

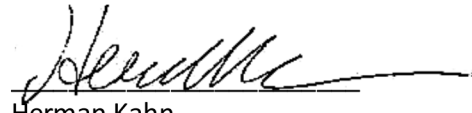
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(71) Applicant: KONICA MINOLTA, INC. [JP/JP]; 2-7-2 Marunouchi,
Chiyoda-ku, Tokyo 1007015 (JP).(72) Inventor: MATSUI Kazuki; c/o Konica Minolta, Inc., 2-7-2
Marunouchi, Chiyoda-ku, Tokyo, 1007015 (JP)(74) Agent: TAMURA Keijiro et al.
Masumoto Bldg. 8F, 7-4-3 Nishi-Shinjuku, Shinjuku-ku, Tokyo
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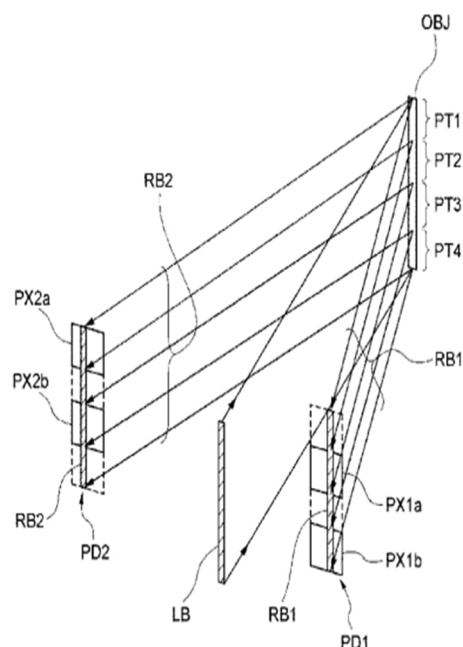
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(54) Title: LIGHT PROJECTION/RECEPTION UNIT, AND RADAR

(54) Title of the invention: Light projection/reception unit and radar

[FIG. 6]



(57) Abstract: Provided are: a radar which is capable of suppressing omissions in detection, while having a high resolution and suppressing costs; and a light projection/reception unit which is used in same. A first light reception unit PD1 and a second light reception unit PD2 are disposed so as to be separated from each other in a second direction. First light reception elements PX1 of the first light reception unit PD1 and second light reception elements PX2 of the second light reception unit PD2 are respectively arranged along a first direction with intervals therebetween. At least two adjacent first light reception elements PX1 are configured so as to come into contact with a second light reception element PX2 located therebetween, without any gaps, when the first light reception elements PX1 are shifted in the second direction relative to the second light reception elements PX2. Accordingly, a high resolution is achieved with a simple configuration, and faint reflected beams of light from an object can be detected without any omissions, while suppressing incidence of ambient light.

(57) Abstract: To provide a radar, and light projection/reception unit for use therein, which makes it possible to achieve high resolution and reduce detection failure while keeping costs down. A first light receiving part PD1 and a second light receiving part PD2 are spaced apart in a second direction and configured such that first light receiving elements PX1 of the first light receiving part PD1 and second light receiving elements PX2 of the second light receiving part PD2 are spaced apart and arranged side by side in a first direction such that at least two adjacent first light receiving elements PX1 would come into gapless contact with a second light receiving element PX2 interposed therebetween when the first light receiving elements PX1 are shifted relative to the second light receiving elements PX2 in the second direction, thus providing high resolution with a simple configuration and making it possible to detect faint reflected light beams from an object while suppressing the input of ambient stray light.

SPECIFICATION

Title of the invention: Light projection/reception unit and radar

Technical field

[0001] The present invention relates to a radar, and to a light projection/reception unit used in a radar, for detecting an object by irradiating it with a light beam from a light source.

Background art

[0002] In recent years, for example, in the field of automobiles and security robots, there has been an increasing demand for accurate detection of obstacles within the range of movement of a moving body for the purpose of preventing collisions of the moving body. As a method of detecting such obstacles, a radio radar has been proposed that emits radio waves and detects reflected waves, but this involves the problem that, from the standpoint of resolution, it is difficult to accurately ascertain the position of distant objects.

[0003] To address this, laser radars using a TOF (Time of Flight) scheme have also been developed. The TOF scheme makes it possible to measure the distance to an object by measuring the time it takes for pulsed laser light to strike an object and return. However, laser radars that use the TOF scheme generally use light receiving elements with a high amplification factor, such as APDs (avalanche photodiodes) to detect faint reflected light that is produced when laser light is irradiated onto a distant object. Furthermore, in order to increase the resolution of the object to be detected, multiple light receiving elements that receive reflected light may be arrayed to ensure high resolution.

[0004] Patent document 1 discloses a radar device in which a laser light is irradiated from a light source, and a one-dimensional scanner scans the irradiated laser light in a scanning direction, and the light receiving surface of a light detection part in which four pixels are arranged in a two-dimensional matrix detects reflected light from the object in each of the four pixels.

[0005] With the radar device of patent document 1, a single iteration of laser light irradiation by a light source can irradiate reflected light onto one pixel in the scanning direction and cause reflected light to be

simultaneously inputted into multiple pixels in a direction perpendicular to the scanning direction, thereby making it possible to obtain a greater electrical signal compared to the case of inputting reflected light into one pixel only, thus making it possible to detect faint reflected light.

Prior art documents

Patent documents

[0006] Patent document 1: Japanese Unexamined Patent Application Publication 2015-78953

Patent document 2: Specification of US Patent No. 7969558

Summary of the invention

Problem to be solved by the invention

[0007] However, in the radar device of patent document 1, laser light emitted from the light source is scanned by a one-dimensional scanner, while the four pixels are fixed, so the optical axis differs from the reflected light of the scanned laser light, thus making it easy for other ambient stray light to be received, which poses the concern of misdetection. Furthermore, in order to accurately detect the position of the object, four light receiving elements are provided independently for the four pixels, but in order to provide wiring, etc., it is necessary to ensure a certain amount of space between the light receiving elements. However, when reflected light strikes this space, an electrical signal cannot be generated, and since this space is in the same coordinate position corresponding to the four pixels, the radar device of patent document 1 naturally has a non-detection zone in which objects cannot be detected, and as a result, it becomes difficult to accurately detect distant objects.

[0008] By contrast, patent document 2 discloses a light measurement device that can receive reflected light from an object, produced by laser light emitted from a light source, one by one at the corresponding light receiving element, by rotating a unit in which numerous light sources and the same number of light receiving elements are arrayed two-dimensionally. According to such a light measuring device, the reflected light produced by the scanned laser light is detected by the corresponding light receiving element, thus providing the advantage of not being prone to receiving other ambient stray light.

[0009] However, in the light measurement device of patent document 2, providing numerous light sources and light receiving elements causes the cost to increase greatly, and since it is physically impossible to completely fill the space between the multiple light sources, there is a high risk that localized gaps will occur in the laser light irradiated onto the object, leading to the problem of detection failure occurring.

[0010] It is an objective of the present invention to provide a radar, and a light projection/reception unit for use therein, which makes it possible to achieve high resolution and reduce detection failure while keeping costs down.

Means for solving the problem

[0011] To achieve at least one of the objectives described above, a light projection/reception unit reflecting one aspect of the present invention comprises:

- a light source;

- a light projection optical system that emits a light beam, emitted from said light source, toward an object;

- a scanning mechanism that drives said light projection optical system and scans the light beam emitted from said light projection optical system;

- a first light receiving part that receives a first reflected light beam produced by reflection of the aforementioned light beam from said object; and

- a second light receiving part that receives a second reflected light beam reflected from said object concurrently with said first reflected light beam;

- wherein said first light receiving part and said second light receiving part are spaced apart in a second direction corresponding to the direction in which the light beam emitted from said light projection optical system is scanned;

- said first light receiving part comprises a plurality of first light receiving elements spaced apart and arranged side by side in a first direction orthogonal to said second direction;

- said second light receiving part comprises a plurality of second light receiving elements spaced apart and arranged side by side in said first direction; and

- said first light receiving elements and said second light receiving elements are arranged such that two adjacent said first light receiving elements would come into gapless contact with, or partially overlap, the second light receiving element interposed therebetween if said first light receiving elements were to be shifted relative to said second light receiving elements in said second direction.

[0012] To achieve at least one of the objectives described above, another light projection/reception unit reflecting one aspect of the present invention comprises:

a light source;

a light projection optical system that emits a light beam, emitted from said light source, toward an object;

a scanning mechanism that drives said light projection optical system and scans the light beam emitted from said light projection optical system;

a light reception optical system which receives a reflected light beam, produced by reflection of the aforementioned light beam from said object;

a splitting means comprising a splitting surface that transmits a portion of said reflected light beam collected by said light reception optical system to form a first light beam, and reflects the remainder of said reflected light beam to form a second light beam;

a first light receiving part which receives said first light beam; and

a second light receiving part which receives said second light beam;

wherein said first light receiving part comprises a plurality of first light receiving elements spaced apart and arranged side by side in a first direction orthogonal to a second direction corresponding to the direction in which a light beam emitted from said light projection optical system is scanned;

said second light receiving part comprises a plurality of second light receiving elements spaced apart and arranged side by side in said first direction; and

said first light receiving elements and said second light receiving elements are arranged such that, when said first light receiving elements are projected along said first light beam onto said splitting surface and said second light receiving elements are projected along said second light beam onto said splitting surface, the projected images of two adjacent said first light receiving elements come into gapless contact or partially overlap with the projected image of the second light receiving element interposed therebetween.

Effect of the invention

[0013] According to the present invention, it is possible to provide a radar, and a light projection/reception unit for use therein, which makes it possible to achieve high resolution and reduce detection failure while keeping costs down.

Brief description of the drawings

[0014] [FIG. 1] is a schematic drawing showing the state of mounting a laser radar equipped with a light projection/reception unit according to an embodiment of the present invention on a vehicle.

[FIG. 2] is a schematic diagram of the laser radar LR according to the present embodiment.

[FIG. 3] is a schematic drawing showing the light receiving surfaces of the first light receiving part PD1 and the second light receiving part PD2.

[FIG. 4] is a drawing showing the arrangement of the elements when the light projection/reception unit is viewed in the direction of the axis of rotation RO.

[FIG. 5] is a drawing showing the object region to be scanned by the laser radar LR.

[FIG. 6] is a drawing showing the principle of detecting the reflected light beam generated on an object irradiated with a collimated light beam.

[FIG. 7] (a) is a drawing showing light receiving elements of a single light receiving part as a comparative example, and (b) is a drawing showing the light receiving elements of two light receiving parts used in the present embodiment.

[FIG. 8] is a flowchart showing the decision-making processing performed by the control circuit CONT.

[FIG. 9] is a drawing showing examples of patterns of a reflected light beam entering the light receiving region of a light receiving element schematically represented by a rectangular frame.

[FIG. 10] is a drawing showing examples of patterns of a reflected light beam entering the light receiving region of a light receiving element schematically represented by a rectangular frame.

[FIG. 11] is a drawing similar to FIG. 3, showing the light receiving surfaces of the first light receiving part and the second light receiving part according to a modified example.

[FIG. 12] is a perspective view of a laser radar LR equipped with a light projection/reception unit according to another embodiment.

[FIG. 13] is a drawing showing the state of scanning on a screen G, which is the scope of detection of laser radar LR with emitted collimated light beam LB (indicated by hatching), in accordance with the rotation of mirror unit MU.

[FIG. 14] is a drawing similar to FIG. 13, pertaining to another embodiment.

[FIG. 15] is a perspective view of a laser radar LR equipped with a light projection/reception unit according to yet another embodiment.

Modes for carrying out the invention

[0015] Below, an embodiment of the present invention will be described with reference to the attached drawings.

FIG. 1 is a schematic drawing showing the state of mounting a laser radar equipped with a light projection/reception unit according to the present embodiment on a vehicle. The laser radar LR of the present embodiment is provided behind the front window 1a or the front grille 1b of the vehicle 1.

[0016] FIG. 2 is a schematic diagram of the laser radar LR according to the present embodiment. The laser radar LR has a motor MT attached to the vehicle body and a casing CS attached to the distal end of a rotary shaft SFT of the motor MT. The casing CS can rotate around the axis of rotation RO along with the rotary shaft SFT. The axis of rotation RO extends in the vertical direction, although in actuality, this changes depending on the inclination of the vehicle body. Here, it will be assumed that the direction of the axis of rotation RO is the Z direction, that the optical axis direction of the semiconductor laser LD to be described later is the X direction, and that the direction orthogonal to the Z direction and the X direction is the Y direction.

[0017] In the casing CS, as a light projection/reception unit, there is arranged: a semiconductor laser (light source) LD that emits a pulsed laser light beam; a collimating lens (light projection optical system) CL that converts divergent light from the semiconductor laser LD into a collimated light beam; a first lens (first light reception optical system) LS1 that focuses the reflected light beam (first reflected light beam) from the object OBJ onto which light was projected and scanned; a first light receiving part PD1 that receives the light focused by the first lens LS1; a second lens (second light reception optical system) LS2 that is arranged on the side opposite to the first lens LS1 across the collimating lens CL and focuses another reflected light beam (second reflected light beam) from the object OBJ; a second light receiving part PD2 that receives the light focused by the second lens LS2; and a control circuit CONT serving as a processing device. These components are designed to rotate about the axis of rotation RO along with the casing CS. The semiconductor laser LD, the first light receiving part PD1, and the second light receiving part PD2 are connected to the control circuit CONT by wiring HS so as to allow transmission of signals.

