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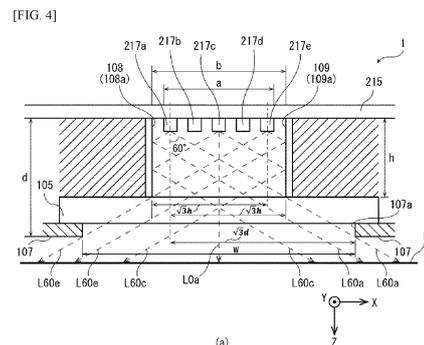
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(54) **LIGHT IRRADIATION DEVICE**

(57) A light irradiation device for irradiating, with light, an irradiation object that is capable of moving relative thereto, the light irradiation device comprising: a substrate; a plurality of light-emitting elements which are arranged on the substrate in an array of n-units (n is an integer of 2 or more) by m-rows (m is an integer of 2 or more); a cover glass which allows light from the respective light-emitting elements to pass therethrough; a support part which has an opening for light to pass therethrough and which supports the cover glass; and a pair of first reflective mirrors which are disposed between the substrate and the cover glass and which is for guiding light, wherein the expressions (1) and (2) are satisfied, where a represents the distance from a light-emitting element in the first row positioned on the most upstream side to a light-emitting element in the m-th row positioned on the most downstream side, b represents the interval between the pair of first reflective mirrors, h represents the height of the pair of first reflective mirrors, d represents the distance from the substrate to the support part, and w represents the width of the opening in a first direction. (1): $h \leq (a+b)/2\sqrt{3}$, (2): $w \geq d \cdot 2\sqrt{3}-a$.



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Description

[Technical Field]

[0001] The present invention relates to a light irradiation device that irradiates an irradiation object with light when the irradiation object is transferred in one direction.

[Background Art]

[0002] In the related art, there has been known a printing device that performs a printing process using UV ink that is cured by being irradiated with ultraviolet rays. The printing device discharges ink from a nozzle of a head toward a medium and emits ultraviolet rays to dots formed on the medium. The dots are fixed on the medium as the dots are cured by being irradiated with ultraviolet rays, such that a smooth printing process may be performed even on a medium that hardly absorbs a liquid.

[0003] Recently, an ultraviolet irradiation device used for such a printing device practically uses a light-emitting diode (LED) element as a light source, instead of the existing discharge lamp, to meet the needs for a reduction in power consumption, a prolonged lifespan, and a compact size of the device (e.g., Patent Document 1).

[Document of Related Art]

[Patent Document]

[0004] (Patent Document 1) Japanese Patent No. 5482537

[Disclosure]

[Technical Problem]

[0005] The ultraviolet irradiation device disclosed in Patent Document 1 has a light source unit having a plurality of ultraviolet ray light sources (ultraviolet ray LEDs) arranged in a direction perpendicular to a transfer direction of an irradiation object, and a pair of reflective members disposed between the light source unit and the irradiation object so that the light source unit is fitted with the pair of reflective members from upstream and downstream sides based on the transfer direction. The ultraviolet irradiation device adopts a configuration that provides directionality to ultraviolet rays by guiding the ultraviolet rays from an ultraviolet ray source to a pair of reflective plates and emitting the ultraviolet rays.

[0006] However, in case that the configuration disclosed in Patent Document 1 is adopted, the light amount (intensity) of the ultraviolet rays decreases each time the ultraviolet rays are reflected by the reflective members, because the reflective members have predetermined reflectance. For this reason, it is necessary to increase the number of ultraviolet LEDs to supplement the light amount by the amount of decrease in light amount in

order to obtain a predetermined light amount on the irradiation object (i.e., the light amount for assuredly curing the UV ink). Further, as a result, there occurs a problem in that the cost, size, and power consumption of the device are increased. Accordingly, there is a need for a light irradiation device capable of performing efficient irradiation without increasing the number of LEDs.

[0007] The present invention has been contrived in consideration of the above-mentioned problems in the related art, and an object of the present invention is to provide a light irradiation device capable of performing efficient irradiation while providing directionality to exiting light.

[Technical Solution]

[0008] To achieve the above-mentioned object, a light irradiation device of the present invention emits rays to an irradiation object capable of relatively moving in a first direction and includes: a substrate defined in the first direction and a second direction perpendicular to the first direction; a plurality of light-emitting elements arranged on the substrate so that the number of light-emitting elements in the second direction is n (n is two or more integers) and the light-emitting elements are arranged in m (m is two or more integers) rows in the first direction, the plurality of light-emitting elements being disposed so that directions of optical axes thereof are aligned with a third direction orthogonal to the first direction and the second direction; a cover glass configured to transmit the rays emitted from the plurality of light-emitting elements; a support part configured to support the cover glass and having an opening portion through which the rays having passed through the cover glass passes; and a pair of first reflective mirrors disposed between the substrate and the cover glass so that optical paths of the plurality of light-emitting elements are interposed therebetween in the first direction, the pair of first reflective mirrors being configured to guide the rays, in which following Expressions (1) and (2) are satisfied on the assumption that a distance from a light-emitting element in a first row positioned at a most upstream side based on the first direction to a light-emitting element in an m -th row positioned at a most downstream side in the first direction is a , an interval between the pair of first reflective mirrors is b , a height of the pair of first reflective mirrors in the third direction is h , a distance from the substrate to the support part is d , and a width of the opening portion in the first direction is w when viewed in the second direction:

$$h \leq (a+b)/2\sqrt{3} \quad (1)$$

$$w \geq d \cdot 2\sqrt{3} - a \quad (2)$$

[0009] With this configuration, because the ray (ultra-

violet ray) having high intensity and the diffusion angle of 60° or less reaches the irradiation object P while being reflected by the first reflective surfaces 108a and 109a once or without being reflected, the influence made by the reflection by the first reflective surfaces 108a and 109a (i.e., a decrease in light amount) rarely occurs. Therefore, the first reflective surfaces 108a and 109a may provide directionality to the exiting light and perform efficient irradiation.

[0010] Further, the light irradiation device may include a second reflective mirror extending to an upstream side based on the first direction from a tip portion of the first reflective mirror positioned at the upstream side based on the first direction so as to face the cover glass, the second reflective mirror being configured to reflect the rays, which have been reflected by the irradiation object, to the irradiation object. In addition, in this case, the second reflective mirror may be integrated with the first reflective mirror positioned at the upstream side based on the first direction.

[0011] In addition, the light irradiation device may include a third reflective mirror extending to a downstream side based on the first direction from a tip portion of the first reflective mirror positioned at the downstream side based on the first direction so as to face the cover glass, the third reflective mirror being configured to reflect the rays, which have been reflected by the irradiation object, to the irradiation object. In addition, in this case, the third reflective mirror may be integrated with the first reflective mirror positioned at the downstream side based on the first direction.

[0012] Further, the light irradiation device may include a housing configured to accommodate the substrate, the plurality of light-emitting elements, and the pair of first reflective mirrors, and the support part and the cover glass may constitute a part of the housing.

[0013] In addition, the ray may be a ray in an ultraviolet wavelength region. In addition, in this case, the irradiation object may have a sheet shape, and the ray in the ultraviolet wavelength region may cure ink applied onto a surface of the irradiation object.

