such as BK**7**, quartz, or resin is used. In particular, in the case of the second transmissive optical part **14**, unlike the first transmissive optical part **13**, since the illumination light LW which has been used for scanning in one direction by the first transmissive optical part **13** is incident on the second transmissive optical part **14**, the illumination light WL incident on the second transmissive optical part **14** is lower in light density than the illumination light WL at the time point when entering the first transmissive optical part **13**. Therefore, the possibility that a resin material low in light resistance and heat resistance can be used is higher than in the case of the first transmissive optical part **13**.

[0065] The second transmissive optical part **14** has a third surface **14***a* and a fourth surface **14***b* crossing the second rotational axis C**2**, and four second side surfaces **14***c* having perpendicular contact with the third surface **14***a* and the fourth surface **14***b*. That is, the second transmissive optical part **14** has a square prismatic shape having six planar surfaces including the third surface

14*a*, the fourth surface **14***b*, and the four second side surfaces **14***c*. A cross-sectional shape of the second transmissive optical part **14** cut by a plane perpendicular to the second rotational axis C**2** is a square shape. The four second side surfaces **14***c* have the same area as each other, and any pair of the second side surfaces opposed to each other are parallel to each other.

[0066] The second transmissive optical part **14** transmits the illumination light WL emitted from the first transmissive optical part **13** while rotating around the second rotational axis C**2**. Therefore, the second side surface from which the illumination light WL emitted from the first transmissive optical part **13** enters the second transmissive optical part **14** is not uniquely fixed but changes with time. Similarly, the second side surface from which the illumination light WL incident on the second transmissive optical part **14** is emitted to the outside space is not uniquely fixed, but changes with time. In the second transmissive optical part **14**, the second side surface on which the illumination light WL emitted from the first transmissive optical part **13** is incident is referred to as a second plane of incidence. The second side surface from which the illumination light WL incident on the second plane of incidence is emitted is referred to as a second exit surface. In this case, the second plane of incidence and the second exit surface change with time, and are any of the two second side surfaces parallel to each other out of the four second side surfaces **14***c*.

[0067] The second transmissive optical part **14** has the four second side surfaces **14***c* in the case of the present embodiment, but the number of second side surfaces is not necessarily required to be four, and is desirably 2×n (n is a natural number no smaller than 2). That is, the number of second side surfaces is desirably an even number such as six or eight. When the number of second side surfaces is the even number, all the second side surfaces each become parallel to the second side surface opposed to that second side surface, and there is no second side surfaces parallel to each other. Thus, the stray light rarely occurs in the second transmissive optical part **14**, and it is possible to increase the light use efficiency.

[0068] The first transmissive optical part **13** and the second transmissive optical part **14** both have a square prismatic shape in the present embodiment, but may be different in shape as long as a plane of incidence and an exit surface parallel to each other are provided.

[0069] The first transmissive optical part **13** is shown in FIG. **2** so as to be the same in size as the second transmissive optical part **14**, but may instead have a side in the Y-axis direction shorter in length than a side in the X-axis direction and a side in the Z-axis direction since the first transmissive optical part **13** performs the scanning with the illumination light WL in the Z-axis direction but does not perform the scanning in the Y-axis direction as described later. That is, the first transmissive optical part **13** may have a rectangular parallelepiped shape having a side in the Y-axis direction shorter in length than a side in the X-axis direction and a side in the Z-axis direction instead of the shape approximate to the square parallelepiped shape shown in FIG. **2**. Thus, a reduction in thickness of the first transmissive optical part **13** can be achieved. In that case, the second transmissive optical part **14** becomes larger in dimension than the first transmissive optical part **13**, but a resin material can be used in the second transmissive optical part **14** as described above since the light density of the incident light is low. When the resin material is used as the glass material of the light transmissive members, since the second transmissive optical part **14** is reduced in weight, a reduction in size of the second rotating part **16** can be achieved.

[0070] At least one of the first transmissive optical part **13** and the second transmissive optical part **14** may be formed of quartz. In each of the first transmissive optical part **13** and the second transmissive optical part **14**, the light intensity absorbed by the light transmissive member increases as the light intensity transmitted through the light transmissive member increases, and thermal strain is induced in the light transmissive member in some cases. In this case, the polarization direction of the illumination light WL emitted from the light source unit **10** is disturbed, and the linearly polarized light incident on the light transmissive member is converted into elliptically polarized light and is then emitted from the light transmissive member. As a result, it becomes unachievable to obtain the advantage that by using the laser diode for each of the light source units

101, **102**, and **103** in the projector **200**, predetermined contrast can be obtained without providing the incident side polarization plate. That is, although laser diodes are used for the light source units **101**, **102**, and **103**, there arises a necessity of using the incident side polarization plate for uniformizing the polarization directions. Therefore, in order to obtain the advantage described above, it is desirable to use a glass material low in Young's modulus and thermal expansion coefficient as the glass material small in thermal strain, and as an example, it is desirable to use quartz.

[0071] The behavior of the illumination light WL when being transmitted through the first transmissive optical part **13** and the second transmissive optical part **14** will hereinafter be described. Note that since the first transmissive optical part **13** and the second transmissive optical part **14** are substantially the same in function, but are different only in direction from each other, the first transmissive optical part **13** will hereinafter be illustrated and described alone.

[0072] FIGS. **4**A to **4**F are schematic diagrams illustrating the behavior of the illumination light WL when the first transmissive optical part **13** rotates. In this example, the first transmissive optical part **13** rotates clockwise around the first rotational axis C**1** when viewed from the +Y side, and in the drawings, time elapses from the state shown in FIG. **4**A toward the state shown in FIG. **4**F.

[0073] In FIGS. **4**A to **4**F, the angle between the optical axis AX and a straight line M, which passes through the first rotational axis C**1** and is perpendicular to the first side surface **13***c***1** of the first transmissive optical part **13**, is defined as a rotation angle ω of the first transmissive optical part **13**. Further, although the illumination light WL actually has a predetermined light flux width in the Z-axis direction, consideration will be made here focusing attention on the behavior of the light beam WL**1** as a principal ray of the illumination light WL propagating on the optical axis AX.

[0074] FIG. **4**A shows an initial state of the first transmissive optical part **13**. That is, the first transmissive optical part **13** is not rotating, the straight line M overlaps the optical axis AX, and the rotation angle ω is 0 degree. In this case, since the light beam WL**1** is incident on the first side surface **13***c***1** at right angle, the light beam WL**1** is not refracted at the first side surface **13***c***1** but travels inside the first transmissive optical part **13** along the optical axis AX. Then, the light beam WL**1** is also incident on the first side surface **13***c***3**, which is parallel to the first side surface **13***c***1**, at right angle. Therefore, the light beam WL**1** is not refracted at the first side surface **13***c***3**, but is emitted from the first transmissive optical part **13**, and then travels on the optical axis AX.

[0075] Then, as shown in FIG. **4**B, when the first transmissive optical part **13** rotates by the rotation angle ω, the light beam WL**1** is incident on the first side surface **13***c***1** at the incidence angle equal to the rotation angle ω. The light beam WL**1** is therefore refracted in the direction (+Z side) shown in the drawing and then travels inside the first transmissive optical part **13**. Since the light beam WL**1** is then incident on the first side surface **13***c***3** at a predetermined incidence angle, the light beam WL**1** is refracted at the first side surface **13***c***3** and is then emitted from the first transmissive optical part **13**. On this occasion, since the first side surface **13***c***1** and the first side surface **13***c***3** are parallel to each other, the incidence angle of the light beam WL**1** incident on the first side surface **13***c***1** and the incidence angle of the light beam WL**1** incident on the first side surface **13***c***3** are equal to each other, and the refraction angle of the light beam WL**1** incident on the first side surface **13***c***1** and the refraction angle of the light beam WL**1** emitted from the first side surface **13***c***3** are opposite in sign and equal in absolute value. The refraction angle of the light beam WL**1** incident on the first side surface **13***c***1** and the refraction angle of the light beam WL**1** emitted from the first side surface **13***c***3** are canceled each other out. As a result, the light beam WL**1** travels in parallel to the optical axis AX at a position displaced by a displacement amount d from the optical axis AX toward the +Z side.

[0076] Then, as shown in FIG. **4**C, when the rotation angle ω of the first transmissive optical part **13** increases from the value shown in FIG. **4**B, the incidence angle of the light beam WL**1** increases and the refraction angle increases accordingly. Therefore, the displacement amount d of the light beam WL**1** from the optical axis AX becomes larger than in FIG. **4**B. Further, the state in which the light beam WL**1** travels in parallel to the optical axis AX is constantly maintained. When the rotation angle ω is between 0 degree and 45 degrees, the displacement amount d monotonously increases as the rotation angle ω increases.

[0077] Then, as shown in FIG. **4**D, when the rotation angle ω of the first transmissive optical part **13** exceeds 45 degrees, the plane of incidence of light beam WL**1** changes from the first side surface **13***c***1** to the first side surface **13***c***2**. On this occasion, the light beam WL**1** is refracted at the first side surface **13***c***2**, but the refraction direction changes from the direction during the period up to FIG. **4**C, and the light beam WL**1** is refracted in the direction (−Z side) shown in the drawing. Further, although the exit surface of the light beam WL**1** also changes from the first side surface **13***c***3** to the first side surface **13***c***4**, since the first side surface **13***c***2** and the first side surface **13***c***4** are parallel to each other, the situation in which the refraction angle of the light beam WL**1** incident on the first side surface **13***c***3** and the refraction angle of the light beam WL**1** emitted from the first side surface **13***c***4** are canceled each other out remains unchanged from the situation during the period up to FIG. **4**C. As a result, the light beam WL**1** travels in parallel to the optical axis AX at a position displaced by the displacement amount d from the optical axis AX toward the −Z side.