[0018] In the present embodiment, the laser light beam emitted from the semiconductor laser LD passes through unillustrated components such as an aperture diaphragm, beam shaper, etc., so that at least in the cross-section (shown by hatching in FIG. 1) of the collimated light beam LB incident on the object OBJ, the dimension A in the direction perpendicular to the central axis of the collimated light beam (the scanning orthogonal direction, described below) is longer than the dimension B in the horizontal direction orthogonal thereto (the scanning direction, described below). Rotating the casing CS causes the collimated light beam LB to change its emission direction while rotating within the XY plane. The direction in which the collimated light beam

LB rotates and moves will be referred to as the scanning direction (the second direction), and the direction orthogonal to the scanning direction (i.e., the Z direction: the first direction) will be referred to as the scanning orthogonal direction. That is, the motor MT constitutes a scanning mechanism that rotationally drives the casing CS. The scanning mechanism rotates the semiconductor laser (light source) LD, the collimating lens (light projection optical system) CL, the first lens (first light reception optical system) LS1, the first light receiving part PD1, the second lens (second light reception optical system) LS2, and the second light receiving part PD2 integrally about an axis in the scanning direction (the second direction), thereby scanning the object OBJ by causing it to be scanned with the collimated light beam LB.

[0019] FIG. 3 is a schematic drawing showing the light receiving surfaces of the first light receiving part PD1 and the second light receiving part PD2, with the Z direction being represented as the up-down direction in the drawing. The first light receiving part PD1 has a plurality of first light receiving elements PX1 arranged in a single row at equal intervals in the Z direction on its light receiving surface facing the first lens LS1, and the second light receiving part PD2 also has a plurality of second light receiving elements PX2 arranged in a single row at equal intervals in the Z direction. Areas other than the first light receiving elements PX1 in the first light receiving part PD1 and areas other than the second light receiving elements PX2 in the second light receiving part PD2 are non-detection regions, which serve as locations where wiring and other components are installed.

[0020] Here, the first light receiving elements PX1 and the second light receiving elements PX2, which receive a light beam and output a signal, have the same rectangular shape (for example, a length of 0.1 mm in the Z direction) and are arranged at the same interval (for example, a Z-direction interval of 0.1 mm), and, as shown in FIG. 3, these elements are arranged in a staggered manner. In other words, the position of the lower edge of a first light receiving element PX1 in the Z direction coincides with the position of the upper edge (meaning the upper edge in the drawing; same hereinafter) of the nearest second light receiving element PX2, and the position of the lower edge of the second light receiving element PX2 coincides with the position of the upper edge of the nearest first light receiving element PX1, so that there obtains a relationship such that, if the first light receiving elements PX1 were to be shifted in the Y direction (second direction) relative to the second light receiving elements PX2, they would come into contact with each other. CP1 is the centerline (array center) of the first light receiving elements PX1, and CP2 is the centerline (array center) of the second light

receiving elements PX2. It should be noted that it is sufficient if at least some of the first light receiving elements PX1 and second light receiving elements PX2 satisfy this relationship.

[0021] FIG. 4 is a drawing showing the arrangement of the elements when the light projection/reception unit is viewed in the direction of the axis of rotation RO. As shown in FIG. 4, the array center CP1 of the first light receiving elements PX1 is shifted in the Y direction relative to the optical axis OA1 of the first lens LS1 in the direction away from the second light receiving part PD2. More preferably, the array center CP1 is shifted to an extent that a reflected light beam incident along the optical axis OA1 of the first lens LS1 can be detected near the edges of the first light receiving elements PX1 on the second light receiving part PD2 side.

[0022] Furthermore, the array center CP2 of the second light receiving element PX2 is shifted in the Y direction relative to the optical axis OA2 of the second lens in the direction away from the first light receiving part PD1. More preferably, the array center CP2 is shifted to an extent that a reflected light beam incident along the optical axis OA2 of the second lens LS2 can be detected near the edges of the second light receiving elements PX2 on the first light receiving part PD1 side. It should be noted that it is sufficient if at least one of the array centers CP1 and CP2 is shifted.

[0023] The reason for shifting the center CP1 of the first light receiving elements PX1 and the center CP2 of the second light receiving elements PX2 in this manner will be explained. In FIG. 4, reflected light that was reflected from distant objects enters the first lens LS1 and the second lens LS2 as shown by solid lines, so that the respective focal positions are on the optical axes OA1 and OA2. On the other hand, reflected light that was reflected from nearby objects enters the first lens LS1 and the second lens LS2 obliquely, as shown by the dot-dash lines, so the focal positions are to the outside of the optical axes OA1 and OA2 in the Y direction. Namely, the regions to the inside of the optical axes OA1 and OA2 in the Y direction are unnecessary for detecting reflected light from objects at distances ranging from near to infinitely far in both the first light receiving elements PX1 and the second light receiving elements PX2. Therefore, by shifting the center CP1 of the first light receiving elements PX1 and the center CP2 of the second light receiving elements PX2 outward in the Y direction relative to optical axis OA1 and optical axis OA2, cost reduction and effective utilization of the light receiving parts PD1 and PD2 can be achieved.

[0024] Next, the distance measurement operation of the laser radar LR will be described. In FIG. 1, it is assumed that the emission timing of the semiconductor laser LD is known to the control circuit CONT. The divergent

light intermittently emitted in pulsed fashion from the semiconductor laser LD is converted into a collimated light beam LB by the collimating lens CL and is irradiated toward the object. Here, since the casing CS is rotated about the axis of rotation RO by the motor MT, the collimated light beam LB will be scanned horizontally 360 degrees in the external world where the object is present, in accordance with the rotation of the casing CS (see FIG. 5). Because the collimated light beam LB is vertically elongated in the scanning orthogonal direction (vertical direction), a vertical field of view can be ensured, and many objects can be detected in a single scan.

[0025] When the collimated light beam LB is irradiated onto the object OBJ, diffused light emanates from the same point of incidence on the object OBJ. In other words, multiple reflected light rays will emanate from the point of incidence. Therefore, a portion of the reflected light (the first reflected light beam) is received by the first light receiving part PD1, and another portion of the reflected light (the second reflected light beam) is received by the second light receiving part PD2. The signal generated due to the received light is transmitted from the first light receiving part PD1 and the second light receiving part PD2 to the control circuit CONT. The control circuit CONT measures the distance to the object based on the difference between the emission time of the semiconductor laser LD and the light reception time of the first light receiving part PD1 and second light receiving part PD2.

[0026] FIG. 6 is a drawing showing the principle of detecting the reflected light beam generated on an object irradiated with the collimated light beam, although the optical system is omitted. In FIG. 6, it is assumed that the object OBJ is formed from first through fourth continuous parts PT1 through PT4. Therefore, the reflected light beams RB1, RB2, simultaneously generated from the first part PT1 through fourth part PT4 that received the collimated light beam LB, will be received by the first light receiving part PD1 and the second light receiving part PD2. Specifically, the reflected light component emanating from the first part PT1 enters the non-detection region of the first light receiving part PD1 (location indicated by dotted lines) and also enters the second light receiving element PX2a of the second light receiving part PD2. Thus, only the signal from the second light receiving element PX2a will be inputted into the control circuit CONT.

[0027] Furthermore, the reflected light component emanating from the second part PT2 enters the first light receiving element PX1a of the first light receiving part PD1 and the non-detection region of the second light receiving part PD2 (location indicated by dotted lines). Therefore, only the signal from the first light receiving element PX1a will be inputted into the control circuit CONT. Furthermore, the reflected light component emanating from the third part PT3 enters the non-detection region of the first light receiving part PD1 (location indicated by dotted lines) and also enters the second light receiving element PX2b of the second light receiving part PD2. Thus, only the signal from the second light receiving element PX2b will be inputted into the control circuit CONT. Furthermore, the reflected light component emanating from the fourth part PT4 enters the first light receiving element PX1b of the first light receiving part PD1 and the non-detection region of the second light receiving part PD2 (location indicated by dotted lines). Therefore, only the signal from the first light receiving element PX1b will be inputted into the control circuit CONT. Based on the above, by summing the signals from the second light receiving element PX2a, the first light receiving element PX1a, the second light receiving element PX2b and the first light receiving element PX1b, the control circuit CONT can ascertain that the object OBJ is composed of the first part PT1 through fourth part PT4, and can determine the size of the object.

[0028] According to the present embodiment, the first light receiving part PD1 and the second light receiving part PD2 are spaced apart in the second direction and configured such that first light receiving elements PX1 of the first light receiving part PD1 and second light receiving elements PX2 of the second light receiving part PD2 are spaced apart and arranged side by side in the first direction such that, at least two adjacent first light receiving elements PX1 would come into gapless contact with a second light receiving element PX2 interposed therebetween when the first light receiving elements PX1 are shifted relative to the second light receiving elements PX2 in the second direction, thus providing high resolution with a simple configuration and making it possible to detect faint reflected light beams from an object while suppressing the input of ambient stray light.

[0029] Next, the effect of the present embodiment will be described with reference to a comparative example. FIG. 7 (a) is a drawing showing light receiving elements of a single light receiving part as a comparative example, and FIG. 7 (b) is a drawing showing the light receiving elements of two light receiving parts used in the present embodiment. In the light receiving part PD shown in FIG. 7 (a), similarly to the first light

receiving part PD1 in the present embodiment, there are light receiving elements PXa through PXc arranged at equal intervals. Here, even if the light receiving part PD is used alone, the control circuit CONT can detect the object if the reflected light beam enters any of the light receiving elements PXa through PXc. However, as shown in FIG. 7 (a), if the reflected light beam RB enters the non-detection region between the light receiving elements PXa and PXb, no signal is outputted from either light receiving element, and the control circuit CONT cannot detect the object. In other words, there is a risk of detection failure. Furthermore, if the reflected light beam RB' enters the non-detection region between the light receiving elements PXb and PXc, and also crosses over into light receiving element PXc, although a signal will be outputted from light receiving element PXc, it cannot be distinguished from a signal resulting from a reflected light beam being received only by light receiving element PXc, so the accuracy of detecting the size of the reflected beam RB' (i.e., the size of the object) in the control circuit CONT may decrease.

[0030] By contrast, in the case of the present embodiment shown in FIG. 7 (b), when the reflected light beam RB1 enters the non-detection region between the light receiving elements PX1a and PX1b of the first light receiving part PD1, a reflected light beam RB2 of the same shape enters the light receiving element PX2a of the second light receiving part PD2, so a signal is outputted from light receiving element PX2a, and the control circuit CONT can detect the object. Furthermore, when the reflected light beam RB1' enters the non-detection region between light receiving elements PX1b and PX1c of the first light receiving part PD1 and also crosses over into light receiving element PX1c, a signal will be outputted from light receiving element PX1c, and when a reflected light beam RB2' of the same shape enters the non-detection region between light receiving elements PX2b and PX2c of the second light receiving part PD2 and crosses over into light receiving element PX2b, a signal will be outputted from light receiving element PX2b, so that the control circuit CONT can accurately detect the size of the reflected light beam RB' (i.e., the size of the object) by summing the signals outputted from light receiving element PX1c and light receiving element PX2b.

[0031] FIG. 8 is a flowchart showing the decision-making processing carried out by the control circuit CONT. FIGS. 9 and 10 are drawings illustrating examples of patterns of reflected light beams entering light receiving elements. This will be described here taking as an example the pattern where the first reflected light beam RB1 and the second reflected light beam RB2 enter two light receiving elements PX1a, PX1b of the first light

receiving part and one light receiving element PX2a of the second light receiving part. In cases involving more than three light receiving elements, combinations of the following decision-making processing can be used. It should be noted that, as a decision-making criterion, it will be assumed that a signal is outputted from a light receiving element in the case where a reflected light beam has been received at a level of 50% or more (if the threshold value is set at 0.5) of the maximum allowable light reception level of the light receiving element, with such a case being expressed as "the light receiving element is on"; moreover, in the case where the reflected light beam has been received at a level less than 50% of the maximum allowable light reception level of the light receiving element or where no light has been received at all, it will be assumed that a signal is not outputted from the light receiving element, and such a case will be expressed as "the light receiving element is off".

[0032] The decision-making processing performed by the control circuit CONT will be described with reference to FIGS. 8 through 10. If the control circuit CONT receives signals from the respective light receiving elements and detects that light receiving element PX1a is on (decision in step S101 of FIG. 8 is Yes), detects that light receiving element PX2a is on (decision in step S102 is Yes), and detects that light receiving element PX1b is on (decision in step S103 is Yes), and if, furthermore, in step S105, a reflected light beam was received by all of light receiving elements PX1a, PX1b and light receiving element PX2a, then it is determined that a continuous reflected light beam spanning three light receiving elements, as in pattern 5 shown in FIG. 10 (a), has been received. In other words, the laser radar LR can understand that it has detected an object corresponding to this size (the same applies hereafter).

[0033] On the other hand, if it is detected in step S103 that light receiving element PX1b is off (decision is No), the control circuit CONT determines in step S104 that a reflected light beam has substantially not entered light receiving element PX2a and has only entered light receiving elements PX1a, PX1b, and determines that a continuous reflected light beam spanning two light receiving elements, as in pattern 1 shown in FIG. 9 (a), has been received. Furthermore, if it is detected in step S102 that light receiving element PX2a is off (decision is No), the control circuit CONT determines the status of light receiving element PX1b in step S106, and if it is detected that light receiving element PX1b is off (decision is No), it is deemed that a reflected light beam has not substantially entered light receiving element PX2a and light receiving element PX1b and has only

entered light receiving element PX1a, and it is determined in step S107 that a reflected light beam, as in pattern 2 shown in FIG. 9(b), has been received. On the other hand, if it is detected in step S106 that light receiving element PX1b is on (decision is Yes), the control circuit CONT determines that a reflected light beam has substantially not entered light receiving element PX2a and has entered only light receiving elements PX1a, PX1b, and determines in step S108 that a discontinuous reflected light beam, as in pattern 7 shown in FIG. 10 (c), has been received.