[Advantageous Effect]

[0014] According to the present invention described above, it is possible to implement the light irradiation device capable of performing efficient irradiation while providing directionality to exiting light.

[Description of Drawings]

[0015]

FIG. 1 is an external appearance view for explaining a configuration of a light irradiation device according to a first embodiment of the present invention.

FIG. 2 is a cross-sectional view taken along line A-A in FIG. 1(b).

FIG. 3 is a view for explaining a configuration of a light source unit provided in the light irradiation device according to the first embodiment of the present invention.

FIG. 4 is a schematic view for explaining a configuration of the light irradiation device according to the first embodiment of the present invention.

FIG. 5 is a view illustrating a simulation result for explaining an operational effect of the light irradiation device according to the first embodiment of the present invention.

FIG. 6 is a schematic view for explaining a configuration of the light irradiation device according to the first embodiment of the present invention.

<Explanation of Reference Numerals and Symbols>

[0016]

1: Light irradiation device
 1A: Light irradiation device
 100: Housing
 101: Exhaust port
 103: Intake port
 105: Cover glass
 107: Support plate
 107a: Opening
 108: Mirror unit
 108a: First reflective surface
 108b: Second reflective mirror
 109: Mirror unit
 109a: First reflective surface
 109b: Third reflective mirror
 200: Light source unit
 210: LED module
 215: Substrate
 217: LED element
 220: Heat sink
 222: Base plate
 225: Heat radiating fin
 300: Cooling fan

[Mode for Invention]

[0017] Hereinafter, embodiments of the present invention will be described in detail with reference to the drawings. Further, in the drawings, identical or equivalent constituent elements are denoted by the same reference numerals, and descriptions thereof will be omitted.

(First Embodiment)

[0018] FIGS. 1 and 2 are views illustrating a configuration of a light irradiation device 1 according to a first embodiment of the present invention. FIG. 1(a) is a perspective view, and FIG. 1(b) is a front view. In addition, FIG. 2 is a cross-sectional view taken along line A-A in FIG. 1(b). As illustrated in FIGS. 1 and 2, the light irradi-

ation device 1 according to the present embodiment refers to a light source device embedded in a printing device or the like and configured to cure ultraviolet curable ink or ultraviolet curable resin. The light irradiation device 1 is disposed above an irradiation object P (e.g., a sheet-shaped recording medium or the like) transferred in one direction and emits line-shaped ultraviolet rays to the irradiation object P. FIG. 1(a) illustrates only the light irradiation device 1 for convenience of description. However, in an actual printing device or the like, a plurality of recording heads for providing ink with different colors is arranged in a transfer direction of the irradiation object P, and the light irradiation device 1 is disposed in a narrow space at a downstream side of the recording heads. In addition, the present specification, the transfer direction of the irradiation object P is defined and described as an X-axis direction (first direction), an arrangement direction of light-emitting diode (LED) elements 217 to be described below is defined and described as a Y-axis direction (second direction), and a direction in which the LED elements 217 emit ultraviolet rays is defined and described as a Z-axis direction (third direction). In addition, in general, the ultraviolet ray is considered as meaning light having a wavelength of 400 nm or less. However, in the present specification, the ultraviolet ray means light having a wavelength (e.g., a wavelength of 250 to 420 nm) capable of curing the ultraviolet curable ink applied onto the irradiation object P.

[0019] As illustrated in FIGS. 1 and 2, the present embodiment describes a light irradiation device 1 that includes a light source unit 200, cooling fans 300, and a housing 100 configured to accommodate the light source unit 200 and the cooling fans 300.

[0020] The housing 100 is a casing having a box shape elongated in the Y-axis direction, and a cover glass 105 made of glass is provided on a front surface (a surface based on the plus Z-axis direction) of the housing 100 and configured such that the ultraviolet rays exit the cover glass 105. In addition, a pair of mirror units 108 and 109 is disposed between the light source unit 200 and the cover glass 105 and spaced apart from each other in the X-axis direction (FIG. 2). A support plate 107 (support part) is disposed on the front surface of the cover glass 105 and supports a rim portion of the cover glass 105 from a side based on the plus Z-axis direction (FIGS. 1(b) and 2). The support plate 107 has a rectangular opening 107a (opening portion) formed at a central portion thereof. The ultraviolet rays passing through the cover glass 105 are emitted to the irradiation object P through the opening 107a. As described above, in the present embodiment, the cover glass 105 and the support plate 107 are disposed to cover the front surface of the housing 100, and the cover glass 105 and the support plate 107 constitute a part of the housing 100.

[0021] Further, an exhaust port 101 for discharging air in the housing 100 is formed in a left surface (a surface based on the minus X-axis direction) of the housing 100. Four intake ports 103 for supplying air into the housing

100 are formed in a rear surface (a surface based on the minus Z-axis direction) of the housing 100, and the cooling fans 300 are disposed to respectively correspond to the intake ports 103 (FIGS. 1(a) and 2). The light irradiation device 1 is electrically connected to a power source device (not illustrated), and electric power is supplied from the power source device to the light source unit 200, the cooling fans 300, and the like.

[0022] FIG. 3 is a view for explaining a configuration of the light source unit 200 of the present embodiment, FIG. 3(a) is a front view (a view viewed from a side based on the plus Z-axis direction), and FIG. 3(b) is a side view (a view viewed from a side based on the minus X-axis direction). As illustrated in FIG. 3, the light source unit 200 includes four LED modules 210 disposed side by side in the Y-axis direction, and a heat sink 220. The ultraviolet rays emitted from the LED modules 210 are guided by the pair of mirror units 108 and 109 and emitted to the irradiation object P through the opening 107a and the cover glass 105 disposed on the front surface of the housing 100 (see broken-line arrows in FIG. 2).

[0023] The LED module 210 includes a substrate 215 having a rectangular plate shape defined in the X-axis direction and the Y-axis direction, and the plurality of LED elements 217 having the same properties. The LED module 210 is fixed to an end surface (an end surface based on the plus Z-axis direction) of a base plate 222 of the heat sink 220.

[0024] The substrate 215 of each of the LED modules 210 is a rectangular wiring substrate made of a material (e.g., aluminum nitride) having high thermal conductivity. As illustrated in FIG. 3(a), the LED elements 217 of 5 rows (X-axis direction) \times 20 (Y-axis direction) are mounted on the surface of the substrate in a chip-on-board (COB) manner. In addition, in the present embodiment, the LED elements 217 are disposed in an LED mounting region S (a region surrounded by a broken line in FIG. 3(a)) of an approximately central portion of the substrate 215 based on the X-axis direction. The LED elements 217 are disposed at predetermined intervals (e.g., 2 mm) in the X-axis direction and the Y-axis direction. In addition, as illustrated in FIG. 3(b), for convenience of description in the present specification, the LED elements 217 disposed in the respective rows are sequentially referred to as LED elements 217a, 217b, 217c, 217d, and 217e in the X-axis direction.