[0078] Then, as shown in FIG. **4**E, when the rotation angle ω of the first transmissive optical part **13** becomes larger than in FIG. **4**D, the incidence angle of the light beam WL**1** decreases and the refraction angle decreases accordingly. Therefore, the displacement amount d of the light beam WL**1** from the optical axis AX becomes smaller than in FIG. **4**D. As described above, when the rotation angle ω is between 45 degrees and 90 degrees, the displacement amount d monotonously decreases as the rotation angle ω increases.

[0079] Then, as shown in FIG. **4**F, when the rotation angle ω of the first transmissive optical part **13** reaches 90 degrees, the plane of incidence changes from the first side surface **13***c***1** as the initial state to the first side surface **13***c***2**, but the behavior of the light beam WL**1** is the same as that in the initial state shown in FIG. **4**A.

[0080] As described above, when the first plane of incidence and the first exit surface of the first transmissive optical part **13** are parallel to each other, the traveling direction of the light beam WL**1** does not change regardless of the rotation angle ω of the first transmissive optical part **13**, and the light beam WL**1** is translated in a direction parallel to the optical axis AX as the time elapses. When the rotation angle ω is 0 degree, the displacement amount d of the light beam WL**1** is 0, and when the rotation angle ω is between 0 degree and 45 degrees, the displacement amount d increases toward either one of the +Z side and the −Z side. At the moment when the rotation angle ω exceeds 45 degrees, the displacement direction is reversed while keeping the absolute value of the displacement amount d the same, when the rotation angle ω is between 45 degrees and 90 degrees, the displacement amount d decreases, and when the rotation angle ω reaches 90 degrees, the displacement amount d becomes 0. After the rotation angle ω exceeds 90 degrees, the behavior described above is repeated. Therefore, when the first transmissive optical part **13** makes one revolution, the displacement amount d of the light beam WL**1** repeats the cycle described above four times. The displacement amount of the light beam WL**1** can be appropriately set by adjusting parameters such as the refractive index and the size of the first transmissive optical part **13**.

[0081] The displacement in one direction due to the first transmissive optical part **13** has only been described above, but the light source device **1** includes the first transmissive optical part **13** and the second transmissive optical part **14** having rotational axes perpendicular to each other. Therefore, the illumination light WL is displaced in two directions perpendicular to each other as the time elapses. Specifically, as shown in FIG. **3**, the first transmissive optical part **13** performs scanning with the illumination light WL emitted from the light source unit **10** in the Z-axis direction, and the second transmissive optical part **14** performs scanning in the Y-axis direction perpendicular to the Z-axis direction. That is, the first transmissive optical part **13** and the second transmissive optical part **14** scan the inside of a two-dimensional illumination target region Q in the illumination target surface, that is, each of the light modulation parts **30**B, **30**G, and **30**R with the illumination light

WL.

[0082] As shown in FIG. **1**, the illumination light WL is incident on the magnifying optical system **2**. The magnifying optical system **2** includes, for example, a concave lens **2***a* and a convex lens **2***b*. The magnifying optical system **2** magnifies the light flux diameter of the illumination light WL emitted from the light source device **1**.

[0083] The illumination light WL having passed through the magnifying optical system **2** is incident on the color separation optical system **3**.

[0084] The color separation optical system **3** separates the illumination light WL emitted from the light source device **1** into the red light LR, the green light LG, and the blue light LB, and guides them to the respective light modulation parts in the light modulation device **30**.

[0085] The light modulation device **30** in the present embodiment includes a first light modulation part **30**B, a second light modulation part **30**G, a third light modulation part **30**R, and half-wave plates **33**B, **33**R.

[0086] The color separation optical system **3** includes a first dichroic mirror **7***a*, a second dichroic mirror **7***b*, a first total reflection mirror **8***a*, a second total reflection mirror **8***b*, and a third total reflection mirror **8***c*.

[0087] The first dichroic mirror **7***a* separates the illumination light WL from the light source device **1** into the blue light LB and light including the green light LG and the red light LR. The first dichroic mirror **7***a* transmits the blue light LB and reflects the light including the green light LG and the red light LR. Meanwhile, the second dichroic mirror **7***b* reflects the green light LG and transmits the red light LR. Accordingly, the second dichroic mirror **7***b* separates the light including the green light LG and the red light LR into the green light LG and the red light LR.

[0088] The first total reflection mirror **8***a* is disposed in a light path of the blue light LB, and reflects the blue light LB transmitted through the first dichroic mirror **7***a*, toward the first light modulation part **30**B. Meanwhile, the second total reflection mirror **8***b* and the third total reflection mirror **8***c* are disposed in a light path of the red light LR, and guide the red light LR transmitted through the second dichroic mirror **7***b*, to the third light modulation part **30**R. The green light LG is reflected from the second dichroic mirror **7***b* toward the second light modulation part **30**G.

[0089] The first light modulation part **30**B includes a light modulation panel **31**B and an exit-side polarization plate **32**B.

[0090] The second light modulation part **30**G includes a light modulation panel **31**G and an exit-side polarization plate **32**G.

[0091] The third light modulation part **30**R includes a light modulation panel **31**R and an exit-side polarization plate **32**R.

[0092] A transmissive liquid crystal panel is used for each of the light modulation panels **31**B, **31**G, and **31**R. A twisted nematic (TN) method, a vertical alignment (VA) method, an in-plane switching (IPS) method, and so on may be used as a method of driving the liquid crystal panels, but the method is not particularly limited. The drive of each of the light modulation panels **31**B, **31**G, and **31**R of the light modulation parts **30**B, **30**G, and **30**R is controlled by the control device CONT electrically coupled thereto.

[0093] Each of the exit-side polarization plates **32**B, **32**G, and **32**R transmits linearly-polarized light in a specific direction. In the case of the present embodiment, the light source units **101**, **102**, and **103** of the light source device **1** emit laser beams as the blue light LB, the green light LG, and the red light LR, and therefore, it is possible to omit a light incident side polarization plate of each of the light modulation parts **30**B, **30**G, and **30**R.

[0094] The blue light LB is temporally superimposed by two-dimensionally scanning the image forming region of the first light modulation part **30**B with the blue light LB. The first light modulation part **30**B modulates the blue light LB based on, for example, blue image information (first image information) input from an external device to the control device CONT to form blue image light (first image light) B.

[0095] The green light LG is temporally superimposed by two-dimensionally scanning the image forming region of the second light modulation part **30**G with the green light LG. The second light modulation part **30**G modulates the green light LG based on, for example, green image information (second image information) input from an external device to the control device CONT to form green image light (second image light) G.
[0096] The red light LR is temporally superimposed by two-dimensionally scanning the image forming region of the third light modulation part **30**R with the red light LR. The third light modulation part **30**R modulates the red light LR based on, for example, red image information (third image information) input from an external device to the control device CONT to form red image light (third image light) R.
[0097] Upon incidence of the image light emitted from the first light modulation part **30**B, the image light emitted from the second light modulation part **30**G, and the image light emitted from the third light modulation part **30**R, the image light combining part **24** combines the image light corresponding to the blue light LB, the image light corresponding to the green light LG, and the image light corresponding to the red light LR with each other to output the image light thus combined toward the projection optical device **23**. As the image light combining part **24**, there is used, for example, a cross dichroic prism.
[0098] The half-wave plates **33**B, **33**R are disposed between the first light modulation part **30**B and the image light combining part **24** and between the third light modulation part **30**R and the image light combining part **24**, respectively. The half-wave plates **33**B, **33**R apply a phase difference of a half wavelength to the incident colored light to rotate the polarization direction of the linearly-polarized light by 90 degrees. This makes it possible to make the polarization direction of the green light LG incident on the image light combining part **24** different from the polarization direction of the blue light LB and the red light LR incident on the image light combining part **24**. According to this configuration, the light use efficiency of the image light combining part **24** can be increased.
[0099] The projection optical device **23** is formed of a plurality of projection lenses. The projection optical device **23** projects the image light emitted from the image light combining part **24** toward a projection target surface such as a screen in an enlarged manner. Thus, an image is displayed on the projection target surface.
[0100] When the light modulation part is temporally scanned with the light transmitted through the transmissive optical part rotating as described above, unevenness usually occurs in the illuminance distribution formed on the light modulation part. The present inventors performed a simulation in order to examine how various parameters such as the refractive index and shape of the transmissive optical part affect the illuminance distribution in the illumination target region. The simulation results will be described below.
[0101] FIG. **5** is a schematic diagram showing a transmissive optical part **18** serving as a model of the simulation. In the transmissive optical part, it is sufficient for the cross-sectional shape perpendicular to the rotational axis to be a regular n-gon (n is an even number no smaller than 4), but in FIG. **5**, the cross-sectional shape of the transmissive optical part **18** is assumed as a square (n=4). Further, a distance between surfaces opposed to each other of the transmissive optical part **18** is denoted by I, a refractive index of an external space of the transmissive optical part **18** is denoted by n**1**, and a refractive index of the transmissive optical part **18** is denoted by n**2**.
[0102] As illustrated in FIG. **5**, an optical axis AX of a light source unit (not shown) that emits the light beam WL**1** toward the transmissive optical part **18** passes through the center of the rotational axis O of the transmissive optical part **18**. The light beam WL**1** travels in parallel to the optical axis AX, enters a first plane of incidence **18***a* of the transmissive optical part **18** at an incidence angle θ**1** at a point P**1**, and is refracted at a refractive angle θ**2**, and is then emitted from a first exit surface **18***b* of the transmissive optical part **18** at a point P**2**, and travels in parallel to the optical axis AX.
[0103] The light beam WL**1** transmitted through the transmissive optical part **18** which is rotating

travels in parallel to the optical axis AX at a position shifted by the displacement amount d corresponding to the rotation angle of the transmissive optical part **18** in a direction orthogonal to (crossing) the optical axis AX. Therefore, Formula (1) described below is established between the displacement amount d, the incidence angle θ**1**, and the refraction angle θ**2** of the light beam WL**1** based on Snell's law.