[0034] Returning again to step S101, if the control circuit CONT detects that light receiving element PX1a is off (decision is No), and further determines the state of light receiving element PX2a in step S109 and detects that light receiving element PX2a is on (decision is Yes), then in the subsequent step S110, the state of light receiving element PX1b is determined, and if it is detected that light receiving element PX1b is on (decision is Yes), then the control circuit CONT deems that a reflected beam has substantially not entered light receiving element PX1a and has entered only light receiving elements PX2a, PX1b, and determines in step S112 that a continuous reflected light beam spanning two light receiving elements, as in pattern 4 shown in FIG. 9 (d), has been received. On the other hand, if in step S110 it is detected that light receiving element PX1b is off (decision is No), the control circuit CONT deems that a reflected light beam has substantially not entered light receiving elements PX1a, PX1b and has only entered light receiving element PX2a, and determines in step S111 that a reflected light beam as in pattern 3 shown in FIG. 9 (c) has been received.

[0035] Returning again to step S109, if the control circuit CONT detects that light receiving element PX2a is off (decision is No), and further determines the state of light receiving element PX1b in step S113 and detects that light receiving element PX1b is on (decision is Yes), then the control circuit CONT deems that a reflected light beam has substantially not entered light receiving elements PX1a, PX2a and has only entered light receiving element PX1b, and determines in step S114 that a reflected light beam as in pattern 6 shown in FIG. 10 (b) has been received. On the other hand, if in step S113 it is detected that light receiving element PX1b is off (decision is No), the control circuit CONT deems that a reflected light beam has substantially not entered any of the light receiving elements PX1a, PX1b or light receiving element PX2a, and determines in step S115 that either a negligible reflected light beam as in pattern 8 shown in FIG. 10 (d) has been received, or that no

reflected light beam is present. If there are more than four light receiving elements, decision-making similar to those above can be performed to detect reflected light beams that span between the light receiving elements.

[0036] FIG. 11 is a drawing similar to FIG. 3, showing the light receiving surfaces of the first light receiving part and the second light receiving part according to a modified example. In this modified example, the widths in the Y direction of the first light receiving elements PX1 and the second light receiving elements PX2' are the same, but the lengths in the Z direction are different. More specifically, the length in the Z direction of the first light receiving elements PX1 is L1, while the length in the Z direction of the second light receiving elements PX2' is L2 (>L1). Furthermore, the interval between adjacent first light receiving elements PX1 is C1, while the interval between adjacent second light receiving elements PX2' is C2, where the relationship $(L1+C1) = (L2+C2)$ obtains.

[0037] Therefore, the position of the lower edge of a first light receiving element PX1 in the Z direction is located lower than the position of the upper edge of the nearest second light receiving element PX2, and the position of the lower edge of a second light receiving element PX2 is located lower than the position of the upper edge of the nearest first light receiving element PX1, so that there obtains a relationship such that, if the first light receiving elements PX1 were to be shifted in the Y direction (second direction) relative to the second light receiving elements PX2, they would overlap each other. Assuming that $\Delta 1$ is amount of overlap at the upper edge of a second light receiving element PX2' and $\Delta 2$ is the amount of overlap at the lower edge or the same, it is preferable that $\Delta 1 = \Delta 2$.

[0038] Making the dimension in the Z direction of the second light receiving element PX2' greater than the dimension in the Z direction of the first light receiving element PX1 eliminates the need to precisely align the upper and lower edges of the second light receiving elements PX2' and the first light receiving elements PX1, thus reducing manufacturing difficulty and contributing to cost reduction. Furthermore, because the surface area of the second light receiving element PX2' expands, the amount of light received increases, making it easier to detect faint reflected light beams. It should be noted that, in the embodiment described previously, in the decision-making processing shown in FIG. 8, the threshold values serving as the on-off decision-making criteria for the first light receiving elements PX1 and the second light receiving elements PX2 were made equal, but in this modified example, it is preferable to set a higher (first) threshold value for the second light receiving elements PX2, which have a larger light receiving surface area, than the (second) threshold value

for the first light receiving elements PX1, which have a relatively smaller light receiving surface area. The rest of the configuration is the same as in the embodiment described previously.

[0039] FIG. 12 is a perspective view of a laser radar LR equipped with a light projection/reception unit according to another embodiment. Here, the control circuit, etc. will be omitted. In FIG. 12, the light projection/reception unit of the laser radar LR comprises: a semiconductor laser (light source) LD that emits a pulsed laser light beam; a collimating lens (light projection optical system) CL that converts divergent light from the semiconductor laser LD into a collimated light beam; a first lens (first light reception optical system) LS1 that focuses the reflected light beam (first reflected light beam) from the object OBJ onto which light has been projected and scanned; a first light receiving part PD1 that receives the light focused by the first lens LS1; a second lens (second light reception optical system) LS2 that is arranged on the side opposite to the first lens LS1 across the optical axis of the collimating lens CL and focuses another reflected light beam (second reflected light beam) from the object OBJ; a second light receiving part PD2 that receives the light focused by the second lens LS2; and a rotating mirror unit MU. Here, the direction of the axis of rotation RO of the mirror unit MU is designated as the Z direction, the optical axis direction of the semiconductor laser LD is designated as the X direction, and the direction orthogonal to the Z direction and the X direction is designated as the Y direction. It should be noted that, when the reflected light beam is reflected by the mirror and enters the first light receiving part and the second light receiving part, in some cases the scanning direction may not coincide with the second direction and/or the scanning orthogonal direction may not coincide with the first direction, but the respective associations will be assumed even in such cases.

[0040] The semiconductor laser LD and the collimating lens CL constitute a light projection system LPS, the first lens LS1 and the first light receiving part PD1 constitute a first light reception system RPS1, and the second lens and second light receiving part PD2 constitute a second light reception system RPS2. The first light receiving part PD1 and the second light receiving part PD2 have the same configuration as in the embodiment described above. The light beam emitted from the light projection system LPS is longer in the sub-scanning angle direction than in the scanning angle direction in the measurement range of the object.

[0041] The substantially square tube shaped cylindrical mirror unit MU is retained so as to be rotatable about its axis, i.e. the axis of rotation RO, and has four trapezoidal first mirror surfaces M1 on its lower outer periphery and, facing them, four trapezoidal second mirror surfaces M2 on its upper outer periphery. The angle of

intersection between the paired upper and lower first mirror surfaces M1 and second mirror surfaces M2 are different. The optical axis of the light projection system LPS is orthogonal to the axis of rotation RO of the mirror unit MU, and the optical axes of the first light reception system RPS1 and the second light reception system RPS2 are disposed parallel to and on either side of the optical axis of the light projection system LPS. In other words, the scanning mechanism composed of a motor (not illustrated), etc. rotates the mirror unit MU integrally about an axis in the second direction, thereby scanning the object by causing the collimated light beam to scan over the object. It should be noted that the mirror may be a single one, but when using a single mirror, it is desirable to oscillate the mirror back and forth within a certain angular range. The rest of the configuration is the same as in the embodiment described previously.

[0042] Next, the distance measurement operation of the laser radar LR of the present embodiment will be described. Divergent light intermittently emitted in pulsed fashion from the semiconductor laser LD is converted into a parallel light beam by the collimating lens CL, then strikes a point P1 on the first mirror surface M1 of the rotating mirror unit MU, is reflected there, travels along the axis of rotation RO, and is further reflected at point P2 on the second mirror surface M2, and is then scanned and projected onto the object OBJ.

[0043] FIG. 13 is a drawing showing the state of scanning on a screen G, which is the scope of detection of laser radar LR with emitted collimated light beam LB (indicated by hatching) in accordance with the rotation of mirror unit MU. The combinations of the first mirror surface M1 and the second mirror surface M2 of the mirror unit MU each have a different angle of intersection. The collimated light beam LB sequentially reflects off the rotating first mirror surface M1 and second mirror surface M2. First, the collimated light beam LB reflected by the first pair of first mirror surface M1 and second mirror surface M2 is scanned across the uppermost region Ln1 of the screen G horizontally from left to right in accordance with the rotation of the mirror unit MU, and then the collimated light beam LB reflected by the second pair of first mirror surface M1 and second mirror surface M2 is scanned across the second from the top region Ln2 of the screen G horizontally from left to right in accordance with the rotation of the mirror unit MU. Next, the collimated light beam LB reflected by the third pair of first mirror surface M1 and second mirror surface M2 is scanned across the third from the top region Ln3 of the screen G horizontally from left to right in accordance with the

rotation of the mirror unit MU. Next, the collimated light beam LB reflected by the fourth pair of first mirror surface M1 and second mirror surface is scanned across the lowermost region Ln4 of the screen G horizontally from left to right in accordance with the rotation of the mirror unit MU. This completes one scan of the screen. Then, once the mirror unit MU has rotated once and the first pair of first mirror surface M1 and second mirror surface M2 return, the scan is repeated starting from the top of the screen G.

[0044] In FIG. 12, among the projected and scanned light beams, one of the reflected light beams (the first reflected light beam) that has struck the object OBJ and been reflected enters point P3A on the second mirror surface M2 of the mirror unit MU, as indicated by the dotted line, is reflected there, travels along the axis of rotation RO, is further reflected at point P4A on the first mirror surface M1, and is focused by the first lens LS1 and is detected by a light receiving element of the first light receiving part PD1. At the same time, another one of the reflected light beams (the second reflected light beam) that has struck the object OBJ and been reflected enters point P3B on the second mirror surface M2 of the mirror unit MU, as indicated by the dotted line, is reflected there, travels along the axis of rotation RO, is further reflected at point P4B on the first mirror surface M1, and is focused by the second lens LS1 and is detected by a light receiving element of the second light receiving part PD2. The signals generated due to reception of light by the light receiving elements are transmitted from the first light receiving part PD1 and second light receiving part PD2 to an unillustrated control circuit, where the distance to the object is measured based on the difference between the emission time of the semiconductor laser LD and the reception time of the first light receiving part PD1 and second light receiving part PD2. This allows detection of the object OBJ across the entire range of the screen G.

[0045] FIG. 14 is a drawing similar to FIG. 13, pertaining to another embodiment. In the present embodiment, the first light receiving part PD1 has four first light receiving elements PX11 through PX14 spaced at equal intervals in the Z direction, and the second light receiving part PD2 has four second light receiving elements PX21 through PX24 spaced at equal intervals in the Z direction. The shapes of the first light receiving elements and the second light receiving elements are all identical. Moreover, the positions of the lower edges of the first light receiving elements PX11 through PX14 in the Z direction are located below the upper edges of their nearest second light receiving elements PX21 through PX24, and the positions of the lower edges of

the second light receiving elements PX21 through PX24 coincide with the positions of the upper edges of the nearest first light receiving elements PX11 through PX14. Namely, if the first light receiving elements were to be shifted in the Y direction (the second direction) relative to the second light receiving elements, the respective light receiving regions would partially overlap. In such cases, the control device CONT performs signal processing by associating the respective elements, as described later.

[0046] This will be explained below taking the first light receiving element PX11 and its nearest second light receiving element PX21 as an example. If the following formula is satisfied when the first light receiving element PX11 is shifted relative to the second light receiving element PX21 in the Y direction so as to overlay the two, the resolution can be improved.

$$L/H < 0.5 \quad (1)$$

wherein:

L: Amount of overlap between the first light receiving element PX11 and the second light receiving element PX21 in the Z direction

H: Length of the first light receiving element PX11 or second light receiving element PX21 in the Z direction

[0047] Furthermore, assuming that PX11a is the non-overlapping region of the light receiving region in the first light receiving element PX11, PX11b is the overlapping region in first light receiving element PX11, PX21a is the non-overlapping region of the light receiving region in the second light receiving element PX21, and PX21b is the overlapping region in the second light receiving element PX21, as shown in the drawing, it will be assumed that the first reflected light RB1 from the object only enters the overlapping region PX11b of the light receiving region in the first light receiving element PX11, and the second reflected light RB2 from the same object enters both the non-overlapping region PX21a and the overlapping region PX21b of the light receiving region in the second light receiving element PX21.

[0048] In such a case, the control device CONT compares the signal outputted from the first light receiving element PX11 to a threshold value and determines the signal to be reflected light from the object if the threshold value is exceeded. Moreover, the control device CONT compares, to a threshold value, a difference signal, obtained by eliminating the signal component emitted from the overlapping region PX21b out of the

signal outputted from the second light receiving element PX21, and determines the signal to be reflected light from the object if the threshold value is exceeded.

[0049] If one were to simply compare the signal outputted from the first light receiving element PX11 and the signal outputted from the second light receiving element PX21 individually to a threshold value, the signal portion emitted from either of the overlapping regions PX11b, PX21b would be redundant, lowering the resolution. Therefore, in the present embodiment, the resolution is improved by comparing the difference signal, obtained by eliminating the signal component emitted from the overlapping region PX21b out of the signal outputted from the second light receiving element PX21, to a threshold value. The difference signal can be obtained, for example, by multiplying the signal outputted from the second light receiving element PX21 by $(H-L)/H$. Moreover, the threshold value used here can be the same as the threshold value used for signals from the light receiving elements of the embodiment described previously, where the light receiving regions do not overlap. The relationship between the first light receiving elements PX11 and the second light receiving elements PX21 described above can also be reversed.