[0025] An anode pattern (not illustrated) and a cathode pattern (not illustrated) are formed on the substrate 215 to supply electric power to each of the LED elements 217. Each of the LED elements 217 is electrically connected to the anode pattern and the cathode pattern by soldering. In addition, the substrate 215 is electrically connected to a non-illustrated driver circuit by means of a non-illustrated wire cable, and each of the LED elements 217 is configured to be supplied with a drive current from the driver circuit through the anode pattern and the cathode pattern. When the drive current is supplied to each of the LED elements 217, the ultraviolet rays

(e.g., wavelength of 385 nm) corresponding in light amount to the drive current are emitted from each of the LED element 217. The line-shaped ultraviolet rays parallel to the Y-axis direction are emitted from the LED module 210. As illustrated in FIG. 3(a), in the present embodiment, the four LED modules 210 are arranged in the Y-axis direction, and the line-shaped ultraviolet rays from the respective LED modules 210 are continued in the Y-axis direction. Further, the drive current to be supplied to each of the LED elements 217 is adjusted so that each of the LED elements 217 of the present embodiment emits the ultraviolet rays with approximately uniform light amount, and the line-shaped ultraviolet rays emitted from the four LED modules 210 have approximately uniform light amount distributions in the X-axis direction and the Y-axis direction.

[0026] The heat sink 220 refers to a kind of an air-cooled heat sink disposed to be in close contact with a back surface of the substrate 215 of the LED module 210 and configured to dissipate heat generated by each of the LED modules 210. The heat sink 220 is made of a material such as aluminum or copper having good thermal conductivity and includes the base plate 222 having a thin-plate shape extending in the Y-axis direction, and a plurality of heat radiating fins 225 formed on a surface of the heat sink 220 opposite to the surface being in contact with the substrate 215. The heat radiating fins 225 each have a thin-plate shape parallel to the X-Z plane and disposed at predetermined intervals in the Y-axis direction. In addition, in the present embodiment, cooling air produced by the cooling fans 300 uniformly cools the plurality of heat radiating fins 225.

[0027] When the drive current flows in the respective LED elements 217 and the ultraviolet rays are emitted from the respective LED elements 217, a temperature is raised by self-heating of the LED elements 217. However, the heat generated by the respective LED elements 217 is quickly transferred to the heat radiating fins 225 through the substrate 215 and the base plate 222 and dissipated into the ambient air from the heat radiating fins 225. Further, the air heated by the heat radiating fins 225 is quickly discharged through the exhaust port 101 by a flow of cooling air produced by the cooling fans 300. As described above, in the present embodiment, the respective LED modules 210 are uniformly cooled by the heat sink 220 and the cooling fans 300, which inhibits a deterioration in luminous efficiency caused by an increase in temperature of the LED elements 217.

[0028] Further, as described above, in the present embodiment, the pair of mirror units 108 and 109 is disposed between the light source unit 200 and the cover glass 105 and spaced apart from each other in the X-axis direction (FIG. 2). The support plate 107 (support part) is disposed on the front surface of the cover glass 105 and supports the rim portion of the cover glass 105 from the side based on the plus Z-axis direction (FIGS. 1(b) and 2).

[0029] As illustrated in FIG. 2, the pair of mirror units 108 and 109 are each a metallic plate-shaped member

extending in the Y-axis direction so that the optical paths of the respective ultraviolet rays emitted from the LED elements 217 are interposed therebetween in the X-axis direction. When viewed in the Y-axis direction, the mirror units 108 and 109 extend in the Z-axis direction so as to be disposed uprightly and approximately perpendicularly to the cover glass 105 and disposed symmetrically so that the optical paths of the ultraviolet rays emitted from the LED elements 217 are interposed between the mirror units 108 and 109. In addition, the mirror units 108 and 109 respectively have first reflective surfaces 108a and 109a facing each other so that the optical paths of the ultraviolet rays emitted from the LED elements 217 are interposed therebetween.

[0030] In general, the ultraviolet ray emitted from the LED element 217 has been known as being dispersed at a predetermined diffusion angle and decreased in intensity when the ultraviolet ray has a large angle component. However, in the present embodiment, because the first reflective surfaces 108a and 109a are disposed so that the optical paths of the ultraviolet rays emitted from the LED elements 217 are interposed therebetween, the ultraviolet rays, which include even the ultraviolet rays having low intensity and a large angle component, are guided by the first reflective surfaces 108a and 109a and exit through the cover glass 105.

[0031] However, in case that the above-mentioned configuration (i.e., the configuration in which the ultraviolet rays are guided by the first reflective surfaces 108a and 109a) is adopted, the light amount decreases each time the ultraviolet rays are reflected by the first reflective surfaces 108a and 109a because the first reflective surfaces 108a and 109a have predetermined reflectance (e.g., 90%). As a result, there occurs a problem in that the light amount on the irradiation object P decreases.

[0032] Therefore, in the present embodiment, to solve the problem and efficiently extract the ultraviolet rays emitted from the LED elements 217, the ultraviolet ray, which has a small angle component (e.g., the ultraviolet ray with a diffusion angle of $\leq 60^\circ$) among the ultraviolet rays emitted from the LED elements 217, exits after being reflected by the first reflective surfaces 108a and 109a once or without being reflected, and the ultraviolet ray, which has a large angle component (e.g., the ultraviolet ray with a diffusion angle of $> 60^\circ$), exits after being reflected by the first reflective surfaces 108a and 109a one or more times (details will be described below).

[0033] Hereinafter, functions of the first reflective surfaces 108a and 109a of the pair of mirror units 108 and 109 will be described in detail.

[0034] FIG. 4 is a schematic view for explaining a relationship between the arrangement of the LED module 210, the mirror units 108 and 109, the cover glass 105, and the support plate 107 and the rays emitted from the respective LED elements 217. FIG. 4(a) is a view illustrating a relationship with the ultraviolet ray having a small diffusion angle (e.g., a diffusion angle of $\leq 60^\circ$), and FIG. 4(b) is a view illustrating a relationship with the ultraviolet

ray having a large diffusion angle (e.g., a diffusion angle of $> 60^\circ$). In FIG. 4(a), L60a represents the ray having a diffusion angle of 60° and emitted from the LED element 217a, L60c represents the ray having a diffusion angle of 60° and emitted from the LED element 217c, L60e represents the ray having a diffusion angle of 60° and emitted from the LED element 217e, and L0a represents the ray having a diffusion angle of 0° and emitted from the LED element 217a. In FIG. 4(b), L65a represents the ray having a diffusion angle of 65° and emitted from the LED element 217a, and L80e represents the ray having a diffusion angle of 80° and emitted from the LED element 217e. In addition, in FIGS. 4(a) and 4(b), the description of the ultraviolet rays emitted from the LED elements 217b and 217d is omitted for convenience of description. However, actually, the rays identical to the rays emitted from the LED elements 217a, 217c, and 217e are also emitted from the LED elements 217b and 217d. In addition, for convenience of description, FIGS. 4(a) and 4(b) illustrate that each of the LED elements 217 has a rectangular shape. However, actually, each of the LED elements 217 is sufficiently thin in the Z-axis direction, and a light-emitting point of each of the LED elements 217 is substantially disposed on the surface of the substrate 215.