[00001]
$$\begin{aligned} d &= l(\tan\ _1 - \tan\ _2)\ \text{.Math.}\ \cos\ _1 \\ &= l[\tan\ _1 - \tan\{\sin^{-1}(\tfrac{n_1}{n_2}\sin\ _i)\}]\cos\ _1 \end{aligned} \qquad (1)$$

[0104] Further, the maximum incidence angle θmax of the light beam WL**1** in the transmissive optical part **18** is expressed by Formula (2) described below.

[00002] .Math. $_{max}$ .Math. $= \frac{180}{n}$ (2)

[0105] Here, for example, regrading Formula (1), when it is assumed that the distance **1** between the surfaces opposed to each other of the transmissive optical part **18** is 20 mm, the refractive index n**1** of the external space is n**1**=1.0 (air), the rotation angle (degree) is plotted on the horizontal axis, the displacement amount (mm) is plotted on the vertical axis, and the refractive index n**2** of the transmissive optical part **18** is plotted at an appropriate interval from 1.3 to 1000, the relationship between the rotation angle and the displacement amount can be expressed by a periodic function. Further, when the refractive index n**2** of the transmissive optical part **18** is increased toward infinity with respect to this periodic function, the relationship between the rotational angle and the displacement amount can be defined by an ideal sine wave with the amplitude I.

[0106] Since the rotation angle of the transmissive optical part **18** is equal to the incidence angle θ**1**, it is sufficient for the rotation angle of the transmissive optical part **18** to be considered within a range of the maximum incidence angle θmax of the light beam WL**1** as a result. Further, the maximum incidence angle θmax of the transmissive optical part **18** is determined in accordance with the cross-sectional shape as expressed by Formula (2). That is, when the cross-sectional shape of the transmissive optical part **18** is a square as shown in FIG. **5**, the maximum incidence angle θmax is maximized (to 45 degrees).

[0107] Therefore, when the light beam WL**1** traveling on the optical axis AX passing through the rotation center of the transmissive optical part **18** is displaced in a direction perpendicular to the optical axis AX by being transmitted through the transmissive optical part **18**, it is thought to be sufficient to consider within an angle range of ±45 degrees with respect to the periodic function representing the relationship between the rotation angle and the displacement amount of the transmissive optical part **18** having a square shape.

[0108] The present inventors focus attention on the point that the uniformity of the illuminance distribution of light in the illumination target region can be improved as the linearity of the graph increases.

[0109] FIG. **6** is a graph showing a relationship between the rotation angle and the displacement amount of the transmissive optical part **18** having a square shape. In FIG. **6**, the horizontal axis represents the rotation angle (degree), and the vertical axis represents the displacement amount (mm). The graph with a reference symbol A shows when the refractive index n**2** is 1.63. The graph with a reference symbol B shows when the refractive index n**2** is 2.22. The graph with a reference symbol C shows when the refractive index n**2** is 2.46. The graph with a reference symbol D shows when the refractive index n**2** is 2.91. The graph with a reference symbol E shows when the refractive index n**2** is 3.05. The graph with a reference symbol F shows when the refractive index n**2** is 3.27.

[0110] Note that in FIG. **6**, the solid lines denoted by the reference symbols A to F are graphs representing the periodic function representing the relationship between the rotation angle and the displacement amount of the transmissive optical part **18** in an angle range of 0 degree to 45 degrees, and the broken lines denoted by the reference symbols A**1** to F**1** are graphs showing linear approximations of the periodic functions denoted by the reference symbols A to F.

[0111] As shown in FIG. **6**, it can be confirmed that the linearity of the graph increases as the refractive index n**2** of the transmissive optical part **18** increases. That is, when the cross-sectional shape of the transmissive optical part **18** is a square, the linearity of the graph increases as the refractive index increases, and the uniformity of the illuminance distribution of the light in the illumination target region can be improved. For example, when the refractive index of the transmissive optical part **18** is set to 2.91, the solid line and the broken line overlap each other, and therefore, the linearity of the graph becomes sufficiently high, and thus, the uniformity of the illuminance distribution of the light in the illumination target region can sufficiently be improved.

[0112] In contrast, it is poor in implementation at this stage to form the transmissive optical part **18** with a material having a refractive index of 3.0 or higher, and there is a limit in improving the uniformity of the illuminance distribution by devising the material of the transmissive optical part **18**.

[0113] In this regard, the present inventors have found that the refractive index necessary for increasing the linearity of the graph differs depending on the shape of the transmissive optical part.

[0114] A relationship between the refractive index of the transmissive optical part and the shape (regular n-gon) of the transmissive optical part is shown in Table 1. Note that in Table 1, air (refractive index: 1.0) was assumed as the medium outside the transmissive optical part. Further, in Table 1, the determination coefficient, which is the square value (denoted by R**2**) of the correlation coefficient, is set to 0.995 or more in the approximate expression. Note that in Table 1, "-" means that the material is not limited as long as the refractive index is higher than 1.0.

TABLE-US-00001 TABLE 1

REGULAR	R2					
n-GON	0.995	0.999	0.9995	0.9999	0.99995	0.99999
n = 4	1.63	2.22	2.46	2.91	3.05	3.27
n = 6	1.14	1.69	1.96	2.57	2.80	3.20
n = 8	—	1.30	1.54	2.18	2.45	2.99
n = 10	—	1.03	1.24	1.83	2.11	2.73
n = 12	—	—	1.02	1.55	1.83	2.48

[0115] As shown in Table 1, when the cross-sectional shape of the transmissive optical part **18** is a square (n=4), by setting the refractive index of the transmissive optical part **18** to be equal to or greater than 1.63, the determination coefficient of the graph representing the displacement amount becomes 0.995, and the linearity of the graph can be enhanced. In contrast, when the cross-sectional shape of the transmissive optical part is a regular hexagonal shape, the determination coefficient of the graph can be set to 0.995 by setting the refractive index of the transmissive optical part **18** to 1.14. Furthermore, by setting the refractive index to 2.80 when the cross-sectional shape is a regular hexagonal shape, the determination coefficient of the graph becomes 0.99995, and the linearity of the graph can sufficiently be increased. Accordingly, when adopting a regular hexagonal shape as the cross-sectional shape of the transmissive optical part, the linearity of the graph can be enhanced while suppressing the refractive index of the transmissive optical part **18** to a lower level compared to when adopting a square shape as the cross-sectional shape of the transmissive optical part.

[0116] As shown in Table 1 described above, the present inventors have found out that when the cross-sectional shape of the transmissive optical part is a regular octagon, a regular decagon, or a regular dodecagon, that is, a regular polygon having sides no less than those of an octagon, the linearity of the graph is sufficiently improved by setting the refractive index of the transmissive optical part within a general range such as 1 to 2.73. Therefore, when adopting a regular polygon having sides no less than those of an octagon as the cross-sectional shape of the transmissive optical part, the limitation of the refractive index in the transmissive optical part is reduced, and therefore, it is possible to broaden the room for choice of materials available for the transmissive optical part. This facilitates the optical design of the transmissive optical part.

[0117] Based on such a configuration, in the projector **200** according to the present embodiment, it is arranged that the uniformity of the illuminance distribution of the light with which each of the light modulation parts **30**B, **30**G, and **30**R is two-dimensionally scanned is enhanced by appropriately selecting the materials of the first transmissive optical part **13** and the second transmissive optical part **14**.

[0118] Further, the present inventors have focused attention on the fact that when scanning the image forming regions of the light modulation parts **30**B, **30**G, and **30**R with light, for example, the light incident on a black display area in the image forming region is not emitted from the light modulation parts **30**B, **30**G, and **30**R, and therefore the light source device **1** wastes the power. Then, the present inventors have completed the projector **200** according to the present embodiment which improves the power use efficiency of the light source device **1** by performing the light control to adjust the luminance of the light with which the image forming region of each of the light modulation parts **30**B, **30**G, and **30**R is scanned.

[0119] The light control of the projector **200** according to the present embodiment will hereinafter be described.

[0120] FIG. **7** is a flowchart showing a flow of processing of the light control.

[0121] As shown in FIG. **7**, the control device CONT begins the light control processing at the start of the operation of the projector **200**. In step S**1**, the control device CONT reads an image frame contained in the image information input from the outside. The image information is formed of a single image frame or a plurality of image frames in accordance with the type of an image to be displayed.

[0122] In step S**2**, the control device CONT determines whether the image frame thus read includes a light control target area.

[0123] The control device CONT determines whether the display image includes the light control target area based on the image information input from the outside. In the present specification, the light control target area means an area including a light control target pixel. The light control target pixel is a pixel that has a luminance value higher or lower than a light control reference value which is a threshold value for determining whether to perform the light control, and that is a target of the light control. In the present embodiment, there is described when a pixel (white display pixel) having a luminance value higher than the light control reference value (black display pixel) is determined as the light control target pixel.

[0124] Therefore, in step S**2**, the control device CONT in the present embodiment determines whether a plurality of pixels in the image forming region includes the light control target pixel.

[0125] Description will hereinafter be presented citing, as an example, when performing the light control on the blue light LB which is color-separated from the illumination light WL emitted from the light source device **1**, and with which the image forming region of the first light modulation part **30**B is scanned. Note that substantially the same way of thinking holds true for the method of adjusting the luminance of the green light LG with which the image forming region of the second light modulation part **30**G is scanned and the luminance of the red light LR with which the image forming region of the third light modulation part **30**R is scanned.

[0126] FIG. **8** is a diagram illustrating a configuration of an essential part of the image forming region **50** of the first light modulation part **30**B.

[0127] As illustrated in FIG. **8**, the first light modulation part **30**B includes the image forming region **50** provided to the light modulation panel **31**B. The image forming region **50** includes a plurality of pixels **50**G. FIG. **8** is an image diagram when an image for displaying characters “EPSON” on the background with black display is formed on the image forming region **50**.