[0050] FIG. 15 is a perspective view of a laser radar LR equipped with a light projection/reception unit according to yet another embodiment. Here, the control circuit, etc. will be omitted. In FIG. 15, the light projection/reception unit of the laser radar LR comprises: a semiconductor laser (light source) LD that emits a pulsed laser light beam; a collimating lens (light projection optical system) CL that converts the divergent light from the semiconductor laser LD into a collimated light beam; a lens (light reception optical system) LS that focuses the reflected beam from the object OBJ onto which the light has been projected and scanned; a prism (splitting means) PR with a splitting surface PR1 that serves as a half mirror and receives the reflected light beam that has passed through the lens LS; a first light receiving part PD1 that receives the reflected light beam (first light beam) that has passed through the splitting surface PR1; a second light receiving part PD2 that receives the reflected light beam (second light beam) that is reflected by the splitting surface PR1; and a mirror unit MU. The mirror unit MU has the same configuration as in the embodiment shown in FIG. 12. Here, it will be assumed that the direction of the axis of rotation RO is the Z direction, that the optical axis direction of the semiconductor laser LD is the X direction, and that the direction orthogonal to the Z direction and the X direction is the Y direction.

[0051] A light projection system LPS is formed by the semiconductor laser LD and collimating lens CL, and a

light reception system RPS is formed by the lens LS, prism PR, first light receiving part PD1 and second light receiving part PD2. The light beam emitted from the light projection system LPS is longer in the sub-scanning angle direction than in the scanning angle direction in the measurement range of the object.

[0052] The first light receiving part PD1 and the second light receiving part PD2 have the same configuration as in the embodiment shown in FIGS. 3 and 11. Furthermore, the light receiving parts are arranged such that, when the light receiving elements of the first light receiving part PD1 are projected onto the splitting surface PR1 along the first light beam, and the light receiving elements of the second light receiving part PD2 are projected onto the splitting surface PR1 along the second light beam, the projected images of at least adjacent two light receiving elements of the first light receiving part PD1 will come into gapless contact with the projected image of the light receiving element of the second light receiving part PD2 interposed therebetween, or the light receiving regions will partially overlap (see FIGS. 3 and 11). Furthermore, in the case where the two overlaid projected images partially overlap, it is preferable that the following formula be satisfied (see FIG. 14).

$$L'/H < 0.5 \quad (2)$$

wherein:

L': Amount of overlap between a projected image of a first light receiving element and a projected image of a second light receiving element

H: Length of the first light receiving element or the second light receiving elements in the first direction

The rest of the configuration, including the signal processing shown in FIG. 14, is the same as in the previously described embodiment.

[0053] Next, the distance measuring operation of the laser radar LR of the present embodiment will be described. The divergent light intermittently emitted in pulsed fashion from the semiconductor laser LD is converted into a parallel light beam by the collimating lens CL, strikes a point P1 on mirror surface M1 of the rotating mirror unit MU, where it is reflected, travels along the axis of rotation RO, and is further reflected at point P2 on the second mirror surface M2 and is projected toward and scanned across the object OBJ.

[0054] Among the projected and scanned light beams, the reflected light beam that has struck the object OBJ and has been reflected and has entered point P3 on the second mirror surface M2 of the mirror unit MU, as indicated by the dotted line, and has been reflected there, traveled along the axis of rotation RO, and was further reflected at point P4 on the first mirror surface M1 and focused by the lens LS and has further passed through the splitting surface PR1, is received by the first light receiving part PD1, while the reflected light

beam that was reflected by the splitting surface PR1 is received by the second light receiving part PD2. The signals generated due to reception of light by the light receiving elements are transmitted from the first light receiving part PD1 and second light receiving part PD2 to an unillustrated control circuit, where the distance to the object is measured based on the difference between the emission time of the semiconductor laser LD and the reception time of the first light receiving part PD1 and second light receiving part PD2. As in the embodiment shown in FIG. 12, by rotating the mirror unit MU, detection of the object OBJ can be performed over the entire range on screen G.

[0055] It should be obvious to those skilled in the art, from the embodiments and technical idea described in the present specification, that the present invention is not limited to the embodiments and modified examples described in the specification and includes other embodiments and modifications. The descriptions and embodiments in the specification are for illustrative purposes only, and the scope of the invention is indicated by the claims that follow. For example, the content of the present invention described using the drawings can be applied to all embodiments. The laser radar can be applied not only to automobiles but also to aircraft, robots, surveillance cameras, etc. The shapes of the first light receiving elements and second light receiving elements may be the same or different, unless otherwise specified.

Description of reference symbols

[0056]	1	Vehicle
	1a	Front window
	1b	Front grill
	CL	Collimating lens
	CONT	Control circuit
	CP1, CP2	Array center
	CS	Casing
	G	Screen
	HS	Wiring
	LB	Collimated light beam
	LD	Semiconductor laser
	Ln1 to LN4	Region
	LR	Laser radar

LS	Lens
LS1	First lens
LS2	Second lens
M1	First mirror surface
M2	Second mirror surface
MT	Motor
MU	Mirror Unit
OA1	Optical axis
OA2	Optic al axis
OBJ	Object
PD	Light receiving part
PD1	First light receiving part
PD2	Second light receiving part
PR	Prism
PR1	Splitting surface
PX1, PX1a, PX1b, PX1c, PX11 to PX14	First light receiving element
PX2, PX1a, PX1b, PX1c, PX2', PX21 to PX24	Second light receiving element
RB	Reflected light beam
RB1	First reflected light beam
RB2	Second reflected light beam
RO	Axis of rotation
RPS	Light reception system
SFT	Rotary shaft

Scope of Claims

[Claim 1] A light projection/reception unit comprising:

- a light source;
- a light projection optical system that emits a light beam, emitted from said light source, toward an object;
- a scanning mechanism that drives said light projection optical system and scans the light beam emitted from said light projection optical system;
- a first light receiving part that receives a first reflected light beam produced by reflection of the aforementioned light beam from said object; and
- a second light receiving part that receives a second reflected light beam reflected from said object concurrently with said first reflected light beam;

wherein said first light receiving part and said second light receiving part are spaced apart in a second direction corresponding to the direction in which the light beam emitted from said light projection optical system is scanned;

said first light receiving part comprises a plurality of first light receiving elements spaced apart and arranged side by side in a first direction orthogonal to said second direction;

said second light receiving part comprises a plurality of second light receiving elements spaced apart and arranged side by side in said first direction; and

said first light receiving elements and said second light receiving elements are arranged such that two adjacent said first light receiving elements would come into gapless contact with, or partially overlap, the second light receiving element interposed therebetween if said first light receiving elements were to be shifted relative to said second light receiving elements in said second direction.

[Claim 2] A light projection/reception unit as set forth in claim 1, wherein the array center of said first light receiving elements is shifted relative to the center of said first light reception optical system in the direction away from said second light receiving elements.

[Claim 3] A light projection/reception unit as set forth in claim 1 or 2, wherein the following formula is satisfied in the case where said first light receiving elements and said second light receiving elements would partially overlap when said first light receiving elements are shifted relative to said second light receiving elements in said second direction:

$$L/H < 0.5 \quad (1)$$

wherein:

L: Amount of overlap between an aforesaid first light receiving element and an aforesaid second light receiving element in said first direction;

H: Length of the first light receiving element or the second light receiving elements in said first direction.

[Claim 4] A light projection/reception unit as set forth in claim 3, comprising a processing device that processes a signal from said first light receiving part and a signal from said second light receiving part, wherein said processing device associates a first light receiving element and a second light receiving element which would have a mutually overlapping light receiving region when said first light receiving elements are shifted relative to said second light receiving elements in said second direction, and determines that reflected light from said object has been received if the signal from one associated light receiving element exceeds a threshold value, and furthermore determines that reflected light from said object has been received if a difference signal exceeds said threshold value, the difference signal being obtained by eliminating, from the signal from the other associated light receiving element, the signal component outputted from the light receiving region mutually overlapping with said one associated light receiving element.

[Claim 5] A light projection/reception unit as set forth in claim 4, wherein said threshold value is equal to a threshold value used for signals from an aforesaid first light receiving element or an aforesaid second light receiving element that would not have a mutually overlapping light receiving region when said first light receiving elements are shifted relative to said second light receiving elements in said second direction.

[Claim 6] A light projection/reception unit as set forth in any one of claims 1 through 5, wherein said first light receiving elements and said second light receiving elements have identical shapes to each other.

[Claim 7] A light projection/reception unit as set forth in any one of claims 1 through 5, wherein said first light receiving elements and said second light receiving element have different shapes from each other.

[Claim 8] A light projection/reception unit as set forth in any one of claims 1 through 3, comprising a processing device that processes a signal from said first light receiving part and a signal from said second light receiving part, wherein, in the case where said first light receiving elements would partially overlap with said second light receiving elements when shifted relative to said second light receiving element in said second direction, said processing device associates an aforesaid first light receiving element and an aforesaid second light receiving element which would have a mutually overlapping light receiving region and determines that reflected light from said object has been received if the signal from one associated light

receiving element exceeds a first threshold value, and furthermore determines that reflected light from said object has been received if the signal from the other light receiving element exceeds a second threshold, wherein, for the purpose of such determination, said second threshold value is made greater than said first threshold value if the light receiving surface area of said one associated light receiving element is greater than the light receiving surface area of said other associated light receiving element.

[Claim 9] A light projection/reception unit as set forth in any one of claims 1 through 8, wherein said scanning mechanism is adapted to scan said object by integrally rotating said light source, said light projection optical system, said first light receiving part and said second light receiving part about an axis in said second direction.

[Claim 10] A light projection/reception unit as set forth in any one of claims 1 through 8, wherein said scanning mechanism comprises a mirror which reflects said light beam heading from said light projection optical system toward said object, reflects said first reflected light beam and said second reflected light beam coming from said object and causes these light beams to be inputted into said first light receiving part and said second light receiving part, the scanning mechanism being adapted to scan said object by integrally rotating said mirror about an axis in said second direction.

[Claim 11] A light projection/reception unit comprising:

- a light source;
- a light projection optical system that emits a light beam, emitted from said light source, toward an object;
- a scanning mechanism that drives said light projection optical system and scans the light beam emitted from said light projection optical system;
- a light reception optical system which receives a reflected light beam, produced by reflection of the aforementioned light beam from said object;
- a splitting means comprising a splitting surface that transmits a portion of said reflected light beam collected by said light reception optical system to form a first light beam, and reflects the remainder of said reflected light beam to form a second light beam;
- a first light receiving part which receives said first light beam; and
- a second light receiving part which receives said second light beam;

wherein said first light receiving part comprises a plurality of first light receiving elements spaced apart and arranged side by side in a first direction orthogonal to a second direction corresponding to the direction in which a light beam emitted from said light projection optical system is scanned;

said second light receiving part comprises a plurality of second light receiving elements spaced apart and arranged side by side in said first direction; and

said first light receiving elements and said second light receiving elements are arranged such that, when said first light receiving elements are projected along said first light beam onto said splitting surface and said second light receiving elements are projected along said second light beam onto said splitting surface, the projected images of two adjacent said first light receiving elements come into gapless contact or partially overlap with the projected image of the second light receiving element interposed therebetween.

[Claim 12] A light projection/reception unit as set forth in claim 11, wherein said scanning mechanism comprises a mirror that reflects the light beam emitted from said light projection optical system and causes the light beam to head toward said object, and that reflects the reflected light beam returning from said object and causes it to enter said light reception optical system, the scanning mechanism being adapted to scan said object by rotation of said mirror about an axis perpendicular to the direction in which the light beam emitted from the light projection optical system is scanned.

[Claim 13] A light projection/reception unit as set forth in claim 11 or 12, wherein the following formula is satisfied in the case where projected images of said first light receiving elements would partially overlap projected images of said second light receiving element when overlaid thereon:

$$L'/H < 0.5 \quad (2), \text{ wherein:}$$

L': Amount of overlap between a projected image of an aforesaid first light receiving element and a projected image of an aforesaid second light receiving element;

H: Length of the first light receiving element or the second light receiving elements in said first direction.

[Claim 14] A light projection/reception unit as set forth in claim 13, comprising a processing device that processes a signal from said first light receiving part and a signal from said second light receiving part, wherein a first light receiving element and a second light receiving element, which would have a mutually overlapping light receiving region when projected images of said first light receiving elements are overlaid onto projected images of said second light receiving elements, are associated with each other, and wherein it is determined that reflected light from said object has been received if the signal from one associated light

receiving element exceeds a threshold value, and wherein furthermore it is determined that reflected light from said object has been received if a difference signal exceeds said threshold value, the difference signal being obtained by eliminating, from the signal from the other associated light receiving element, the signal component outputted from the light receiving region mutually overlapping with said one associated light receiving element.

[Claim 15] A light projection/reception unit as set forth in claim 14, wherein said threshold value is equal to a threshold value used for signals from an aforesaid first light receiving element or an aforesaid second light receiving element that would not have a mutually overlapping light receiving region when projected images of said first light receiving elements are overlaid onto projected images of said second light receiving elements.

[Claim 16] A light projection/reception unit as set forth in any one of claims 11 through 15, wherein said first light receiving elements and said second light receiving elements have identical shapes to each other.

[Claim 17] A light projection/reception unit as set forth in any one of claims 11 through 15, wherein said first light receiving elements and said second light receiving elements have different shapes from each other.