[0035] As illustrated in FIG. 4(a), in the present embodiment, Expressions 1 and 2 below are satisfied on the assumption that a width of the LED mounting region S in the X-axis direction (i.e., a distance from the LED element 217a in a first row positioned at the most upstream side based on the X-axis direction (a side based on the minus X-axis direction) to the LED element 217e in a fifth row positioned at a most downstream side based on the X-axis direction (a side based on the plus X-axis direction) is a, an interval between the first reflective surfaces 108a and 109a is b, a height of the first reflective surfaces 108a and 109a in the Z-axis direction is h, a distance from the substrate 215 to the support plate 107 is d, and an interval between the support plates 107 in the X-axis direction (i.e., a width of the opening 107a in the X-axis direction) is w when viewed in the Y-axis direction.

$$h \leq (a+b)/2\sqrt{3} \quad (1)$$

$$w \geq d \cdot 2\sqrt{3}-a \quad (2)$$

[0036] Specifically, the ray L60a, which has a diffusion angle of 60° among the ultraviolet rays emitted from the LED element 217a, is reflected by the first reflective surface 108a once and exits through the cover glass 105. The ray L60a exits through the cover glass 105 without entering the first reflective surface 109a (i.e., not passing through a tip of the first reflective surface 109a) (FIG. 4(a)).

[0037] Further, the ray L60c, which has a diffusion an-

gle of 60° among the ultraviolet rays emitted from the LED element 217c, is reflected by the first reflective surfaces 108a and 109a once and exits through the cover glass 105.

[0038] In addition, the ray L60e, which has a diffusion angle of 60° among the ultraviolet rays emitted from the LED element 217e, is reflected by the first reflective surface 109a once and exits through the cover glass 105. The ray L60e exits through the cover glass 105 without entering the first reflective surface 108a (i.e., not passing through a tip of the first reflective surface 108a).

[0039] Therefore, even the ray, which has a diffusion angle smaller than 60° among the ultraviolet rays emitted from the respective LED elements 217, also exits through the cover glass 105 after being reflected by the first reflective surfaces 108a and 109a once or without being reflected. In addition, the ray (the ray L60a, L60c, L60e, or L0a), which has a diffusion angle of 60° or less, passes through the cover glass 105 and then reaches the irradiation object P after passing through the opening 107a (i.e., without being vignetted by the support plate 107).

[0040] Meanwhile, the ray (i.e., the ray L65a having a diffusion angle of 65° or the ray L80e having a diffusion angle of 80°), which has a diffusion angle larger than 60° among the ultraviolet rays emitted from the LED element 217, is reflected by the first reflective surfaces 108a and 109a one or more times and exits through the cover glass 105 (FIG. 4(b)). In addition, some rays (e.g., the rays L65a) each having a diffusion angle larger than 60° pass through the cover glass 105 and the opening 107a (i.e., without being vignetted by the support plate 107) and then reach the irradiation object P, whereas the other rays (e.g., the rays L80e) are randomly reflected by the component such as the support plate 107 without passing through the opening 107a (i.e., while being vignetted by the support plate 107) and then reach the irradiation object P.

[0041] In this case, the positional relationship between the LED element 217, the first reflective surfaces 108a and 109a, and the support plate 107 will be described. A distance in the X-axis direction from a central axis (a light-emitting point) of the LED element 217a to the first reflective surface 109a may be represented by $\sqrt{3}h$ from the relationship with the ray L60a. A distance in the X-axis direction from a central axis (a light-emitting point) of the LED element 217e to the first reflective surface 108a may be represented by $\sqrt{3}h$ from the relationship with the ray L60e. Therefore, an interval b between the first reflective surfaces 108a and 109a may be represented by

$$b \geq \sqrt{3}h + \sqrt{3}h-a.$$

[0042] Expression 1 may be obtained by modifying the above-mentioned expression.

[0043] In addition, a distance in the X-axis direction from the central axis (the light-emitting point) of the LED

element 217a to one end (an end based on the plus X-axis direction) of the support plate 107 may be represented by $\sqrt{3}d$ from the relationship with the ray L60a. Likewise, a distance in the X-axis direction from the central axis (the light-emitting point) of the LED element 217e to the other end (the end based on the minus X-axis direction) of the support plate 107 may be represented by $\sqrt{3}d$ from the relationship with the ray L60e. Therefore, an interval w of the support plate 107 in the X-axis direction may be represented by

$$w \geq \sqrt{3}d + \sqrt{3}d - a.$$

[0044] Expression 2 may be obtained by modifying the above-mentioned expression.

[0045] As described above, in the present embodiment, because the ray (ultraviolet ray) having high intensity and the diffusion angle of 60° or less reaches the irradiation object P while being reflected by the first reflective surfaces 108a and 109a once or without being reflected, the influence made by the reflection by the first reflective surfaces 108a and 109a (i.e., a decrease in light amount) is inhibited. In addition, the ray (ultraviolet ray) having the diffusion angle larger than 60° is reflected by the first reflective surfaces 108a and 109a one or more times, but the influence of the overall amount of light emitted to the irradiation object P is small (i.e., the influence of the decrease in light amount is small) because the ray (ultraviolet ray) having the diffusion angle larger than 60° has low intensity.

[0046] FIG. 5 illustrates a simulation result for explaining an operational effect of the light irradiation device 1 of the present embodiment. The horizontal axis indicates an interval between the support plates 107 in the X-axis direction (i.e., a width w (mm) of the opening 107a in the X-axis direction). In addition, the vertical axis indicates an accumulated amount of ultraviolet rays emitted from the light irradiation device 1, i.e., a relative value when an accumulated amount of light is 1 in case that w is 100 (mm).

[0047] The accumulated amount of light was obtained by changing w (mm) under a simulation condition in which the width a of the LED mounting region S in the X-axis direction (i.e., the distance from the LED element 217a in the first row positioned at the most upstream side based on the X-axis direction (the side based on the minus X-axis direction) to the LED element 217e in the fifth row positioned at the most downstream side based on the X-axis direction (the side based on the plus X-axis direction) is 10 (mm), the interval b between the first reflective surfaces 108a and 109a is 15 (mm), the height h of the first reflective surfaces 108a and 109a in the Z-axis direction is 5 (mm), and the distance d from the substrate 215 to the support plate 107 is 8 (mm).

[0048] As a result, it can be seen that when the accumulated amount of light is about 0.9 and w is 30 (mm) or more in case that w is about 17 (mm), the accumulated

amount of light does not decrease (i.e., the ultraviolet ray emitted from the light irradiation device 1 reaches the irradiation object P without being vignetted by the support plate 107).

[0049] In this case, the flowing expressions are made by inputting the simulation condition into Expression 1 and satisfies Expression 1.

$$h \leq (a+b)/2\sqrt{3} \quad (1)$$

$$5(\text{mm}) \leq (10(\text{mm})+15(\text{mm}))/2\sqrt{3}$$

$$5(\text{mm}) \leq 7.2(\text{mm})$$

[0050] In addition, the following expression are made by inputting the simulation condition into Expression 2.

$$w \geq d \cdot 2\sqrt{3} - a \quad (2)$$

$$w \geq 8(\text{mm}) \times 2\sqrt{3} - 10(\text{mm})$$

$$w \geq 17.8(\text{mm})$$

[0051] That is, it can be seen that the accumulated amount of the ultraviolet ray emitted from the light irradiation device 1 rarely decreases (i.e., the accumulated amount of light is 0.9 or more) when the conditions of Expressions 1 and 2 approximately coincide with the simulation result and Expressions 1 and 2 are satisfied.

[0052] While the present embodiment has been described above, the present invention is not limited to the above-mentioned configurations, and various modifications may be made within the scope of the technical spirit of the present invention.