[0128] Note that the image forming regions of the second light modulation part **30**G and the third light modulation part **30**R each have substantially the same configuration as that of the image forming region **50** of the first light modulation part **30**B.

[0129] The image forming region **50** includes a first region A**1** constituting a character of “EPSON” and a second region A**2** constituting the background with black display. Hereinafter, the pixels **50**G constituting the first region A**1** are referred to as first pixels **50**G**1**, and the pixels **50**G constituting the second region A**2** are referred to as second pixels **50**G**2**.

[0130] FIG. **9** is an image diagram showing a locus of the blue light LB with which the image forming region **50** of the first light modulation part **30**B is scanned.

[0131] As shown in FIG. **9**, the blue light LB forms a spot SP having a substantially circular shape on the image forming region **50**. The spot SP of the blue light LB is moved in scanning so as to draw, for example, a plurality of trajectories obliquely extending from the upper right toward the lower left in the drawing. The trajectory drawn by the spot SP of the blue light LB on the image forming region **50** may hereinafter be referred to as a scanning line in some cases.

[0132] Note that the uniformity of the illuminance distribution in the image forming region **50** and the resolution of the light control area are improved as the radius of the spot SP of the blue light LB decreases, or as the number of scanning lines that scan the image forming region **50** increases.

[0133] Note that decreasing the radius r of the spot SP of the blue light LB means that the radius r becomes relatively small with respect to the image forming region **50** on the first light modulation part **30**B, and for example, the radius r of the spot SP may be decreased by increasing the size of the light modulation part.

[0134] The first pixels **50**G**1** are pixels for displaying characters, and are therefore required to transmit the blue light LB. On the other hand, the second pixels **50**G**2** are pixels for black display, and are therefore not required to transmit the blue light LB. When the blue light LB is supposedly incident on both the first pixels **50**G**1** and the second pixels **50**G**2**, the blue light LB incident on the second pixels **50**G**2** is blocked by the exit-side polarization plate **32**B in the posterior stage of the second pixels **50**G**2**, and therefore, the blue light LB incident on the second pixels **50**G**2** results in loss.

[0135] The control device CONT handles the first region A**1** of the image forming region **50** as the "light control target area," and the first pixels **50**G**1** in the first region A**1** as the "light control target pixels."

[0136] That is, when the image shown in FIG. **8** is displayed in the image forming region **50**, the control device CONT determines in step S**2** that the plurality of pixels in the image forming region includes the light control target pixel (YES in step S**2**), and proceeds to step S**3** illustrated in FIG. **7**. In step S**3**, the control device CONT calculates the timing and a light control amount of the light control.

[0137] Note that when it is determined in step S**2** that the image frame thus read does not include the light control target area (NO in step S**2**), the control device CONT proceeds to step S**7** described later.

[0138] Specific processing in step S**3** will hereinafter be described with reference to the drawings.

[0139] FIG. **10** is a diagram illustrating the light control when displaying the characters shown in FIG. **8**. In FIG. **10**, only "E" out of the characters "EPSON" to be displayed on the image forming region **50** is shown in an enlarged manner in order to facilitate viewing of the drawing. Note that in FIG. **10**, a solid line represents the spot SP formed on the image forming region **50** when the blue light LB is actually emitted, and a broken line represents a virtual spot SP formed on the image forming region **50** when the blue light LB is assumed to be supposedly incident when the blue light LB is not emitted. Hereinafter, the spot SP represented by the solid line may be referred to as an actual spot SP**1**, and the spot SP represented by the broken line may be referred to as a virtual spot SP**2** in some cases.

[0140] As shown in FIG. **10**, the spot SP of the blue light LB is obliquely moved in scanning from the upper right toward the lower left in the drawing on the image forming region **50**. The spot SP of the blue light LB passes through the first pixel **50**G**1** or the second pixel **50**G**2** described above on the image forming region **50**.

[0141] Hereinafter, when describing the positional relationship on the image forming region **50**, an x-y coordinate system is set on the image forming region **50**. Further, a direction along the left and right sides of the image forming region **50** illustrated in FIG. **10** is referred to as a left-right direction x, and a direction along the upper and lower sides of the image forming region **50** is referred to as an up-down direction y.

[0142] FIG. **11** is a diagram showing a displacement of the spot SP of the blue light LB due to the rotations of the first transmissive optical part **13** and the second transmissive optical part **14**. In FIG. **11**, the horizontal axis represents time (s), and the vertical axis represents displacement (mm). In FIG. **11**, displacement amounts in the x direction and the y direction of the blue light LB in the image forming region **50** are shown, a portion represented by a straight line corresponds to a period in which the blue light LB is emitted, and a portion in which the straight line is broken corresponds to a period in which the blue light LB is not emitted.
[0143] As shown in FIG. **10**, at the timing when the actual spot SP**1** of the blue light LB passes through the first pixel **50**G**1**, the control device CONT turns ON the first light source unit **101** with the first light source drive unit CON**1** illustrated in FIG. **2** so as to emit the blue light LB in a period corresponding to the portion represented by the straight line in FIG. **11**. Thus, as shown in FIG. **10**, the blue light LB irradiates the first pixel **50**G**1**.
[0144] As shown in FIG. **10**, at the timing when the virtual spot SP**2** of the blue light LB passes through the second pixel **50**G**2**, the control device CONT turns OFF the first light source unit **101** with the first light source drive unit CON**1** illustrated in FIG. **2** so as to put off the blue light LB in a period corresponding to the broken portion of the straight line in FIG. **11**. Accordingly, as shown in FIG. **10**, the second pixel **50**G**2** is not irradiated with the blue light LB.
[0145] In this manner, the control device CONT can suppress the loss of the power consumption of the light source unit **10** by performing the light control of adjusting the luminance of the blue light LB so that the blue light LB is put on in accordance with the timing at which the blue light LB is transmitted through the first pixel **50**G**1** and the blue light LB is put OFF in accordance with the timing at which the blue light LB is transmitted through the second pixel **50**G**2**.
[0146] The timing in the light control will hereinafter be described more specifically.
[0147] Here, defining the incidence angle of the blue light LB with respect to the first transmissive optical part **13** that is in charge of the displacement in the left-right direction x on the image forming region **50** as θx(t), θx(t) becomes a saw-tooth wave having an amplitude θmax and a period T. Therefore, when θx(t) is applied to a general formula of saw-tooth waves, Formula (3) described below is established.
[00003] $_x(t) = 2\ _{x\max}\{\frac{t}{T} - \text{floor}(\frac{t}{T} + 0.5)\}$ (3)
[0148] Here, floor(x) is a floor function for the real number x, and is defined as a maximum integer no greater then x.
[0149] Since the incidence angle θx(t) of the blue light LB to the first transmissive optical part **13** is expressed by Formula (1) described above, the displacement amount dx(t) in the x-axis direction of the blue light LB on the image forming region **50** of the first light modulation part **30**B is expressed by Formula (4) described below.
[00004] $dx = l[\tan\ _x(t) - \tan\{\sin^{-1}(\frac{n_1}{n_2}\sin\ _x(i))\}]\cos\ _x(t)$ (4)
[0150] Note that the incidence angle of the blue light LB with respect to the second transmissive optical part **14** in charge of the displacement in the up-down direction y on the image forming region **50** is expressed by substantially the same formula as Formula (3) described above, and the displacement amount dy(t) in the y-axis direction of the blue light LB on the first light modulation part **30**B is expressed by a similar formula obtained by replacing x in Formula (4) with y.
[0151] Here, a position coordinate of the first pixel **50**G**1** in the image forming region **50** is defined as (px, py), a radius in the scanning direction of the blue light LB on the image forming region **50** is defined as r, and a position coordinate of the blue light LB on the image forming region **50** at the time t is defined as (dx(t), dy(t)).
[0152] On this occasion, the control device CONT increases the output of the first light source unit **101** at a timing which satisfies Formula (5) described below. Specifically, in the present embodiment, the control device CONT changes the first light source unit **101** from an OFF state to an ON state to thereby control the light intensity of the blue light LB incident on the first pixel

50G**1** to increase. In the case of the present embodiment, the control device CONT sets the light control amount of the first light source unit **101** such that luminance of the blue light LB becomes, for example, about 80% of the maximum luminance.

[00005] $\sqrt{\{p_x - d_x(t)\}^2 + \{p_y - d_y(t)\}^2} \leqq r$ (5)

[0153] Formula (5) described above means that the position coordinate of the first pixel **50**G**1** is located within the radius r of the blue light LB. That is, the timing represented by Formula (5) means the timing at which the actual spot SP**1** of the blue light LB overlaps at least a part of the first pixel **50**G**1** as shown in FIG. **10**.

[0154] After calculating the timing and the light control amount of the light control in step S**3**, the control device CONT proceeds to step S**4**.

[0155] In step S**4**, the control device CONT determines whether there are two or more light control target pixels. That is, the control device CONT calculates the number of first pixels **50**G**1** located within the first region A**1** of the image forming region **50**.

[0156] When there are two or more first pixels **50**G**1** (YES in step S**4**), the control device CONT proceeds to step S**5**.

[0157] In step S**5**, the control device CONT determines the order of performing the light control on the two or more first pixels **50**G**1**. Specifically, the control device CONT rearranges the order in which the light control of each first pixel **50**G**1** is performed to the order in which the blue light LB, with which the image forming region **50** is scanned, passes through the first pixels **50**G**1**, and then proceeds to step S**6**.

[0158] In step S**6**, the control device CONT performs the light control of turning ON the first light source unit **101** for emitting the blue light LB at the timing at which the blue light LB overlaps each first pixel **50**G**1** in accordance with the order of the light control set in step S**5**, and then proceeds to step S**7**.