[Claim 18] A light projection/reception unit as set forth in any one of claims 11 through 13, comprising a processing device that processes a signal from said first light receiving part and a signal from said second light receiving part, wherein, in the case where said first light receiving elements would partially overlap with said second light receiving elements when shifted relative to said second light receiving element in said second direction, said processing device associates an aforesaid first light receiving element and an aforesaid second light receiving element which would have a mutually overlapping light receiving region and determines that reflected light from said object has been received if the signal from one associated light receiving element exceeds a first threshold value, and furthermore determines that reflected light from said object has been received if the signal from the other light receiving element exceeds a second threshold, wherein, for the purpose of such determination, said second threshold value is made greater than said first threshold value if the light receiving surface area of said one associated light receiving element is greater than the light receiving surface area of said other associated light receiving element.

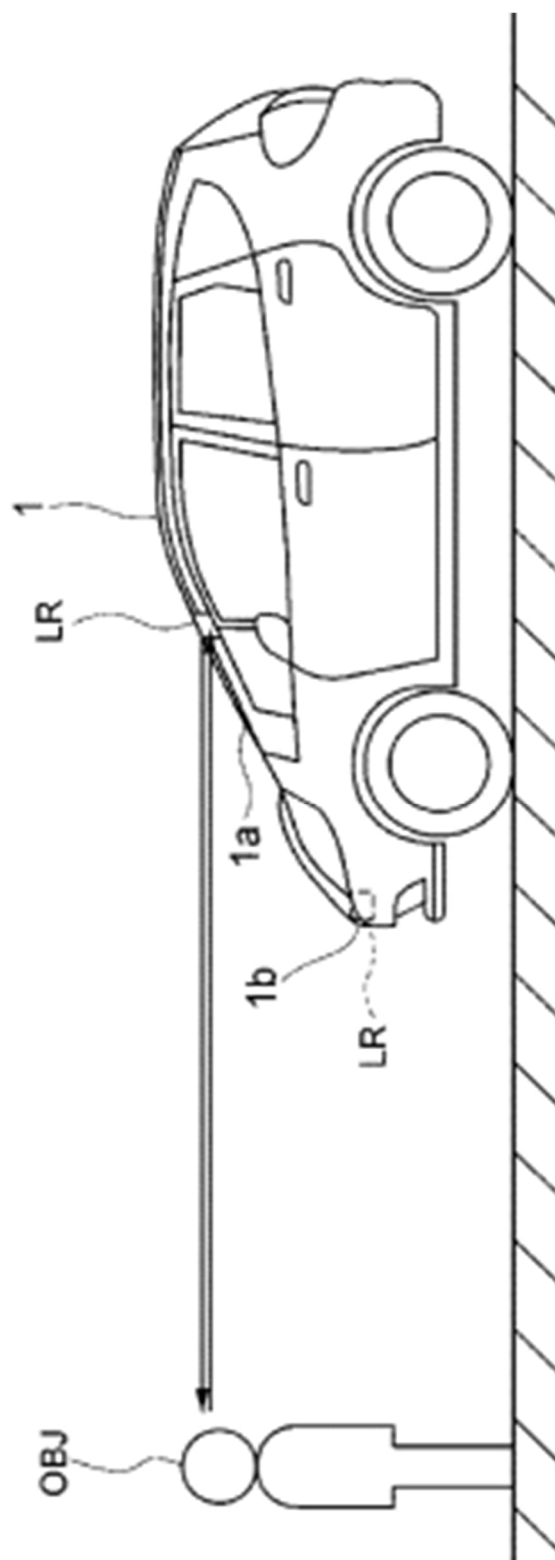
[Claim 19] A light projection/reception unit as set forth in any one of claims 1 through 18, wherein said first light receiving elements each have an identical shape and said second light receiving elements each have an identical shape.

[Claim 20] A light projection/reception unit as set forth in any one of claims 1 through 19, wherein the optical axis

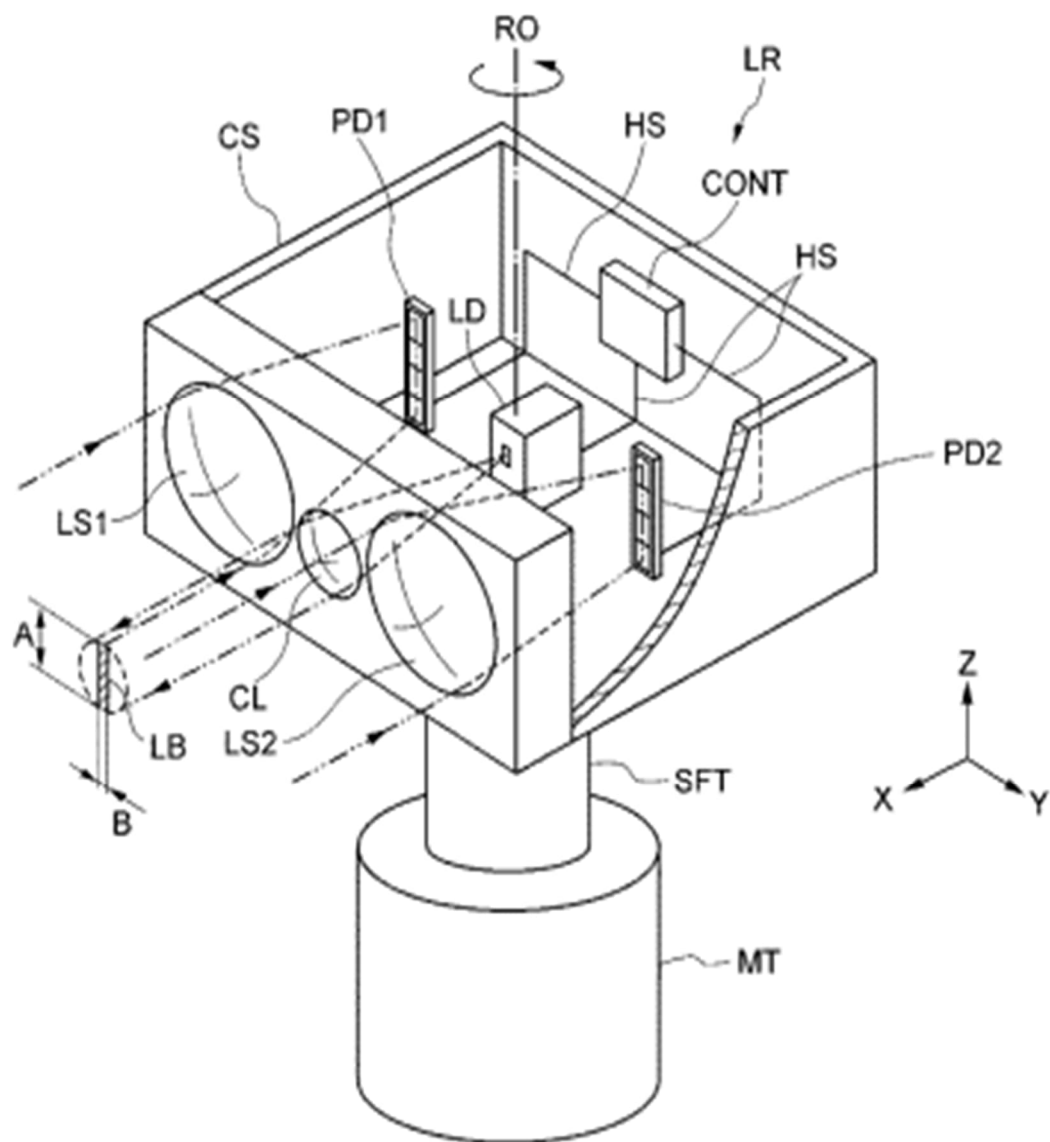
of said light projection optical system and the optical axis of said light reception optical system are parallel.

[Claim 21] A radar comprising a light projection/reception unit as set forth in any one of claims 1 through 20, which measures the distance to said object on the basis of the difference between the time when a light beam is emitted from said light source and the time when said reflected light beam is received by said first light receiving part and said second light receiving part.

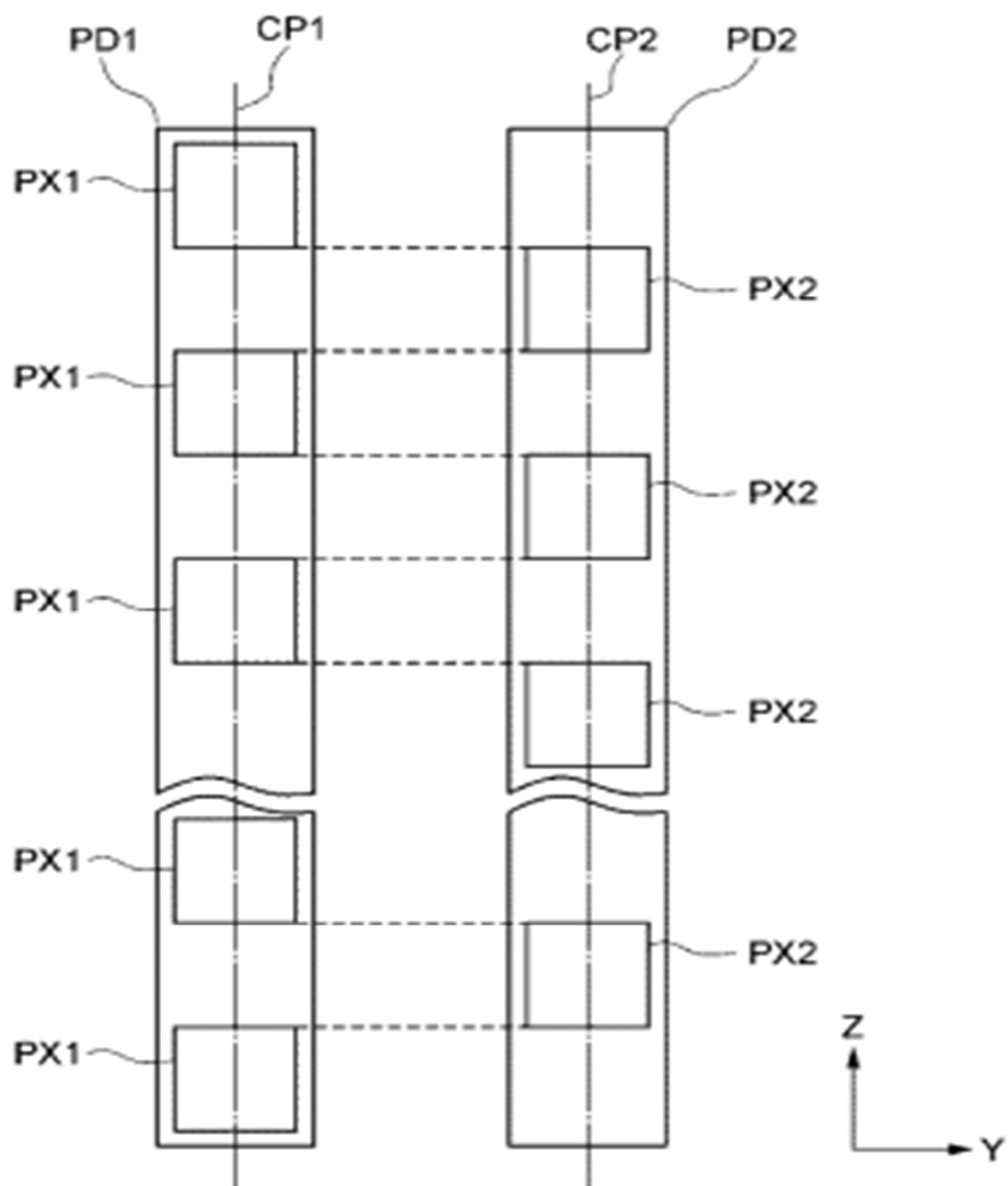
[FIG. 1]



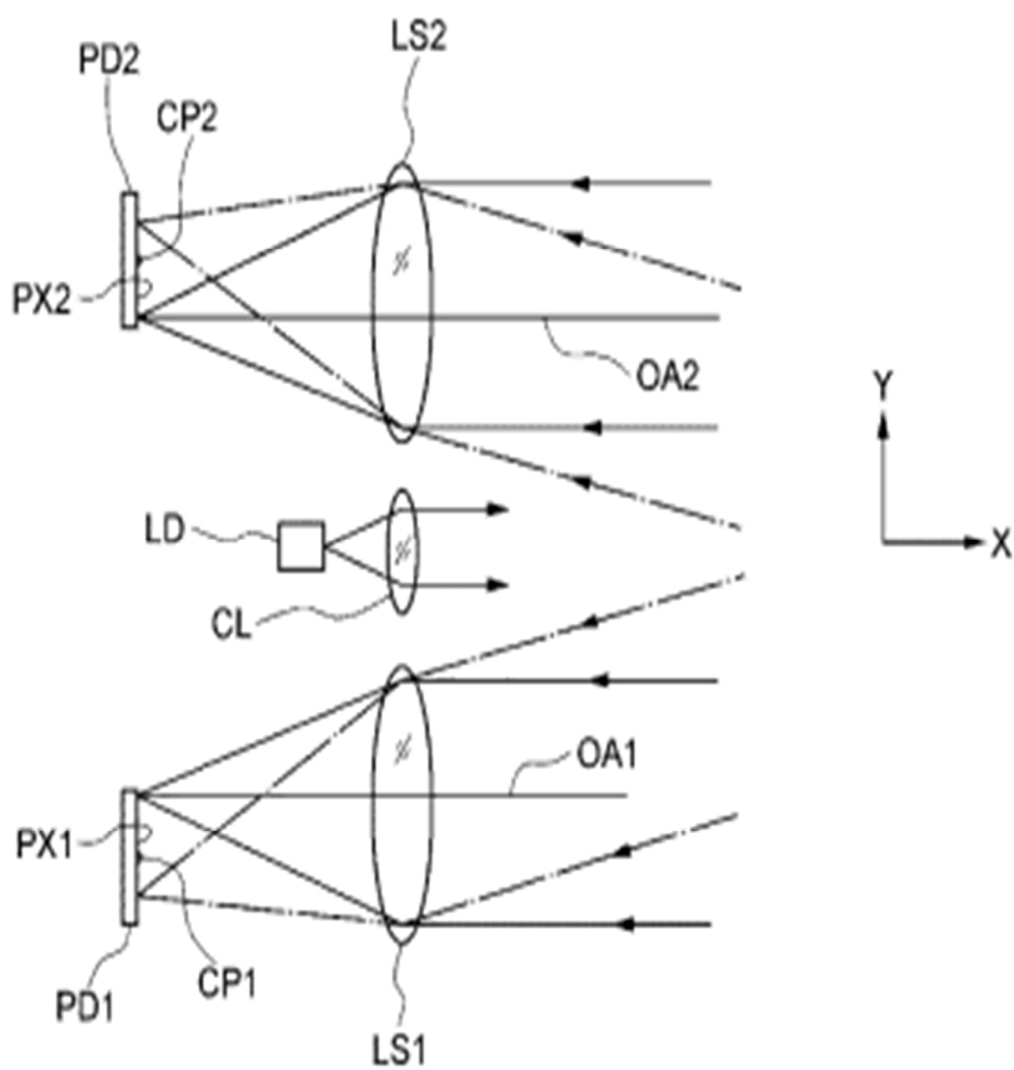
[FIG. 2]