[0053] For example, the configuration has been described in which in the LED module 210 of the present embodiment, the LED elements 217 are arranged in the aspect of 5 rows (X-axis direction) \times 20 (Y-axis direction). However, the present invention is not limited to this configuration. The LED elements 217 may be arranged such that the number of LED elements 217 in the Y-axis direction is n (n is two or more integers), and the LED elements 217 are arranged in m rows (m is two or more integers) in the X-axis direction.

[0054] Further, the first reflective surfaces 108a and 109a of the present embodiment have been described as extending in the Z-axis direction to be provided uprightly and approximately perpendicularly to the cover glass 105 and disposed symmetrically so that the optical paths of the ultraviolet rays emitted from the respective LED elements 217 are interposed therebetween. However, the first reflective surfaces 108a and 109a need not be necessarily parallel to the Z-axis direction. For example, the first reflective surfaces 108a and 109a may be

disposed to be widened in a \sphericalangle shape in the Z-axis direction.

[0055] In addition, in the present embodiment, the configuration has been described in which the positional relationship between the LED element 217, the first reflective surfaces 108a and 109a, and the support plate 107 satisfies Expressions 1 and 2, but the present invention is not necessarily limited to this configuration. For example, the positional relationship may satisfy Expressions 3 and 4 below.

$$h \leq (a+b)/2\sqrt{2} \quad (3)$$

$$w \geq d \cdot 2\sqrt{2} - a \quad (4)$$

(Second Embodiment)

[0056] FIG. 6 is a view for explaining a configuration of a light irradiation device 1A according to a second embodiment of the present invention. As illustrated in FIG. 6, the light irradiation device 1(a) of the present embodiment differs from the light irradiation device 1 of the first embodiment in that an X-Z cross-section of each of a pair of mirror units 108 and 109 has an L shape, and the light irradiation device 1A includes a second reflective mirror 108b extending in the minus X-axis direction from a tip portion of a first reflective surface 108a of the mirror unit 108 so as to face the cover glass 105, and a third reflective mirror 109b extending in the plus X-axis direction from a tip portion of a first reflective surface 109a of the mirror unit 109 so as to face the cover glass 105.

[0057] As illustrated in FIG. 6, the second reflective mirror 108b and the third reflective mirror 109b are configured to reflect the ultraviolet rays, which are emitted from the LED elements 217 (the LED element 217c in FIG. 6) and reflected by the irradiation object P, back to the irradiation object P (see broken line arrows in FIG. 6).

[0058] Therefore, according to the configuration of the present embodiment, the ultraviolet ray (i.e., the ultraviolet ray reflected by the irradiation object P), which does not contribute to the curing of the ultraviolet curable ink on the irradiation object P, is reflected back to the irradiation object P, which makes it possible to further improve efficiency in using the ultraviolet ray.

[0059] Further, FIG. 6 illustrates that the rays are reflected by the second reflective mirror 108b and the third reflective mirror 109b only once. However, the rays are reflected multiple times in accordance with the angle components of the ultraviolet rays. In addition, to enable the rays to be reflected multiple times, a width of each of the second reflective mirror 108b and the third reflective mirror 109b in the X-axis direction may be as large as possible. In this case, the width of the cover glass 105 in the X-axis direction may be increased, and the interval between the support plates 107 in the X-axis direction (i.e., the width of the opening 107a in the X-axis direction)

may be increased.

[0060] In addition, both the second reflective mirror 108b and the third reflective mirror 109b need not be necessarily installed, and any one of the second reflective mirror 108b and the third reflective mirror 109b may be installed.

[0061] Furthermore, the configuration has been described in which the X-Z cross-section of each of the mirror units 108 and 109 of the present embodiment has an L shape, the first reflective surface 108a and the second reflective mirror 108b are integrated, and the first reflective surface 109a and the third reflective mirror 109b are integrated. However, the present invention is not necessarily limited to this configuration. The first reflective surface 108a and the second reflective mirror 108b may be separately formed, and the first reflective surface 109a and the third reflective mirror 109b may be separately formed.

[0062] In addition, it should be interpreted that the embodiments disclosed above are illustrative in all aspects, and the present invention is not limited thereto. The scope of the present invention is defined by the claims instead of the above-mentioned descriptions, and all modifications within the equivalent scope and meanings to the claims belong to the scope of the present invention.

Claims

1. A light irradiation device, which emits rays to an irradiation object capable of relatively moving in a first direction, the light irradiation device comprising:

a substrate defined in the first direction and a second direction perpendicular to the first direction;

a plurality of light-emitting elements arranged on the substrate so that the number of light-emitting elements in the second direction is n (n is two or more integers) and the light-emitting elements are arranged in m (m is two or more integers) rows in the first direction, the plurality of light-emitting elements being disposed so that directions of optical axes thereof are aligned with a third direction orthogonal to the first direction and the second direction;

a cover glass configured to transmit the rays emitted from the plurality of light-emitting elements;

a support part configured to support the cover glass and having an opening portion through which the rays having passed through the cover glass passes; and

a pair of first reflective mirrors disposed between the substrate and the cover glass so that optical paths of the plurality of light-emitting elements are interposed therebetween in the first direction, the pair of first reflective mirrors being con-

figured to guide the rays,
 wherein following Expressions (1) and (2) are
 satisfied on the assumption that a distance from
 a light-emitting element in a first row positioned
 at a most upstream side based on the first di-
 rection to a light-emitting element in an m-th row
 positioned at a most downstream side in the first
 direction is a, an interval between the pair of first
 reflective mirrors is b, a height of the pair of first
 reflective mirrors in the third direction is h, a dis-
 tance from the substrate to the support part is
 d, and a width of the opening portion in the first
 direction is w when viewed in the second direc-
 tion:

$$h \leq (a+b)/2\sqrt{3} \quad (1)$$

$$w \geq d \cdot 2\sqrt{3} - a \quad (2).$$

2. The light irradiation device of claim 1, comprising:
 a second reflective mirror extending to an upstream
 side based on the first direction from a tip portion of
 the first reflective mirror positioned at the upstream
 side based on the first direction so as to face the
 cover glass, the second reflective mirror being con-
 figured to reflect the rays, which have been reflected
 by the irradiation object, to the irradiation object.

3. The light irradiation device of claim 2, wherein the
 second reflective mirror is integrated with the first
 reflective mirror positioned at the upstream side
 based on the first direction.

4. The light irradiation device of any one of claims 1 to
 3, comprising:
 a third reflective mirror extending to a downstream
 side based on the first direction from a tip portion of
 the first reflective mirror positioned at the down-
 stream side based on the first direction so as to face
 the cover glass, the third reflective mirror being con-
 figured to reflect the rays, which have been reflected
 by the irradiation object, to the irradiation object.

5. The light irradiation device of claim 4, wherein the
 third reflective mirror is integrated with the first re-
 flective mirror positioned at the downstream side
 based on the first direction.