[0159] Note that when the number of first pixels **50**G**1** is one (No in step S**4**), the control device CONT skips step S**5** to proceed to step S**6** to perform the light control of turning ON the first light source unit **101** for emitting the blue light LB at the timing at which the blue light LB overlaps the one first pixel **50**G**1**, and then proceeds to step S**7**.

[0160] In step S**7**, the control device CONT determines whether there are any subsequent image frames. When there is a subsequent image frame (YES in step S**7**), the control device CONT returns to step S**1** and repeats step S**1** to step S**6** described above. That is, when the image information includes a plurality of image frames, the control device CONT performs the light control by repeating the processing described above every time each image frame is read. Specifically, the light control for the first pixel **50**G**1** contained in the image frame to be performed every time the image frame is read in sequence is performed by the control device CONT on all the image frames. Then, after completing the processing for all the image frames, the control device CONT terminates the light control.

[0161] Note that in the light control of the green light LG and the red light LR incident on the second light modulation part **30**G and the third light modulation part **30**R, the control device CONT performs substantially the same processing as in the light control of the blue light LB incident on the first light modulation part **30**B.

[0162] In this way, the control device CONT controls the output of the first light source unit **101** so as to adjust the light intensity of the blue light LB incident on the light control target pixels of the first light modulation part **30**B based on the blue image information, controls the output of the second light source unit **102** to adjust the light intensity of the green light LG incident on the light control target pixels of the second light modulation part **30**G based on the green image information, and controls the output of the third light source unit **103** to adjust the light intensity of the red light LR incident on the light control target pixels of the third light modulation part **30**R based on the red image information.

[0163] Note that the light modulation parts **30**B, **30**G, and **30**R may adjust the degree of modulation of the image forming regions based on the luminance of the colored light LB, LG, and LR that have been subjected to the light control, respectively. Accordingly, it is possible to generate the image light with a desired color tone, and thus, it is possible to display an image higher in quality.

[0164] As described above, the projector **200** according to the present embodiment includes the light source unit **10** that emits the illumination light WL, the first transmissive optical part **13** including the first plane of incidence on which the illumination light WL emitted from the light source unit **10** is incident and the first exit surface that reflects the light incident from the first plane of incidence, the first rotating part **15** that rotates the first transmissive optical part **13**, the light modulation device **30** that modulates the illumination light WL emitted from the first transmissive optical part **13** based on the image information to generate the image light, and the control device CONT that controls the output of the light source unit **10**. The light modulation device **30** includes the image forming region **50** including the plurality of pixels **50**G. The first transmissive optical part **13** is a light transmissive member having the first plane of incidence and the first exit surface parallel to each other, and rotates around the first rotational axis C**1** extending along the Y-axis direction crossing the X-axis direction as the incident direction of the illumination light WL with respect to the first transmissive optical part **13** to thereby scan the image forming region **50** of the light modulation device **30** with the illumination light WL emitted from the light source unit **10**. The control device CONT selects the first pixel **50**G**1** from among the plurality of pixels **50**G based on the image information, and performs the light control of adjusting the light intensity of the illumination light WL incident on the first pixel **50**G**1** by decreasing the output of the light source unit **10** when the luminance value corresponding to the first pixel **50**G**1** in the image light is smaller than the light control reference value at the timing which satisfies the following formula when defining the position coordinate of the first pixel **50**G**1** in the image forming region **50** as (px, py), the radius in the scanning direction of the illumination light WL in the image forming region **50** as r, and the position coordinate of the illumination light WL on the image forming region **50** at the time t as (dx(t), dy(t)).

[00006] $\sqrt{\{p_x - d_x(t)\}^2 + \{p_y - d_y(t)\}^2} \leqq r$

[0165] According to the projector **200** of the present embodiment, since the control device CONT performs the light control on the colored light LB, LG, and LR emitted from the respective light source units **101**, **102**, and **103** toward the first pixels **50**G**1** based on the image information, the light intensity blocked by the exit-side polarization plates **32**B, **32**G, and **32**R disposed at the posterior stage of the light modulation parts **30**B, **30**G, and **30**R can be reduced. Accordingly, the light use efficiency of the colored light LB, LG, and LR emitted from the light source units **101**, **102**, and **103** can be improved.

[0166] Therefore, according to the projector **200** of the present embodiment, it is possible to realize a projector which achieves the lower power consumption of the light source units **101**, **102**, and **103**, and which is excellent in display quality.

[0167] Further, since the light intensity absorbed by the exit-side polarization plates **32**B, **32**G, and **32**R is reduced, the loads of the exit-side polarization plates **32**B, **32**G, and **32**R can be reduced. This makes it possible to expect the advantages such as an improvement of the reliability of the exit-side polarization plates **32**B, **32**G, and **32**R, and an improvement of the contrast by adopting the polarization plates made of an organic material.

[0168] Further, according to the projector **200** of the present embodiment, the image forming regions **50** of the light modulation parts **30**B, **30**G, and **30**R can be illuminated in a substantially rectangular shape without using an optical system for shaping the light into a rectangular shape, such as a multi-lens. Therefore, the total optical path length can be relatively shortened, and the number of interfaces between the optical system and the air can be reduced by reducing the number of optical components, and therefore, it is possible to reduce the loss of light due to the interfacial reflection.

[0169] Note that in the present embodiment, there is cited when the light transmissive members having a square shape are used as the first transmissive optical part **13** and the second transmissive optical part **14** as an example, but the transmissive optical parts having the cross-sectional shape of a regular polygon no smaller in the number of sides than a regular octagon, that is a regular polygon the number of sides of which is an even number no smaller than 8 may be used as the first transmissive optical part **13** and the second transmissive optical part **14**. According to this configuration, even when a material having an ordinary refractive index is used as the light transmissive member, the linearity of the displacement amount of the colored light LB, LG, and LR can be enhanced, and therefore, the uniformity of the illuminance distribution in the image forming regions **50** of each of the light modulation parts **30**B, **30**G, and **30**R can more easily and conveniently be improved.

First Modified Example

[0170] As shown in FIG. **2**, the control device CONT may include an image processing unit CON**0**. The image processing unit CON**0** performs predetermined image processing on the image information input from the outside. The image processing unit CON**0** performs image processing for correcting the image information input from the outside into, for example, information compatible with a display mode selected by the user.

[0171] Examples of the display mode include a “dynamic mode” suitable for viewing in a bright environment, a “living mode” suitable for viewing in a thin light, a “natural mode” capable of reproducing an image faithful to an input signal in a dark environment, and a “theater mode” suitable for movie viewing in a dark environment. For example, the “dynamic mode” is a brightness emphasizing mode in which brightness of an image is more emphasized than a color tone of the image.

[0172] In this case, the control device CONT desirably calculates the light intensity of each colored light to be incident on the first pixel **50**G**1** of the image forming region **50** of each of the light modulation parts **30**B, **30**G, and **30**R based on the image information on which the image processing by the image processing unit CON**0** has been performed. According to this configuration, the control device CONT performs the light control of the colored light with which the image forming region **50** is scanned based on the image information compatible with the display mode, and therefore, it is possible to display the high-quality image more suitable for the display mode.

Second Modified Example

[0173] In the first embodiment, there is cited when the light control reference value is set to the black display pixel, the light control target pixel is set to the white display pixel, and the light control is performed by turning ON the light source unit in accordance with the timing of passing on the light control target pixel as an example, but the present disclosure is not limited to this example. For example, the light control reference value may be set to the white display pixel, the light control target pixel may be set to the black display pixel, and the light control may be performed by turning OFF the light source unit in accordance with the timing of passing on the light control target pixel.

[0174] According to this configuration, since the light is not incident on the light control target pixel of the black display, it is possible to suppress the decrease in the light use efficiency in the light source unit caused by blocking the incident light in the light control target pixel.

[0175] It is assumed that, for example, the light control target pixel PG is present on the boundary between the scanning lines adjacent to each other in the incident light L as shown in FIG. **12** when turning OFF the light source unit **10** in accordance with the timing of passing on the light control target pixel. On this occasion, since light source unit **10** is turned OFF for the two spots adjacent to each other in the light control target pixels PG, the area twice as large as the radius r of the spot of the illumination light becomes the black display. Therefore, when performing the light control of turning OFF the light source unit **10** so as to prevent the light from entering the light control target pixel PG of the black display, the region overlapping the area twice (**2***r*) as large as the radius r of the spot of the incident light L becomes the range A which is affected by the light control. In other words, in the case of the present modified example, the control device CONT can perform the light control when the entire range A of the maximum range **2***r* affected by the light control becomes the black display area. This is because when the range A affected by the light control includes the white display area, a display failure in the white display area occurs.

[0176] Further, the present disclosure is also applicable to when the light control reference value is set to an intermediate gradation level between the black display and the white display, and the pixel higher in luminance value than the intermediate gradation level is determined as the light control target pixel, or the pixel lower in luminance value than the intermediate gradation level is determined as the light control target pixel.

Second Embodiment

[0177] A second embodiment of the present disclosure will hereinafter be described using the drawings.

[0178] The projector according to the present embodiment is different from the projector according to the first embodiment in that the first transmissive optical part **13** scans one light modulation part with the light from the light source unit. Note that the same reference numerals are given to constituents common to those in the first embodiment to omit the detailed description thereof.

[0179] FIG. **13** is a plan view showing a schematic configuration of a projector **202** according to the present embodiment.

[0180] As illustrated in FIG. **13**, the projector **202** according to the present embodiment includes a light source device **110**, a light modulation device **130**, and the projection optical device **23**.

[0181] The light source device **110** in the present embodiment includes a first light source unit **111**, a second light source unit **112**, a third light source unit **113**, the first transmissive optical part **13**, the first rotating part **15**, a first optical part **16***a*, and a second optical part **16***b*.