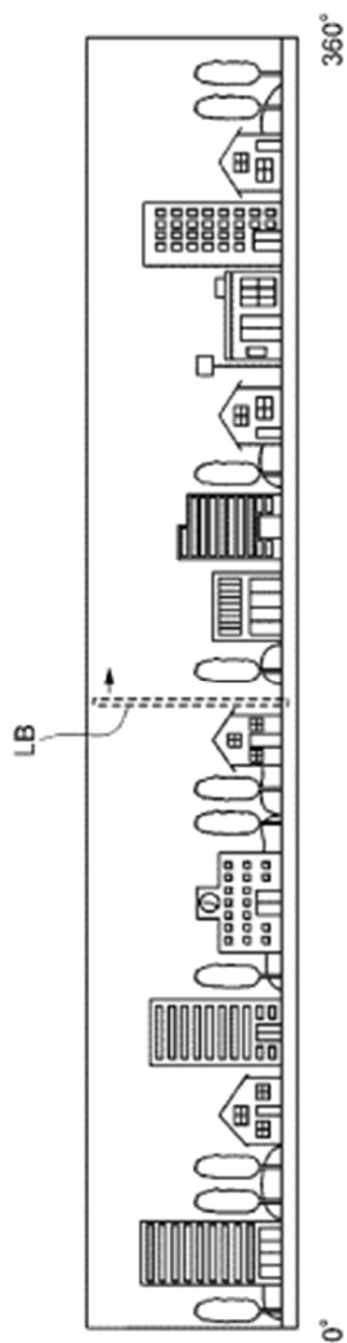
[FIG. 3]



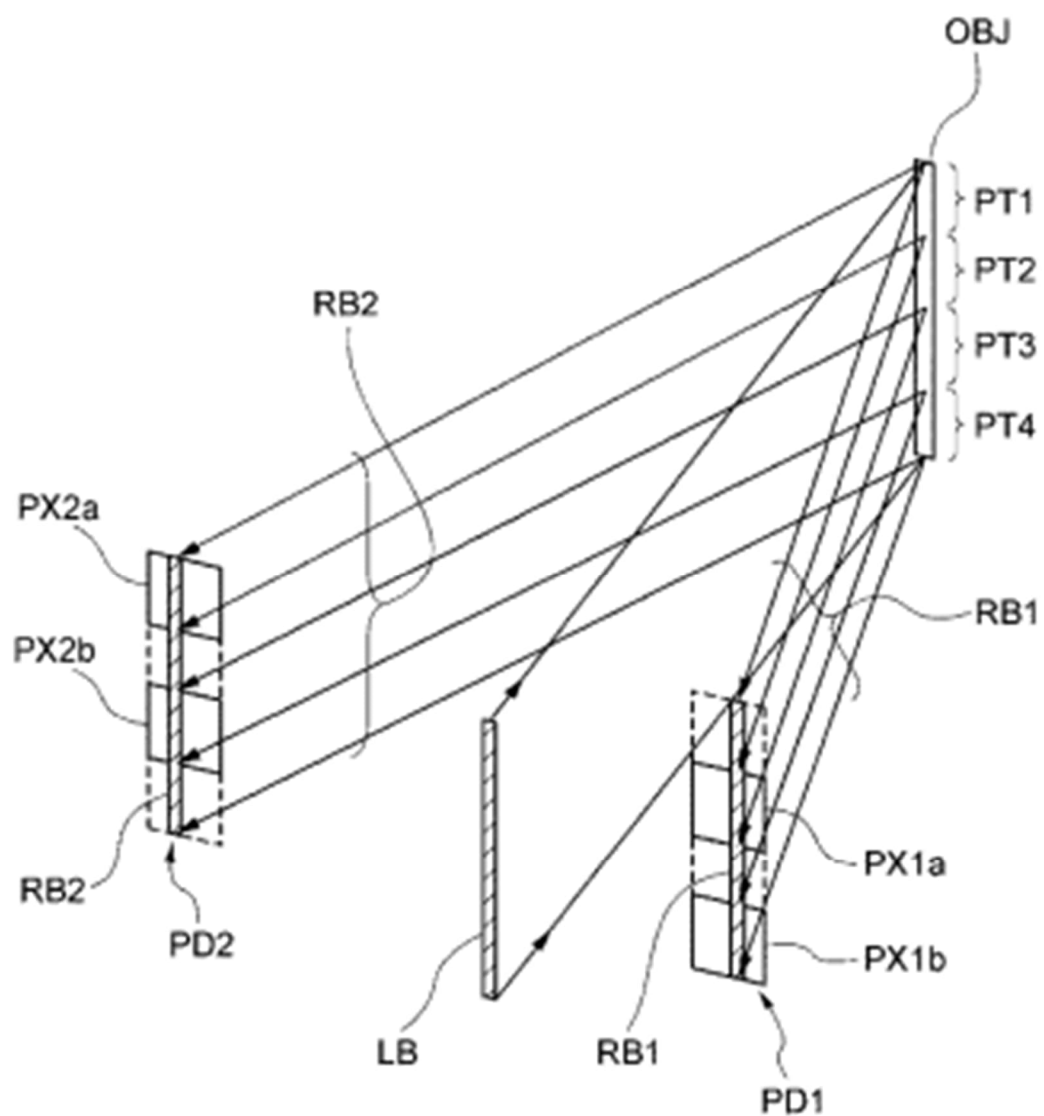
[FIG. 4]



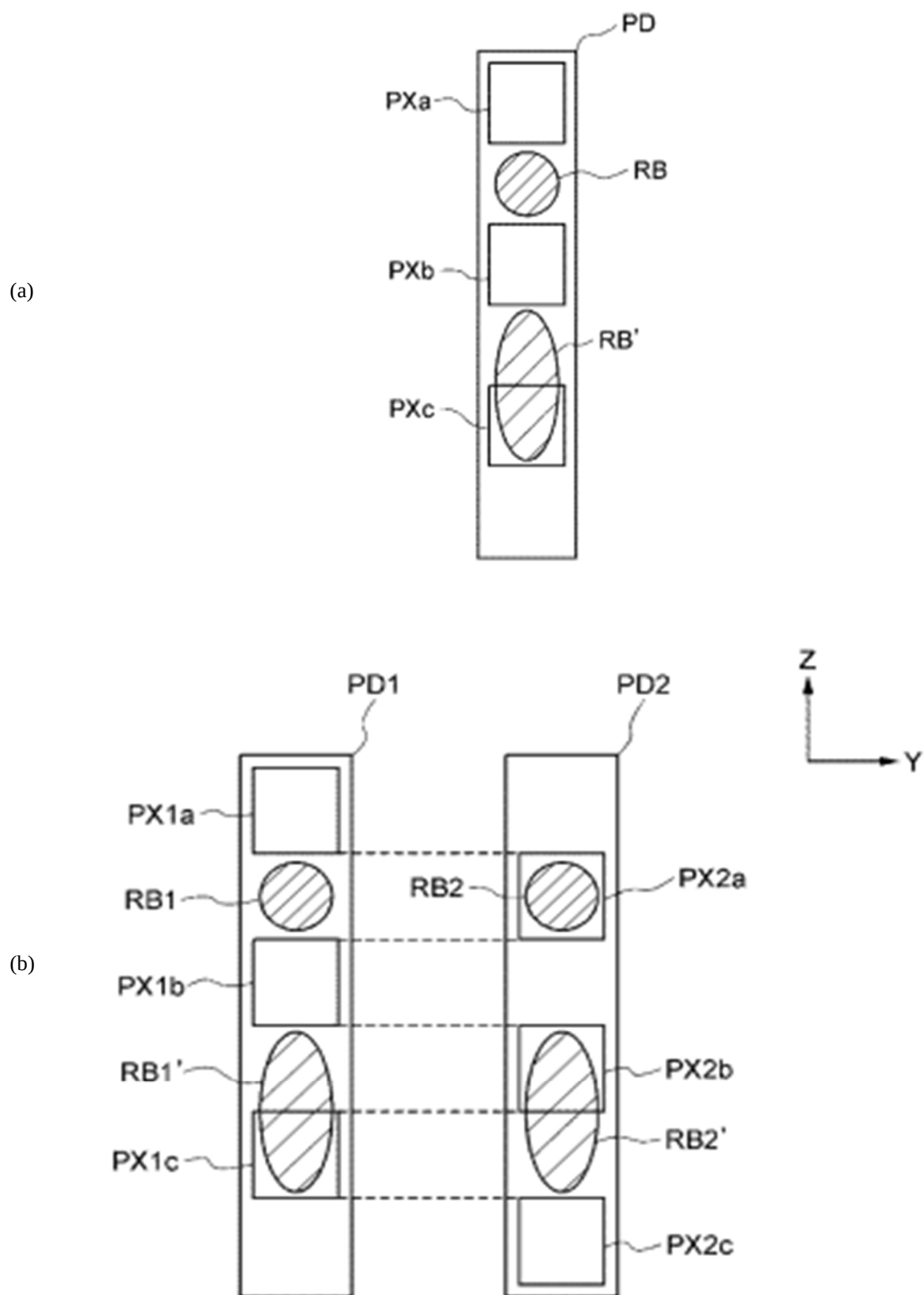
[FIG. 5]



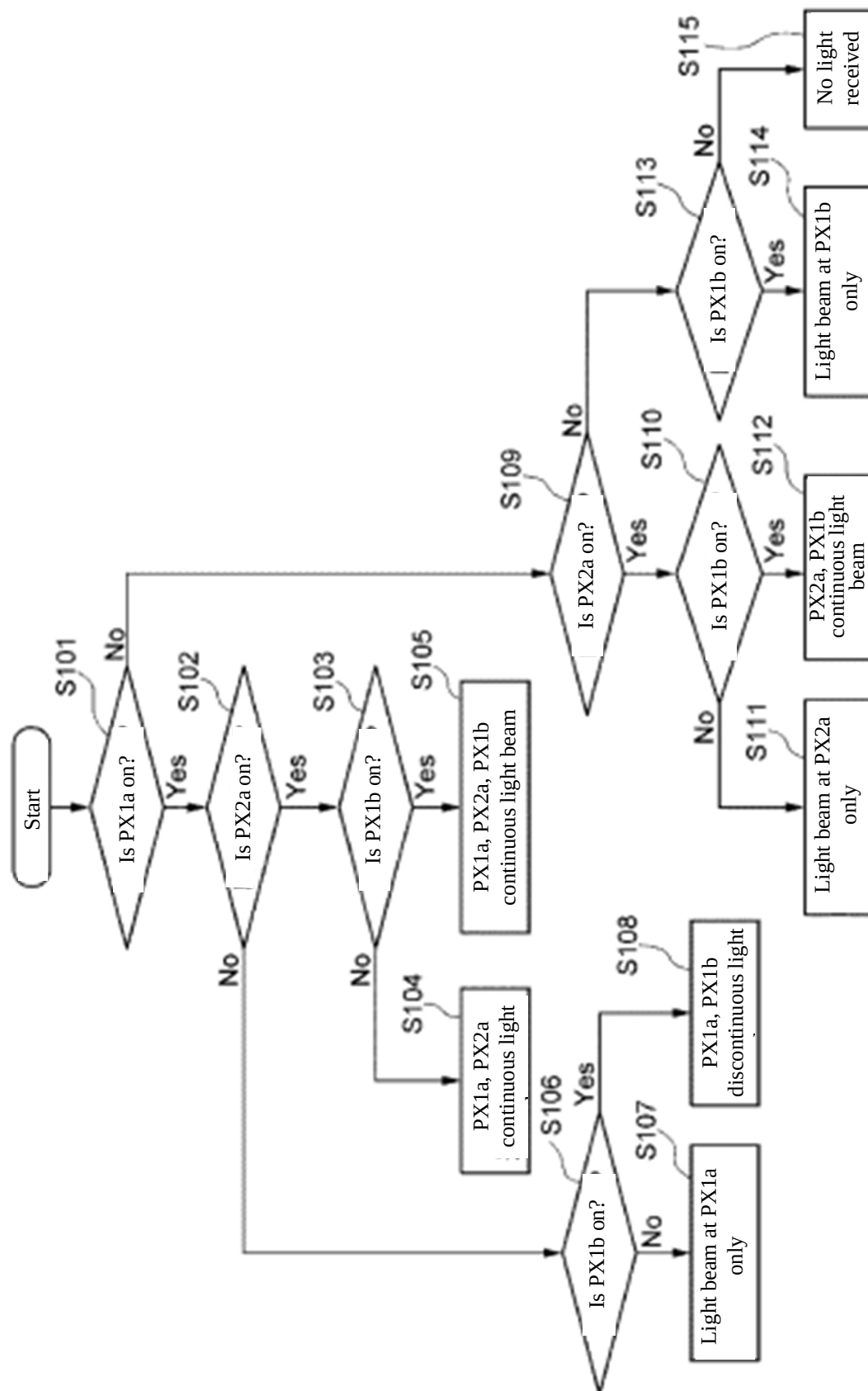
[FIG. 6]