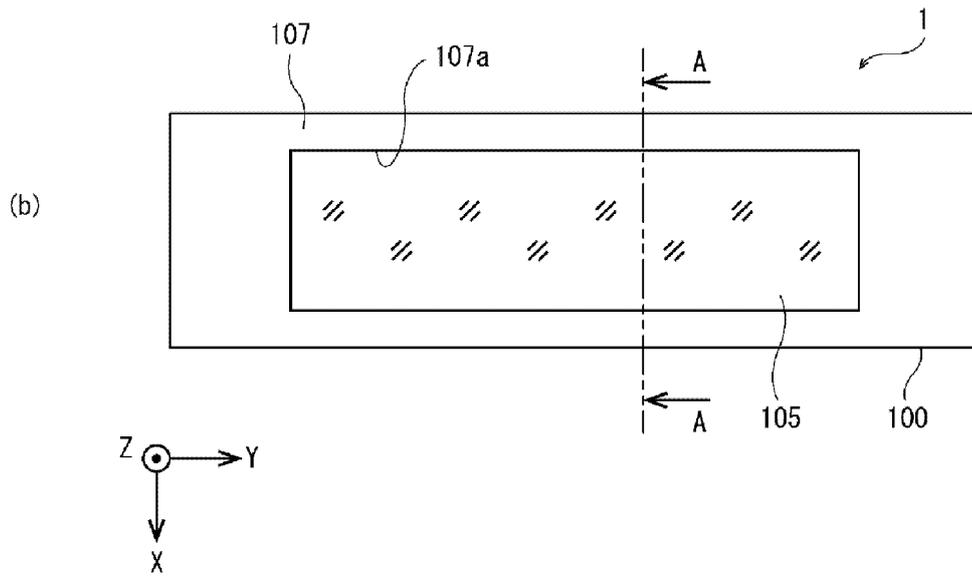
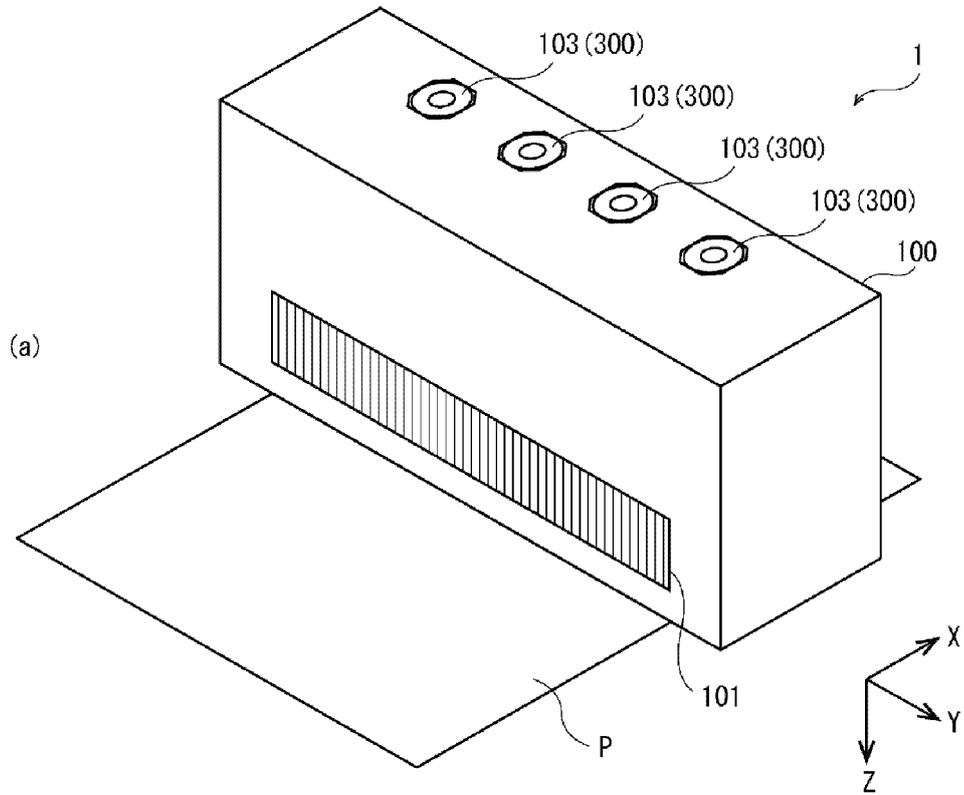
6. The light irradiation device of any one of claims 1 to
 5, comprising:

a housing configured to accommodate the sub-
 strate, the plurality of light-emitting elements,
 and the pair of first reflective mirrors,
 wherein the support part and the cover glass
 constitute a part of the housing.

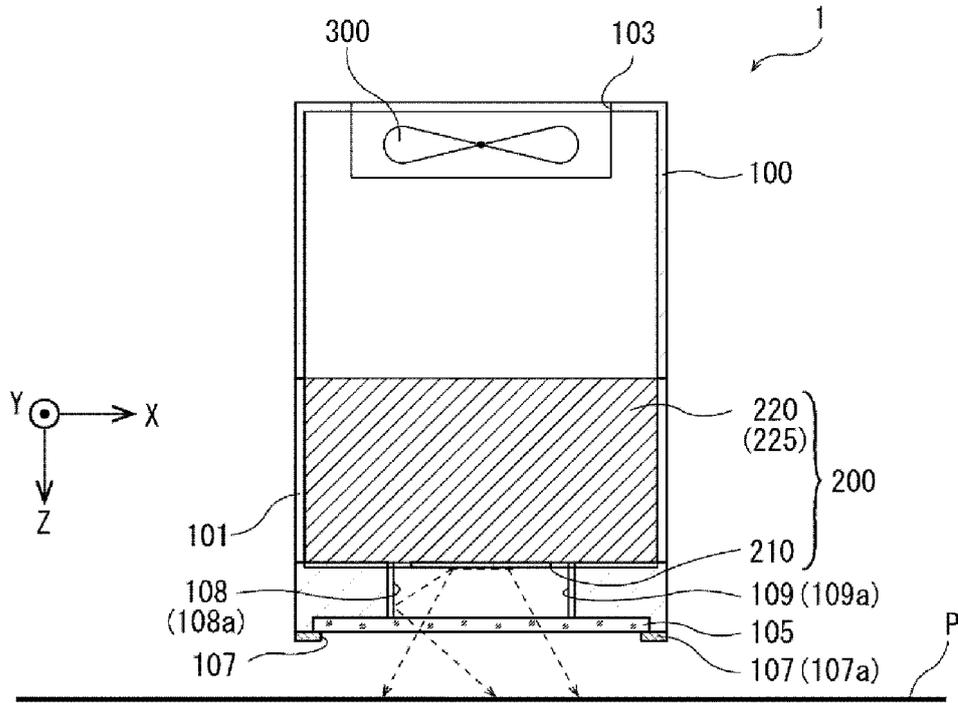
7. The light irradiation device of any one of claim 1 to
 6, wherein the ray is a ray in an ultraviolet wavelength
 region.

8. The light irradiation device of claim 7, wherein the
 irradiation object has a sheet shape, and the ray in
 the ultraviolet wavelength region cures ink applied
 onto a surface of the irradiation object.