[0182] The first light source unit **111** outputs the blue light LB toward the first transmissive optical part **13** (−Z side). The second light source unit **112** outputs the green light LG toward the first transmissive optical part **13** (+X side). The third light source unit **113** outputs the red light LR toward the first transmissive optical part **13** (+Z side).

[0183] The optical axis AX**1** of the first light source unit **111** and the optical axis AX**3** of the third light source unit **113** are located on the same axis. The optical axis AX**2** of the second light source unit **112** is orthogonal to the optical axis AX**1** of the first light source unit **111** and the optical axis AX**3** of the third light source unit **113**, and coincides with the optical axis AX of the light source device **110**. According to this configuration, for example, when each light source unit includes a cooling member such as a heatsink, the cooling member and a flow path of the cooling air do not need to be obliquely disposed. This makes it possible to increase the degree of freedom of the layout of the components constituting the projector **202**, and to reduce the size of the projector **202**.

[0184] The basic configurations of the light source units **111**, **112**, and **113** are substantially the same, and a specific configuration of the second light source unit **112** will hereinafter be described using FIG. **14**. In FIG. **14**, illustration of the first light source unit **111**, the third light source unit **113**, the first optical part **16***a*, the second optical part **16***b*, and the like is omitted.

[0185] As illustrated in FIG. **14**, the second light source unit **112** includes a plurality of second light emitting parts **26** and the substrate **29**. The plurality of second light emitting parts **26** is arranged in a single line at predetermined intervals along the Y-axis direction. In the present embodiment, the second light source unit **112** includes five second light emitting parts **26**, but the number of second light emitting parts **26** is not particularly limited as long as the plurality of second light emitting parts **26** is arranged in a single line along the Y-axis direction.

[0186] Based on such a configuration, the green light LG emitted from the second light source unit

112 is formed of a light flux including a plurality of light beams LGO arranged along the Y-axis direction, and therefore has a strip shape including a long axis extending along the Y-axis direction and a short axis extending along the Z-axis direction.

[0187] Similarly, the first light source unit **111** includes a plurality of first light emitting parts **25** and the substrate **29**. The plurality of first light emitting parts **25** is arranged in a single line at predetermined intervals along the Y-axis direction. The third light source unit **113** includes a plurality of third light emitting parts **27** and the substrate **29**. The plurality of third light emitting parts **27** is arranged in a single line at predetermined intervals along the Y-axis direction.

[0188] Based on such a configuration, the blue light LB emitted from the first light source unit **111** is formed of a light flux including a plurality of light beams arranged along the Y-axis direction, and therefore has a strip shape including a long axis extending along the Y-axis direction and a short axis extending along the X-axis direction. Further, the red light LR emitted from the third light source unit **113** is formed of a light flux including a plurality of light beams arranged along the Y-axis direction, and therefore has a strip shape including a long axis extending along the Y-axis direction and a short axis extending along the X-axis direction.

[0189] As illustrated in FIG. **13**, the first transmissive optical part **13** is provided at a position where the optical axis AX**1** and the optical axis AX**3** cross the optical axis AX**2**. The first transmissive optical part **13** rotates about the first rotational axis C**1** by the drive of the first rotating part **15**.

[0190] The first transmissive optical part **13** transmits each of the blue light LB, the green light LG, and the red light LR emitted from the light source units **111**, **112**, and **113** while rotating about the first rotational axis C**1**.

[0191] The blue light LB is incident on the first position P**11** of the first transmissive optical part **13**. The green light LG is incident on a second position P**12** different from the first position P**11** of the first transmissive optical part **13**. The red light LR is incident on a third position P**13** different from the first position P**11** and the second position P**12** of the first transmissive optical part **13**. That is, the blue light LB, the green light LG, and the red light LR are incident on respective positions different from each other in the first transmissive optical part **13**. In particular in the case of the present embodiment, since the first light source unit **111**, the second light source unit **112**, and the third light source unit **113** are in a positional relationship of rotating by 90 degrees around the intersection between the optical axes AX**1**, AX**2**, and AX**3**, the blue light LB, the green light LG, and the red light LR are incident on the respective first side surfaces **13***c* different from each other of the first transmissive optical part **13**.

[0192] The behavior of each of the colored light LB, LG, and LR when transmitted through the first transmissive optical part **13** is the same as the behavior illustrated in FIGS. **4**A to **4**F, and therefore the description thereof will be omitted.

[0193] In the case of the present embodiment, the green light LG is linearly elongated in the Y-axis direction perpendicular to the Z-axis direction in which the green light LG is displaced. Therefore, the two-dimensional illumination target region on an illumination target surface (the light modulation device **130**) is scanned with the green light LG. Although the blue light LB and the red light LR are different in emission direction from the green light LG, the blue light LB and the red light LR are reflected by the respective optical parts **16***a*, **16***b* described later, and then the two-dimensional illumination target region of the illumination target surface (the light modulation device **130**) is scanned with the blue light LB and the red light LR similarly to the case of the green light LG. As described above, the first transmissive optical part **13**, when rotated around the first rotational axis C**1**, scans the two-dimensional illumination target region in the light modulation device **130** as the illumination target surface with the blue light LB, the green light LG, and the red light LR in the Z-axis direction perpendicular to the Y-axis direction.

[0194] FIG. **15** is a diagram showing a state of scanning light on the light modulation device **130**.

[0195] In the case of the present embodiment, as shown in FIG. **13**, for example, the green light LG in a strip shape is moved in scanning in a single direction along the up-down direction y on the light modulation device **130**.

[0196] Therefore, the coordinates px, dx(t) in the left-right direction x are in a constantly coinciding state in Formula (5) described above for defining the timing of the light control of the light control target pixel. Therefore, in the case of the present embodiment, in Formula (5), the term px-dx(t) is constantly 0. Note that the blue light LB and the red light LR are moved in scanning in a single direction along the up-down direction y on the light modulation device **130** in a similar manner.

[0197] Accordingly, in the case of the present embodiment, it is sufficient for the control device CONT to perform the light control of the light control target pixel at the timing which satisfies Formula (6) described below.

[00007] $\sqrt{(p_y - d_y(t))^2} \leqq r \quad (6)$

[0198] That is, in the case of the present embodiment, since it is sufficient for the control device CONT to consider only the coordinates in the up-down direction y in which the colored light LB, LG, and LR moves in scanning, the processing of the light control becomes easy compared to when considering the coordinates in two directions, namely, the left-right direction x and the up-down direction Y.

[0199] The first optical part **16***a* is disposed on the light path of the blue light LB emitted from the first light source unit **111** between the first light source unit **111** and the first transmissive optical part **13**. The first optical part **16***a* is formed of a dichroic mirror that reflects the red light and transmits the blue light. Therefore, the first optical part **16***a* reflects the red light LR emitted from the first transmissive optical part **13** and transmits the blue light LB emitted from the first light source unit **111**. An angle between the first optical part **16***a* and the Z axis is referred to as an inclination angle θ**11** of the first optical part **16***a*. The inclination angle θ**11** of the first optical part **16***a* is larger than 45 degrees.

[0200] The second optical part **16***b* is disposed on the light path of the red light LR emitted from the third light source unit **113** between the third light source unit **113** and the first transmissive optical part **13**. The second optical part **16***b* is formed of a dichroic mirror that reflects the blue light and transmits the red light. Therefore, the second optical part **16***b* reflects the blue light LB emitted from the first transmissive optical part **13** and transmits the red light LR emitted from the third light source unit **113**. An angle between the second optical part **16***b* and the Z axis is referred to as an inclination angle θ**12** of the second optical part **16***b*. The inclination angle θ**12** of the second optical part **16***b* is larger than 45 degrees.

[0201] Since the inclination angle θ**12** of the second optical part **16***b* is set to be greater than 45 degrees, the blue light LB reflected by the second optical part **16***b* travels obliquely with respect to and toward the optical axis AX**2**. Similarly, since the inclination angle θ**11** of the first optical part **16***a* is set to be greater than 45 degrees, the red light LR reflected by the first optical part **16***a* travels obliquely with respect to and toward the optical axis AX**2**.

[0202] Thus, the blue light LB reflected by the second optical part **16***b*, the green light LG output from the first transmissive optical part **13**, and the red light LR reflected by the first optical part **16***a* enter a first microlens array **43** in the anterior stage of a light modulation part **131** from respective directions different from each other as described later, and overlap each other on the first microlens array **43**. In the case of the present embodiment, the incidence angle of the green light LG incident on the first microlens array **43** is 0 degree. In other words, the green light LG is incident on the first microlens array **43** at right angle.

[0203] The light modulation device **130** of the present embodiment includes the light modulation part **131** and an exit-side polarization plate **132**.

[0204] FIG. **16** is a cross-sectional view illustrating a configuration of an essential part of the light modulation device **130** in the present embodiment. In FIG. **16**, a cross-sectional configuration of the light modulation part **131** is illustrated, and illustration of the exit-side polarization plate **132** is omitted.

[0205] As shown in FIG. **16**, a liquid crystal panel that constitutes the light modulation part **131** has an image forming region **150** in which a plurality of blue sub-pixels PX**1**, a plurality of green sub-pixels PX**2**, and a plurality of red sub-pixels PX**3** are periodically arranged in a matrix. The blue sub-pixels PX**1** modulate the blue light LB. The green sub-pixels PX**2** modulate the green light LG. The red sub-pixels PX**3** modulate the red light LR. One pixel, which is a minimum unit of an image, is formed of one blue sub-pixel PX**1**, one green sub-pixel PX**2**, and one red sub-pixel PX**3**. A light blocking film **155** referred to as a black matrix is disposed between two sub-pixels adjacent to each other.