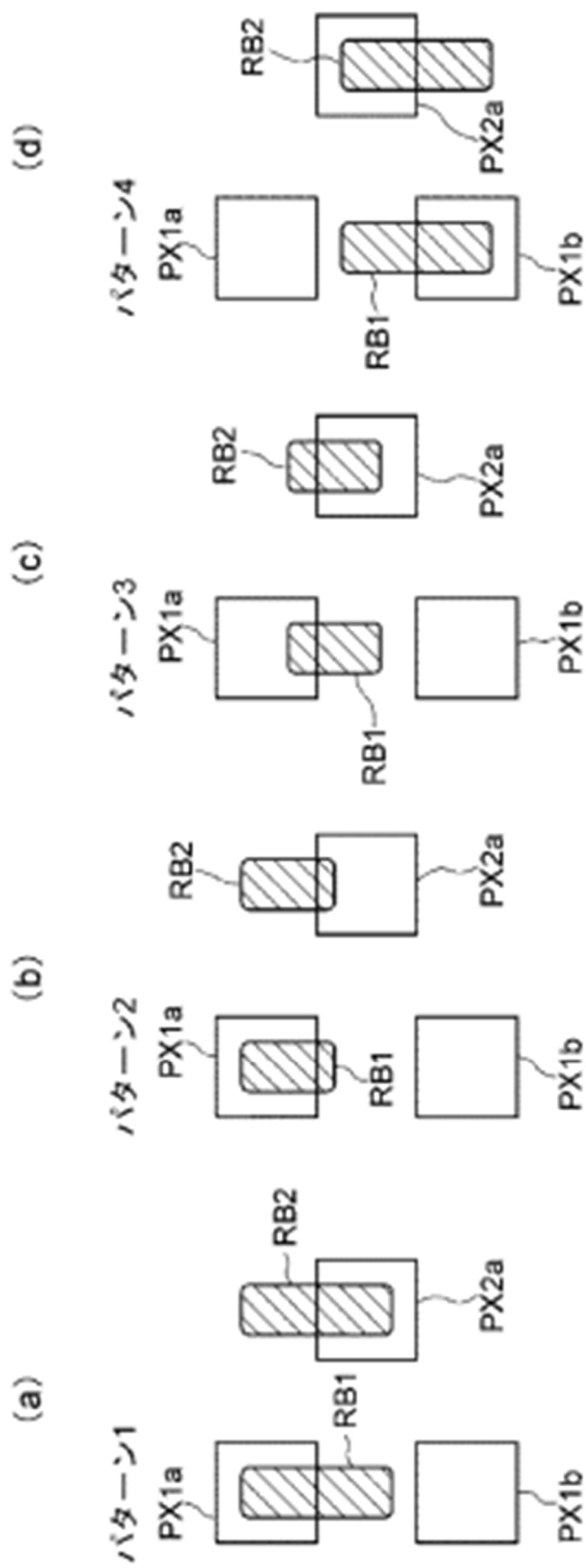
[FIG. 7]



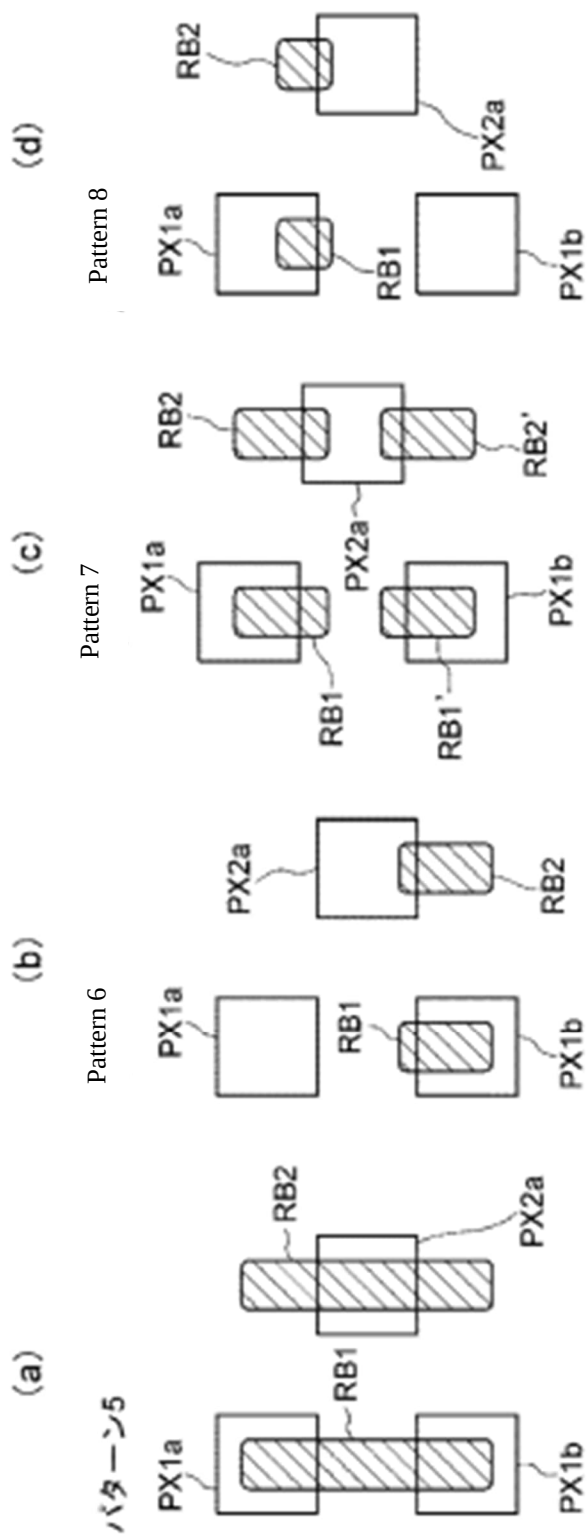
[FIG. 8]



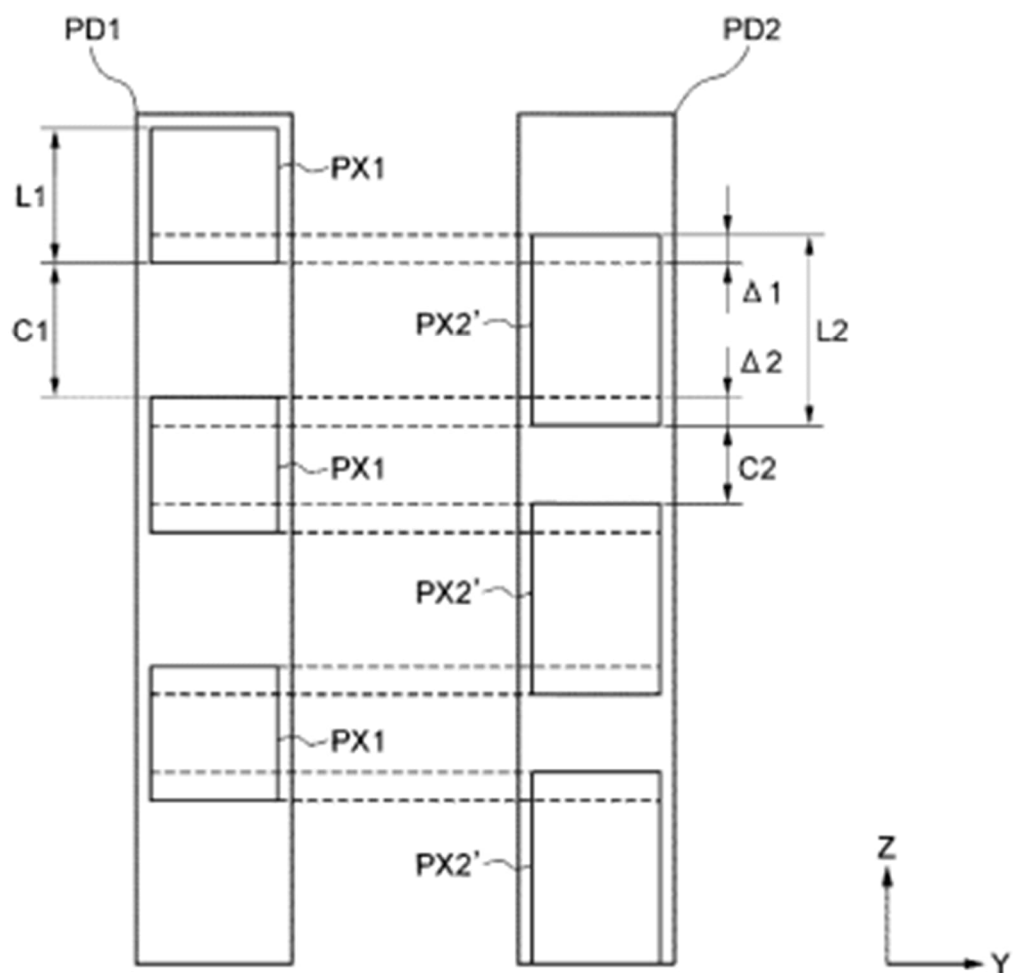
[FIG. 9]



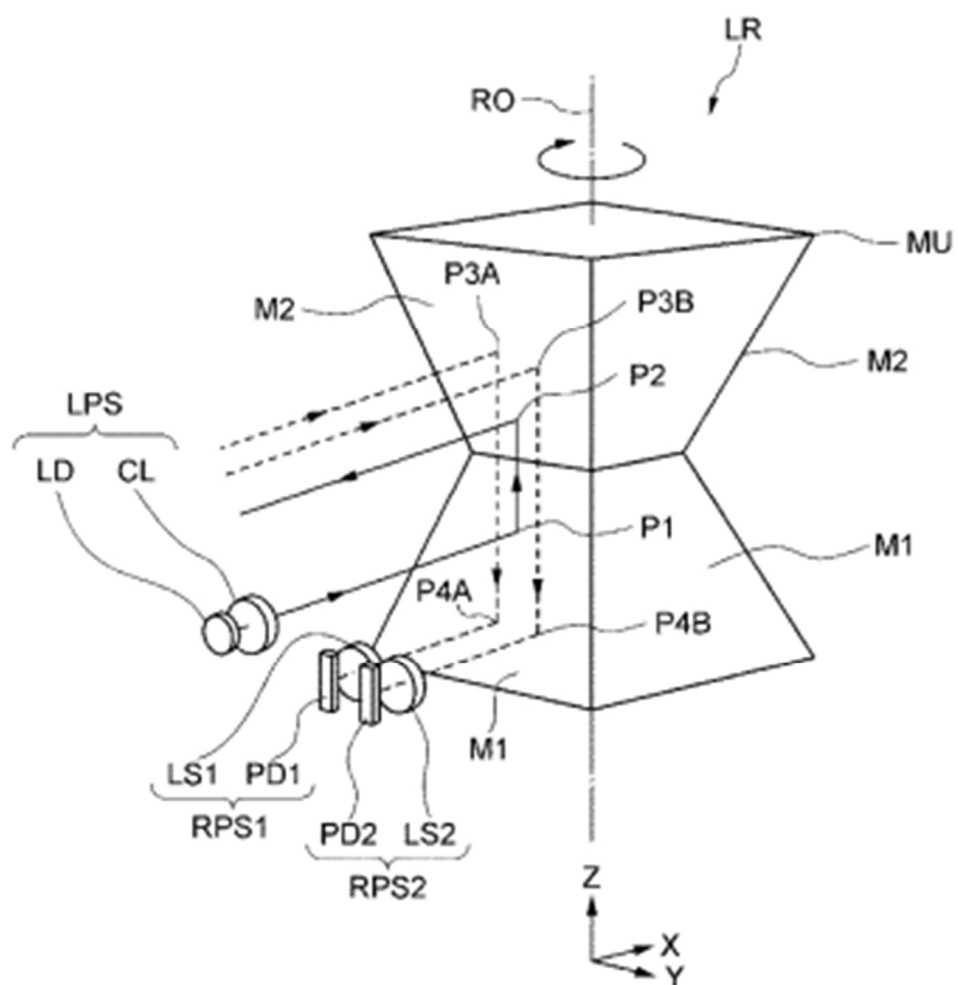
[FIG. 10]