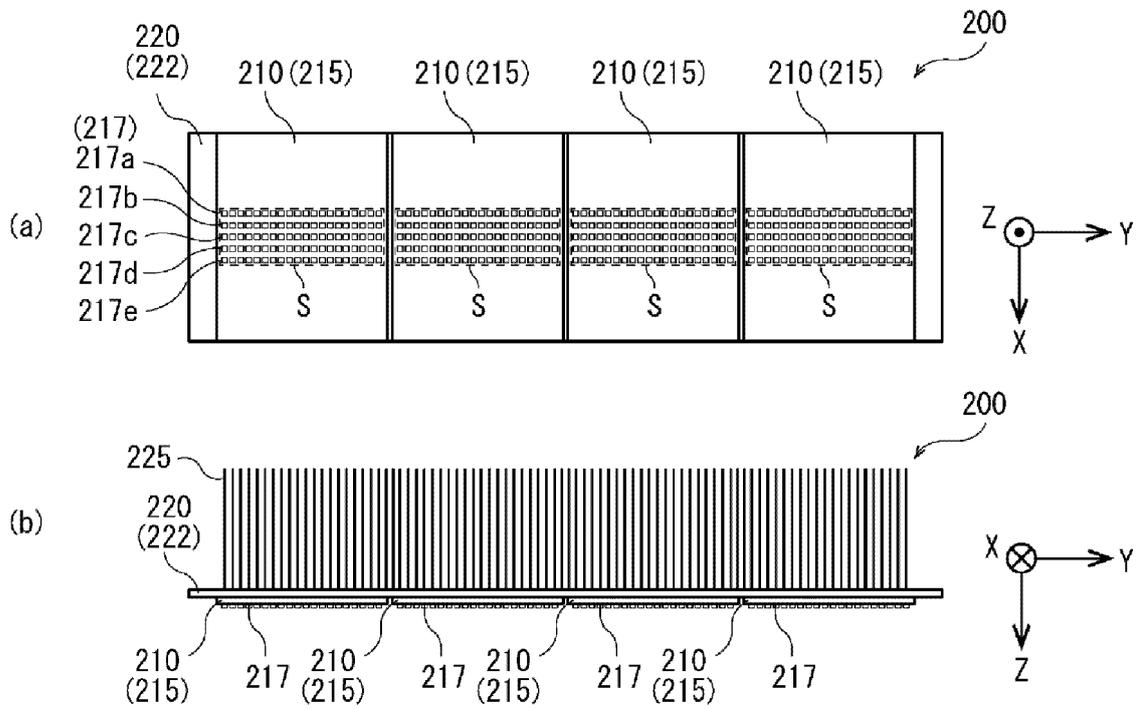
[FIG. 1]



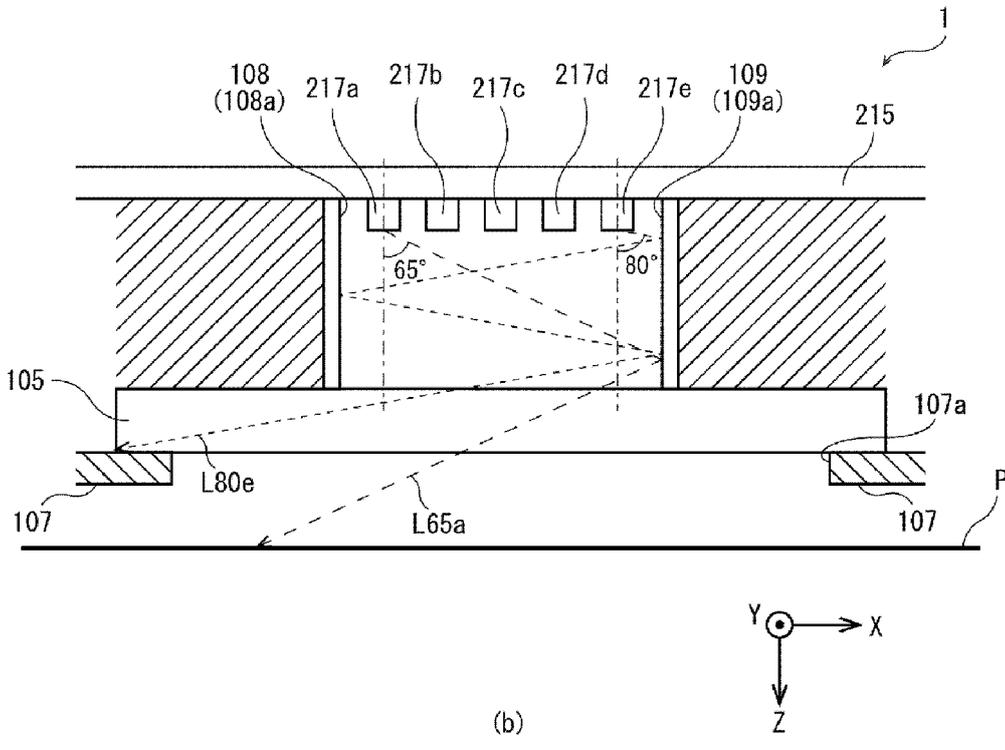
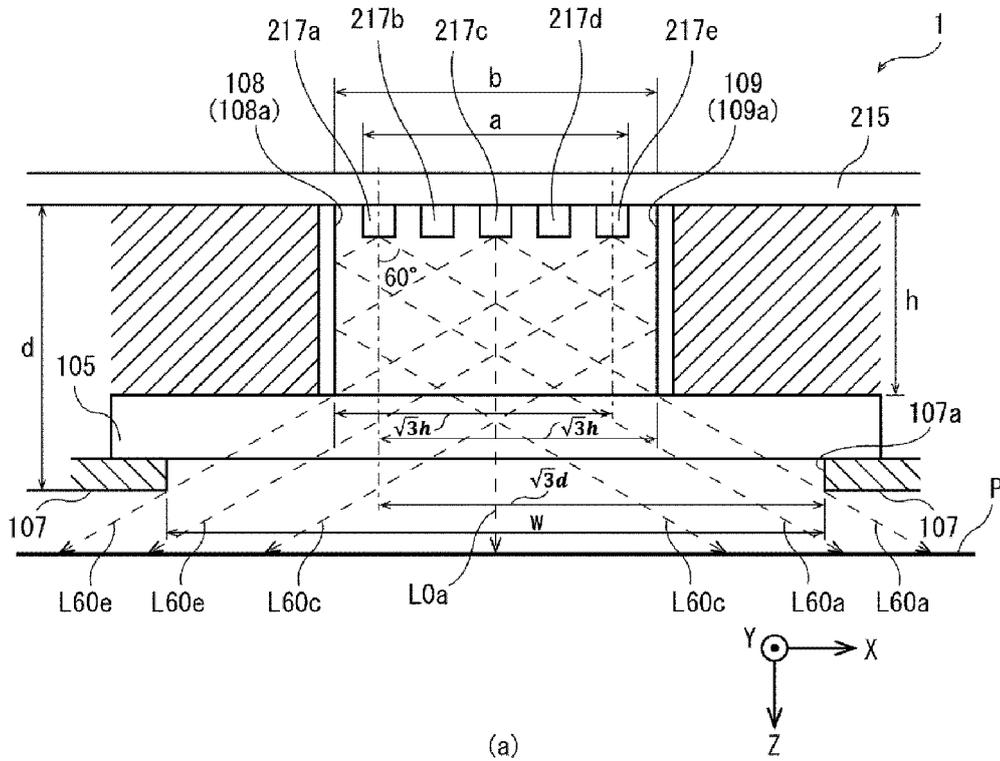
[FIG. 2]