[0206] The first microlens array **43** is disposed at the light incident side of the first substrate **57** constituting the light modulation part **131**. The first microlens array **43** has a configuration in which a plurality of first microlenses **431** is arranged in a matrix. The first microlens array **43** collects the blue light LB, the green light LG, and the red light LR, and guides the light to the sub-pixels PX**1**, PX**2**, and PX**3** of the light modulation part **131**. Each of the first microlenses **431** is formed of a lenticular lens, and is disposed across one pixel, that is, three sub-pixels PX**1**, PX**2**, and PX**3** corresponding to the different colors and arranged in one direction. As each of the first microlenses **431**, the lenticular lens is cited in the present embodiment, but this is not a limitation, and it is possible to adopt a microlens array in which rectangular lenses are arranged in a laid brick form, a microlens array in which lenses are arranged in correspondence with sub-pixels in a delta arrangement, or a microlens array having a honeycomb structure.

[0207] As described above, the blue light LB, the green light LG, and the red light LR are incident on each of the first microlenses **431** at respective angles of incidence different from each other, and therefore travel in respective directions different from each other, and are then collected. Accordingly, the blue light LB is incident on the blue sub-pixel PX**1**, the green light LG is incident on the green sub-pixel PX**2**, and the red light LR is incident on the red sub-pixel PX**3**. That is, the first microlens array **43** causes the blue light LB emitted from the second optical part to be incident on the blue sub-pixels PX**1**, causes the green light LG emitted from the first transmissive optical part to be incident on the green sub-pixels PX**2**, and causes the red light LR emitted from the first optical part to be incident on the red sub-pixels PX**3**.

[0208] The second microlens array **44** is disposed at the light exit side of a second substrate **58** constituting the light modulation part **131**. The second microlens array **44** has a configuration in which a plurality of second microlenses **441** are arranged in a matrix. The second microlens array **44** collimates each of the three types of colored light emitted from the liquid crystal panel. The second microlens **441** is provided to each of the sub-pixels. Note that the example in which each colored light is collimated after being emitted from the liquid crystal panel is cited in the present embodiment, but instead of this configuration, the second microlens array **44** may be disposed at the light incidence side of the liquid crystal panel, and each colored light may be collimated before entering the liquid crystal panel.

[0209] The exit-side polarization plate **22** is disposed on the optical axis AX**2** between the light modulation part **131** and the projection optical device **23**. The exit-side polarization plate **22** transmits the linearly polarized light, which is emitted from the light modulation part **131** and is polarized in a specific direction, toward the projection optical device **23**.

[0210] According to the projector **202** of the present embodiment, the control device CONT adjusts the outputs of the light source units **111**, **112**, and **113** based on the image information to perform the light control of the colored light LB, LG, and LR for illuminating the illumination target region (the light control target pixel of the light modulation part **131**), and therefore, it is possible to obtain substantially the same advantages as in the first embodiment such as an advantage that the light use efficiency of the light source device **110** is improved to realize the low power consumption.

[0211] Further, in the projector **202** according to the present embodiment, the three types of colored

light LB, LG, and LR can be spatially separated and the three types of colored light LB, LG, and LR can be made incident on the sub-pixels PX**1**, PX**2**, and PX**3** corresponding thereto by the arrangement of the light source units **111**, **112**, and **113**, the first transmissive optical part **13**, and the optical parts **16***a*, **16***b* and the function of the first microlens array **43** provided to the light modulation device **130**. Thus, it is possible to realize the projector **202** capable of displaying a color image without using a color filter in the light modulation part **131** of the light modulation device **130**. Furthermore, since the illumination target region of the light modulation device **130** can two-dimensionally be illuminated by scanning the illumination target region in the Z-axis direction with the colored light LB, LG, and LR having the long axis in the Y-axis direction, just one transmissive optical part is sufficient, and simplification of the apparatus configuration and a reduction in size can be achieved.
[0212] Note that the technical scope of the present disclosure is not limited to the embodiments described above, and a variety of changes can be made without departing from the scope of the present disclosure.
[0213] For example, in the first embodiment, there is cited, as an example, when the illumination light WL obtained by combining the colored light LB, LG, and LR travels through the first transmissive optical part **13** and the second transmissive optical part **14**, and is then color-separated, and then the respective light modulation parts **30**B, **30**G, and **30**R are scanned with the colored light thus color-separated, but the present disclosure is not limited to this example. For example, the present disclosure may be applied to a configuration in which the colored light LB, LG, and LR travels through the first transmissive optical part **13** and the second transmissive optical part **14**, respectively, and then the light modulation parts **30**B, **30**G, and **30**R are scanned with the colored light, respectively.
[0214] In the second embodiment, there is cited, as an example, when the colored light LB, LG, and LR is incident on one transmissive optical part from respective directions different from each other, and the colored light LB, LG, and LR is made incident on one liquid crystal panel from the three directions, respectively, but the present disclosure is not limited to this example. For example, the present disclosure may be applied to a configuration in which three transmissive optical parts corresponding to the colored light beam LB, LG, and LR having a strip shape, and three light modulation parts corresponding to the three transmissive optical parts are provided, and the light modulation parts are scanned with the colored light LB, LG, and LR emitted from the transmissive optical parts, respectively.
[0215] In addition, the specific description of the shapes, the numbers, the arrangements, the materials, and the like of the respective component parts of the light source device and the projector are not limited to those in the above described embodiments, but changes can be made as appropriate. Further, in the above described embodiments, the example in which the light source device according to the present disclosure is provided in the projector using the liquid crystal panels is shown, however, the application is not limited to that. The light source device according to the present disclosure may be applied to a projector using digital micromirror devices as the light modulation devices.
[0216] The present disclosure will be summarized below as additional remarks.
Additional Remark **1**
[0217] A projector including [0218] a light source unit configured to emit light, [0219] a first transmissive optical part including a first plane of incidence on which the light emitted from the light source unit is incident, and a first exit surface configured to emit the light incident from the first plane of incidence, [0220] a first rotating part configured to rotate the first transmissive optical part, [0221] a light modulation device configured to modulate, based on image information, the light emitted from the first transmissive optical part to generate image light, and [0222] a control device configured to control an output of the light source unit, in which [0223] the light modulation device includes an image forming region containing a plurality of pixels, [0224] the first

transmissive optical part is a light transmissive member having the first plane of incidence and the first exit surface parallel to each other, and rotates around a first rotational axis extending along a second direction crossing a first direction which is an incident direction of the light with respect to the first transmissive optical part to thereby scan the image forming region of the light modulation device with the light emitted from the light source unit, [0225] the control device performs light control of adjusting light intensity of the light to be incident on a light control target pixel by [0226] selecting the light control target pixel from among the plurality of pixels based on the image information, [0227] decreasing the output of the light source unit when a luminance value corresponding to the light control target pixel in the image light is smaller than a light control reference value, and [0228] increasing the output of the light source unit when the luminance value is larger than the light control reference value at a timing which satisfies the following conditional expression when defining a position coordinate of the light control target pixel in the image forming region as (px, py), a radius in a scanning direction of the light on the image forming region as r, and a position coordinate of the light on the image forming region at a time t as (dx(t), dy(t)).
[00008] $\sqrt{\{p_x - d_x(t)\}^2 + \{p_y - d_y(t)\}^2} \leqq r$
[0229] According to the projector of this configuration, since the control device performs the light control of the light emitted from the light source unit toward the light control target pixel based on the image information, it is possible to reduce the light intensity blocked by the light modulation device. Accordingly, the light use efficiency of the light emitted from the light source unit can be improved.
[0230] According to this configuration, it is possible to achieve the reduction in power consumption, and to realize a projector excellent in display quality.
Additional Remark **2**
[0231] The projector described in Additional Remark **1**, in which, [0232] when setting a plurality of light control target pixels from among the plurality of pixels, the control device performs the light control in accordance with a passing order in which the light with which the image forming region is scanned passes through the plurality of light control target pixels.
[0233] According to this configuration, the light control can be performed at an appropriate timing when the light passes through each light control target pixel.
Additional Remark **3**
[0234] The projector described in Additional Remark **1** or **2**, in which the image information includes a plurality of image frames, and the control device performs the light control in accordance with a timing at which each of the plurality of image frames is input to the light modulation device.
[0235] According to this configuration, the light control can be performed on each of the plurality of image frames constituting the image information.
Additional Remark **4**
[0236] The projector described in any one of Additional Remarks **1** to **3**, in which [0237] the first transmissive optical part includes a first surface and a second surface crossing the first rotational axis, and 2×m (m: a natural number no smaller than 2) first side surfaces in contact with the first surface and the second surface, and [0238] the first plane of incidence and the first exit surface are two first side surfaces parallel to each other out of the 2×m first side surfaces.
[0239] According to this configuration, since there is no light incident on the first side surfaces that are not parallel to each other, the stray light rarely occurs in the first transmissive optical part, it is possible to increase the light use efficiency.
Additional Remark **5**
[0240] The projector described in Additional Remark **4**, in which the first transmissive optical part has a square cross-sectional shape along a plane perpendicular to the first rotational axis, and a refractive index of the first transmissive optical part is no lower than 1.63.

[0241] According to this configuration, the determination coefficient of the graph representing the relationship between the rotation angle and the displacement amount of the first transmissive optical part becomes no smaller than 0.995. Accordingly, the uniformity of the illuminance distribution of the light in the illumination target region can be improved by increasing the linearity of the graph.

Additional Remark **6**

[0242] The projector described in Additional Remark **4**, in which the first transmissive optical part has a regular hexagonal cross-sectional shape along a plane perpendicular to the first rotational axis, and a refractive index of the first transmissive optical part is no lower than 1.14.

[0243] According to this configuration, the determination coefficient of the graph representing the relationship between the rotation angle and the displacement amount of the first transmissive optical part becomes no smaller than 0.995. Accordingly, the uniformity of the illuminance distribution of the light in the illumination target region can be improved by increasing the linearity of the graph while suppressing the refractive index of the first transmissive optical part to a low level.