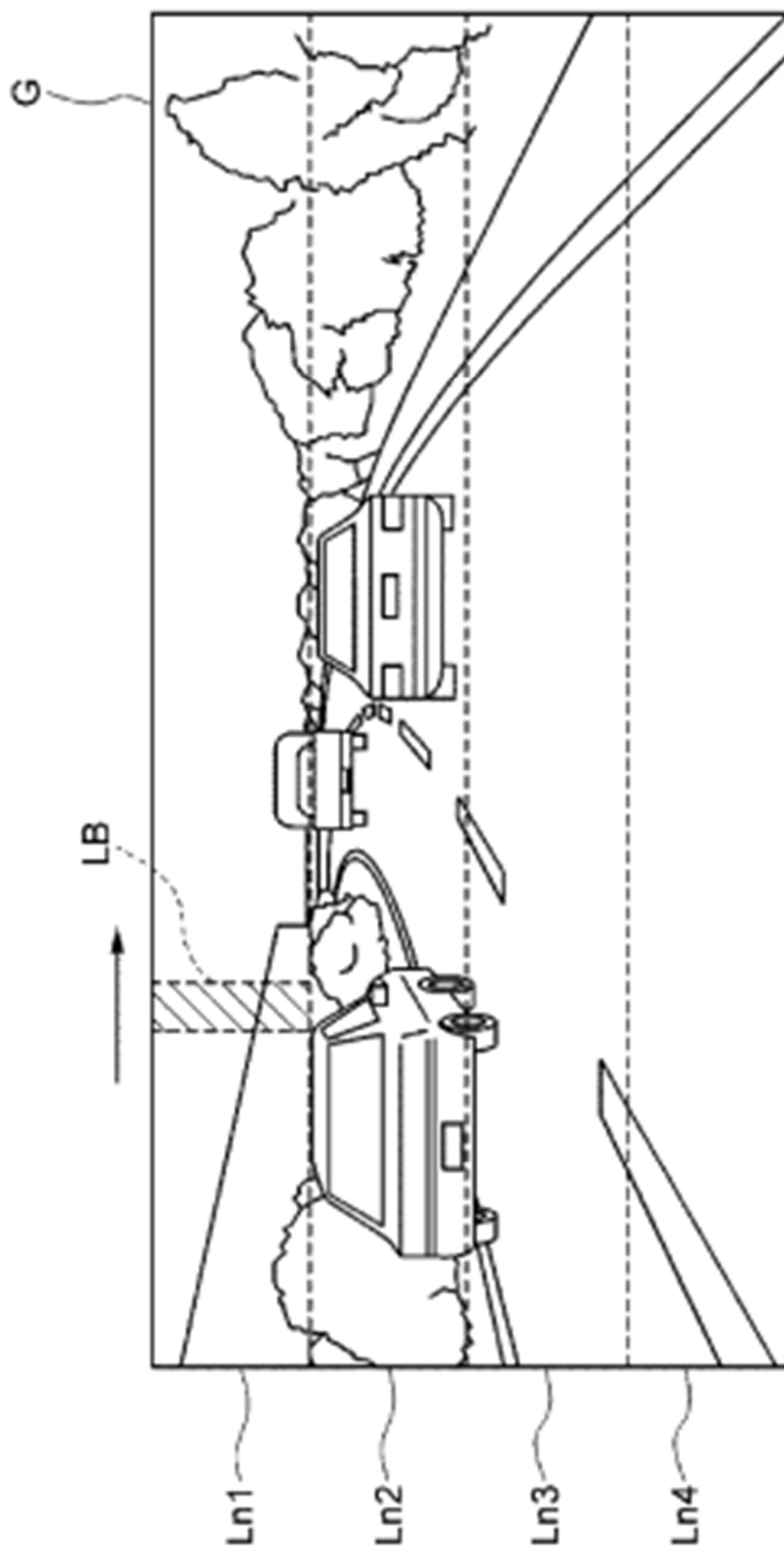
[FIG. 11]



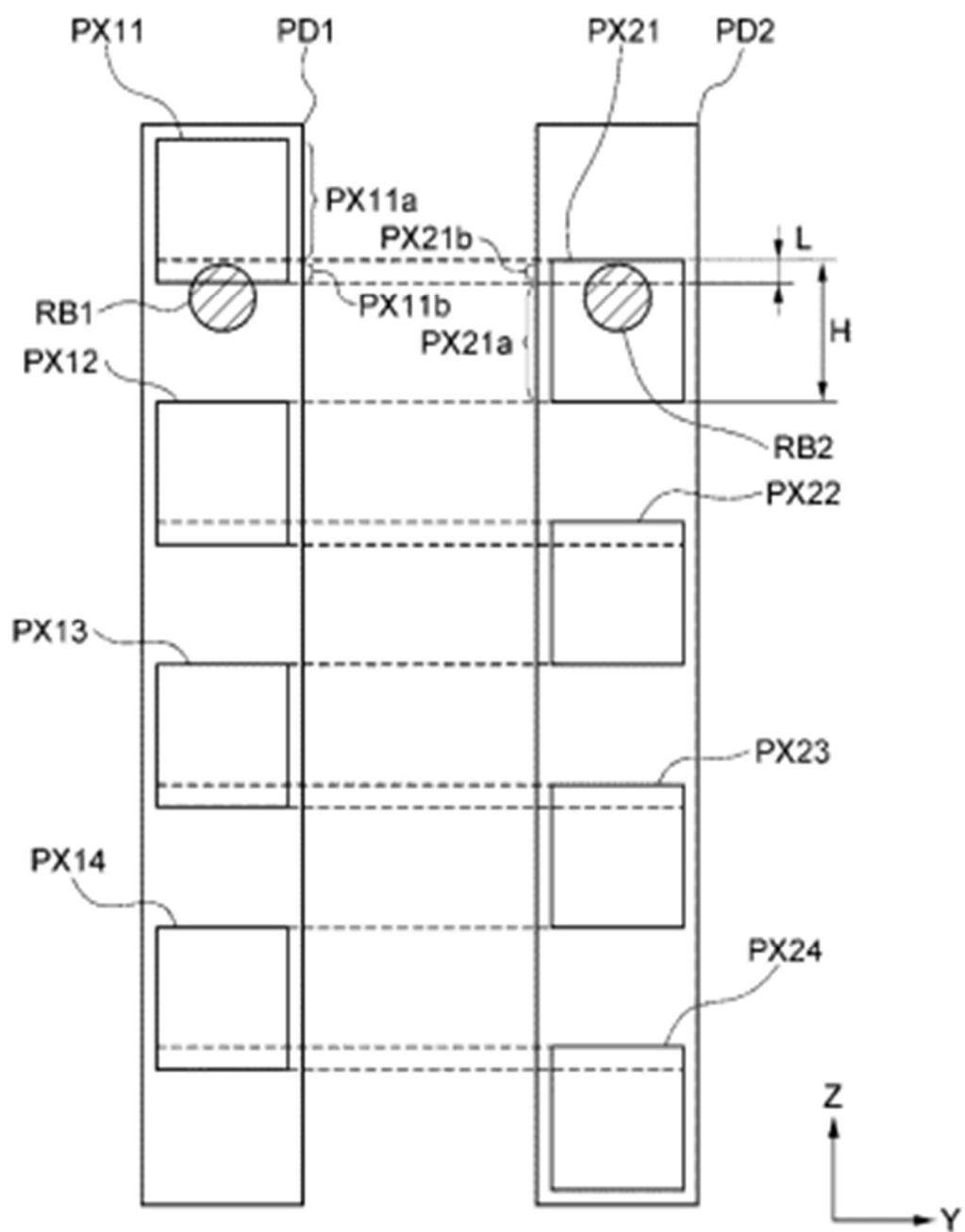
[FIG. 12]



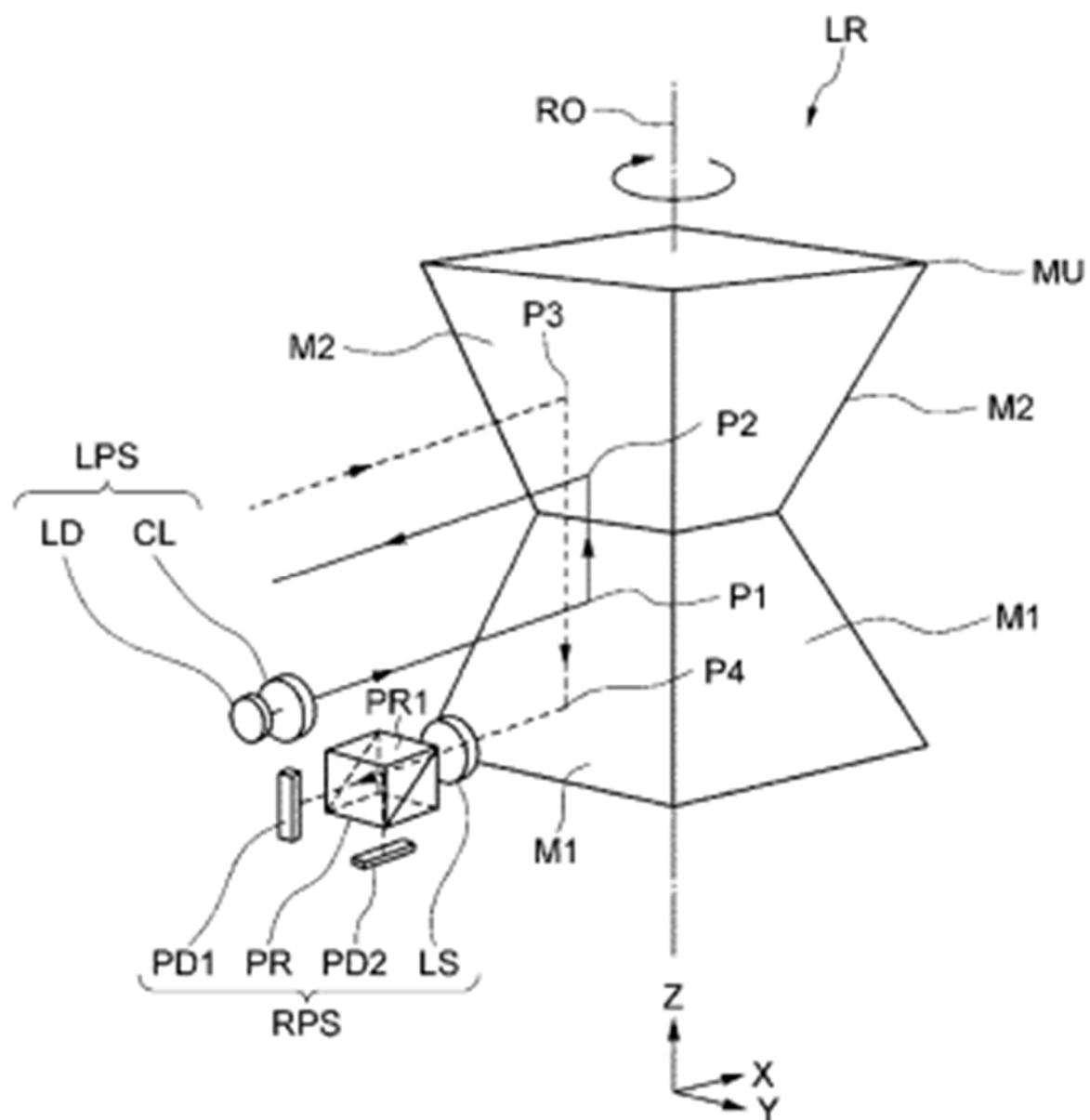
[FIG. 13]



[FIG. 14]



[FIG. 15]



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2016/086978

A. CLASSIFICATION OF SUBJECT MATTER

G01S7/481(2006.01) i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G01S7/48-G01S7/51, G01S17/00-G01S17/95

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2017
Kokai Jitsuyo Shinan Koho	1971-2017	Toroku Jitsuyo Shinan Koho	1994-2017

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.
<u>X</u> Y	WO 2014/129152 A1 (Mitsubishi Electric Corp.), 28 August 2014 (28.08.2014), paragraphs [0023], [0026], [0074] to [0077], [0082]; fig. 14 to 15	<u>1-2, 6, 19</u> <u>1-3, 6-7,</u> 9-13, 16-17, 19-21
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☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

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Date of the actual completion of the international search
13 January 2017 (13.01.17)Date of mailing of the international search report
24 January 2017 (24.01.17)Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2016/086978

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/JP2016/086978

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A. CLASSIFICATION OF SUBJECT MATTER (International Patent Classification (IPC)) Int.Cl. G01S 7/481 (2006.01)i				
B. FIELDS SEARCHED Minimum documentation searched (International Patent Classification (IPC)) Int.Cl. G01S 7/48 - G01S 7/51, G01S 17/00 - G01S 17/95				
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Japanese Utility Model Publications 1922-1996 Japanese Unexamined Utility Model Application Publications 1971-2017 Japanese Utility Model Registrations 1996-2017 Japanese Registered Utility Model Publications 1994-2017				
Electronic data base consulted during the international search (name of database and search terms used)				
C. DOCUMENTS CONSIDERED TO BE RELEVANT				
Cited document category*	Citation of document, with indication, where appropriate, of the relevant passages			Relevant to claim No.
<u>X</u> Y	WO 2014/129152 A1 (Mitsubishi Electric Corp.) 28 August 2014 * [0023], [0026], [0074]-[0077], [0082], fig. 14-15 *			<u>1-2, 6, 19</u> 1-3, 6-7, 9-13, 16-17, 19-21
<u>Y</u> A	WO 2012/085152 A1 (BOROWSKI, A.) 28 June 2012 * [00152]-[00156], [00159], [00178], fig. 7*			<u>1-3, 6-7, 9-13,</u> <u>16-17, 19-21</u> 4-5, 8, 14-15, 18
☒ Further documents are listed in the continuation of Box C.		☒ See patent family annex.		
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Date of actual completion of the international search 13.01.2017		Date of mailing of the international search report 24.01.2017		
Name and mailing address of the ISA Japan Patent Office (ISA/JP) 3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo, 100-8915, Japan		Patent Office Examiner (Authorized officer) TAKABA Masamitsu Telephone No. 03-3581-1101		2S 2910 Extension 3216

C (Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Cited document category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	US 5874733 A (SILVER, A.G.) 23 February 1999 * fig. 1, column 5, lines 32 to 53 *	1-3, 6-7, 9-13, 16-17, 19-21
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