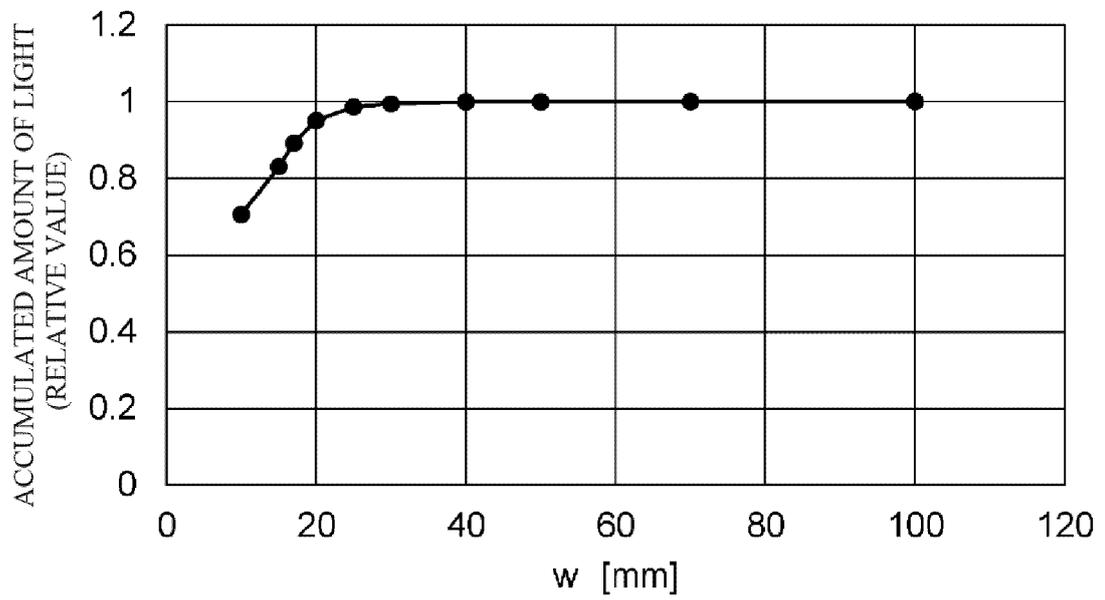
[FIG. 3]



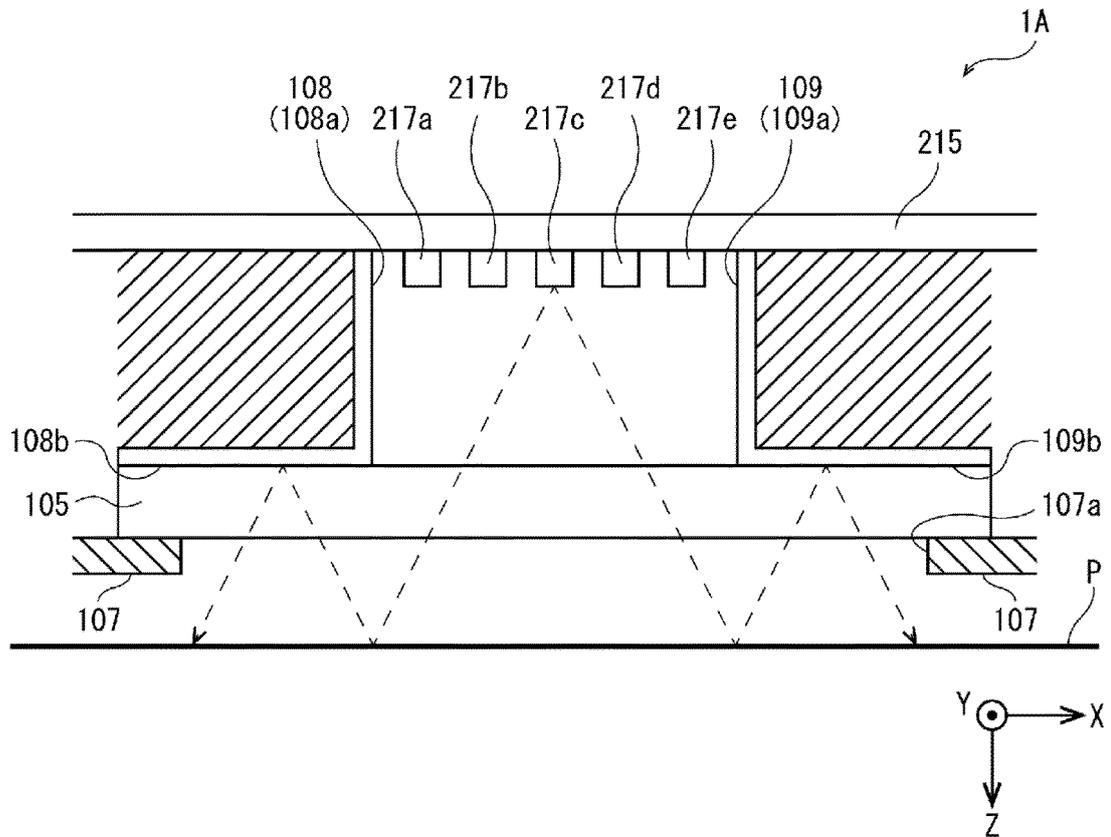
[FIG. 4]



[FIG. 5]



[FIG. 6]



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2021/027040

A. CLASSIFICATION OF SUBJECT MATTER

B41J 2/01(2006.01)i; **B41F 23/04**(2006.01)i; **F21S 2/00**(2016.01)i; **F21V 3/00**(2015.01)i; **F21V 7/09**(2006.01)i;
F21Y 105/16(2016.01)n; **F21Y 115/10**(2016.01)n
 FI: B41J2/01 129; B41F23/04 B; F21S2/00 350; F21V3/00 310; F21V7/09 510; F21Y105:16; F21Y115:10 300

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B41J2/01; B41F23/04; F21S2/00; F21V3/00; F21V7/09; F21Y105/16; F21Y115/10

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

Published examined utility model applications of Japan 1922-1996
 Published unexamined utility model applications of Japan 1971-2021
 Registered utility model specifications of Japan 1996-2021
 Published registered utility model applications of Japan 1994-2021

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2020-66203 A (SEIKO EPSON CORP.) 30 April 2020 (2020-04-30) entire text, all drawings	1-8
A	JP 2020-46119 A (FUJI XEROX CO., LTD.) 26 March 2020 (2020-03-26) entire text, all drawings	1-8
A	JP 2018-69214 A (HOYA CANDEO OPTRONICS CORP.) 10 May 2018 (2018-05-10) entire text, all drawings	1-8
A	JP 2017-226109 A (FUJI XEROX CO., LTD.) 28 December 2017 (2017-12-28) entire text, all drawings	1-8
A	JP 2009-154436 A (MIMAKI ENGINEERING CO., LTD.) 16 July 2009 (2009-07-16) entire text, all drawings	1-8
A	US 2009/0207223 A1 (HEWLETT-PACKARD DEVELOPMENT COMPANY, L. P.) 20 August 2009 (2009-08-20) whole document	1-8

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

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 28 September 2021	Date of mailing of the international search report 12 October 2021
Name and mailing address of the ISA/JP Japan Patent Office (ISA/JP) 3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915 Japan	Authorized officer Telephone No.

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REFERENCES CITED IN THE DESCRIPTION

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