Additional Remark **7**

[0244] The projector described in Additional Remark **4**, in which the first transmissive optical part has a regular polygonal cross-sectional shape along a plane perpendicular to the first rotational axis, the regular polygonal shape being no smaller in a number of sides than an octagonal shape.

[0245] According to this configuration, even when the refractive index of the first transmissive optical part is set within an ordinary range of 1 to 2.73, the linearity of the graph can sufficiently be increased. Accordingly, since the restriction of the refractive index in the first transmissive optical part is reduced, the room for choice of the materials available as the first transmissive optical part is widened, and the optical design of the first transmissive optical part is facilitated.

Additional Remark **8**

[0246] The projector described in any one of Additional Remarks **1** to **7**, in which the light source unit includes a light emitting part including a laser diode configured to emit a laser beam.

[0247] According to this configuration, since the light emitted from the light source unit is a linearly polarized laser beam, when using the liquid crystal panel, for example, as the light modulation device, the incident side polarization plate can be omitted.

Additional Remark **9**

[0248] The projector described in any one of Additional Remarks **1** to **8**, in which the control device further controls drive of the first rotating part and the light modulation device.

[0249] According to this configuration, since the control device collectively controls the light control of the light source unit, the drive control of the first rotating part, and the drive control of the light modulation device, it becomes possible to perform simple and accurate control.

Additional Remark **10**

[0250] The projector described in any one of Additional Remarks **1** to **9**, in which [0251] the control device includes an image processing unit configured to perform predetermined image processing on the image information, and [0252] the control device calculates a light intensity of the light incident on the light control target pixel based on the image information after the image processing is performed on the image information by the image processing unit.

[0253] According to this configuration, the control device performs the light control of the light with which the image forming region is scanned based on, for example, the image information compatible with the display mode, and therefore, it is possible to display the high-quality image more suitable for the display mode.

Additional Remark **11**

[0254] The projector described in any one of Additional Remarks **1** to **10**, further comprising [0255] a second transmissive optical part having a second plane of incidence on which the light is incident and a second exit surface configured to emit the light incident from the second plane of

incidence, and [0256] a second rotating part configured to rotate the second transmissive optical part, in which [0257] the second transmissive optical part is a light transmissive member in which the second plane of incidence and the second exit surface are parallel to each other, and rotates around a second rotational axis extending along a third direction crossing each of the first direction and the second direction, and [0258] the second rotating part rotates the second transmissive optical part around the second rotational axis to thereby two-dimensionally scan the image forming region of the light modulation device with the light.
[0259] According to this configuration, it is possible to easily realize a configuration in which the entire image forming region is illuminated by two-dimensionally scanning the image forming region with the light using the first transmissive optical part and the second transmissive optical part.
Additional Remark **12**
[0260] The projector described in Additional Remark **11**, in which [0261] the second transmissive optical part includes a third surface and a fourth surface crossing the second rotational axis, and 2×n (n: a natural number no smaller than 2) second side surfaces in contact with the third surface and the fourth surface, and [0262] the second plane of incidence and the second exit surface are two second side surfaces parallel to each other out of the 2×n second side surfaces.
[0263] According to this configuration, since there is no light incident on the second side surfaces that are not parallel to each other, the stray light rarely occurs in the second transmissive optical part, it is possible to increase the light use efficiency.
Additional Remark **13**
[0264] The projector described in any one of Additional Remarks **1** to **11**, in which [0265] the light source unit includes [0266] a first light source unit configured to emit first light in a first wavelength band, [0267] a second light source unit configured to emit second light in a second wavelength band different from the first wavelength band, and [0268] a third light source unit configured to emit third light in a third wavelength band different from the first wavelength band and the second wavelength band, [0269] the light modulation device includes [0270] a first light modulation part configured to modulate the first light emitted from the first transmissive optical part based on first image information to generate first image light, [0271] a second light modulation part configured to modulate the second light emitted from the first transmissive optical part based on second image information to generate second image light, and [0272] a third light modulation part configured to modulate the third light emitted from the first transmissive optical part based on third image information to generate third image light, and [0273] the control device controls an output of the first light source unit to adjust a light intensity of the first light incident on the light control target pixel of the first light modulation part based on the first image information, controls an output of the second light source unit to adjust a light intensity of the second light incident on the light control target pixel of the second light modulation part based on the second image information, and controls an output of the third light source unit to adjust a light intensity of the third light incident on the light control target pixel of the third light modulation part based on the third image information.
[0274] According to this configuration, since the light emitted from each of the first, second, and third light source units toward the control target pixels of the first, second, and third light modulation parts is subjected to the light control, the amount of the light blocked by each light modulation part can be suppressed. This can improve the light use efficiency of the light emitted from the first, second, and third light source units.
[0275] Therefore, it is possible to achieve the reduction in power consumption, and to realize a 3-panel projector excellent in display quality.

Claims

1. A projector comprising: a light source unit configured to emit light; a first transmissive optical part including a first plane of incidence on which the light emitted from the light source unit is incident, and a first exit surface configured to emit the light incident from the first plane of incidence; a first rotating part configured to rotate the first transmissive optical part; a light modulation device configured to modulate, based on image information, the light emitted from the first transmissive optical part to generate image light; and a control device configured to control an output of the light source unit, wherein the light modulation device includes an image forming region containing a plurality of pixels, the first plane of incidence and the first exit surface of the first transmissive optical part are parallel to each other, and the first transmissive optical part rotates around a first rotational axis extending along a second direction crossing a first direction which is an incident direction of the light with respect to the first transmissive optical part to thereby scan the image forming region of the light modulation device with the light emitted from the light source unit, the control device performs light control of adjusting light intensity of the light to be incident on a light control target pixel by selecting the light control target pixel from among the plurality of pixels based on the image information, decreasing the output of the light source unit when a luminance value corresponding to the light control target pixel in the image light is smaller than a light control reference value, and increasing the output of the light source unit when the luminance value is larger than the light control reference value at a timing which satisfies the following conditional expression when defining a position coordinate of the light control target pixel in the image forming region as (px, py), a radius in a scanning direction of the light on the image forming region as r, and a position coordinate of the light on the image forming region at a time t as (dx(t), dy(t)). $\sqrt{\{p_x - d_x(t)\}^2 + \{p_y - d_y(t)\}^2} \leqq r$

2. The projector according to claim 1, wherein, when setting a plurality of light control target pixels from among the plurality of pixels, the control device performs the light control in accordance with a passing order in which the light with which the image forming region is scanned passes through the plurality of light control target pixels.

3. The projector according to claim 1, wherein the image information includes a plurality of image frames, and the control device performs the light control in accordance with a timing at which each of the plurality of image frames is input to the light modulation device.

4. The projector according to claim 1, wherein the first transmissive optical part includes a first surface and a second surface crossing the first rotational axis, and 2×m (m: a natural number no smaller than 2) first side surfaces in contact with the first surface and the second surface, and the first plane of incidence and the first exit surface are two first side surfaces parallel to each other out of the 2×m first side surfaces.

5. The projector according to claim 4, wherein the first transmissive optical part has a square cross-sectional shape along a plane perpendicular to the first rotational axis, and a refractive index of the first transmissive optical part is no lower than 1.63.

6. The projector according to claim 4, wherein the first transmissive optical part has a regular hexagonal cross-sectional shape along a plane perpendicular to the first rotational axis, and a refractive index of the first transmissive optical part is no lower than 1.14.

7. The projector according to claim 4, wherein the first transmissive optical part has a regular polygonal cross-sectional shape along a plane perpendicular to the first rotational axis, the regular polygonal shape being no smaller in a number of sides than an octagonal shape.

8. The projector according to claim 1, wherein the light source unit includes a light emitting part including a laser diode configured to emit a laser beam.

9. The projector according to claim 1, wherein the control device further controls drive of the first rotating part and the light modulation device.

10. The projector according to claim 1, wherein the control device includes an image processing unit configured to perform predetermined image processing on the image information, and the control device calculates a light intensity of the light incident on the light control target pixel based on the image information after the image processing is performed on the image information by the image processing unit.

11. The projector according to claim 1, further comprising: a second transmissive optical part having a second plane of incidence on which the light is incident and a second exit surface configured to emit the light incident from the second plane of incidence; and a second rotating part configured to rotate the second transmissive optical part, wherein the second transmissive optical part is a light transmissive member in which the second plane of incidence and the second exit surface are parallel to each other, and rotates around a second rotational axis extending along a third direction crossing each of the first direction and the second direction, and the second rotating part rotates the second transmissive optical part around the second rotational axis to thereby two-dimensionally scan the image forming region of the light modulation device with the light.

12. The projector according to claim 11, wherein the second transmissive optical part includes a third surface and a fourth surface crossing the second rotational axis, and 2×n (n: a natural number no smaller than 2) second side surfaces in contact with the third surface and the fourth surface, and the second plane of incidence and the second exit surface are two second side surfaces parallel to each other out of the 2×n second side surfaces.

13. The projector according to claim 1, wherein the light source unit includes a first light source unit configured to emit first light in a first wavelength band, a second light source unit configured to emit second light in a second wavelength band different from the first wavelength band, and a third light source unit configured to emit third light in a third wavelength band different from the first wavelength band and the second wavelength band, the light modulation device includes a first light modulation part configured to modulate the first light emitted from the first transmissive optical part based on first image information to generate first image light, a second light modulation part configured to modulate the second light emitted from the first transmissive optical part based on second image information to generate second image light, and a third light modulation part configured to modulate the third light emitted from the first transmissive optical part based on third image information to generate third image light, and the control device controls an output of the first light source unit to adjust a light intensity of the first light incident on the light control target pixel of the first light modulation part based on the first image information, controls an output of the second light source unit to adjust a light intensity of the second light incident on the light control target pixel of the second light modulation part based on the second image information, and controls an output of the third light source unit to adjust a light intensity of the third light incident on the light control target pixel of the third light modulation part based on the third image information.