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Tanaka et al.

(10) Patent No.: **US 7,880,865 B2**
(45) Date of Patent: **Feb. 1, 2011**

(54) **LASER RADAR APPARATUS FOR THREE-DIMENSIONAL DETECTION OF OBJECTS**

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(73) Assignee: **DENSO WAVE INCORPORATED**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 348 days.

(21) Appl. No.: **12/071,844**

(22) Filed: **Feb. 28, 2008**

(65) **Prior Publication Data**

US 2009/0002678 A1 Jan. 1, 2009

(30) **Foreign Application Priority Data**

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Sep. 26, 2007 (JP) 2007-248987
Dec. 7, 2007 (JP) 2007-316979

(51) **Int. Cl.**
G01C 3/08 (2006.01)

(52) **U.S. Cl.** **356/4.01**; 356/4.1; 356/5.01; 356/5.15

(58) **Field of Classification Search** 356/3.01–28
See application file for complete search history.

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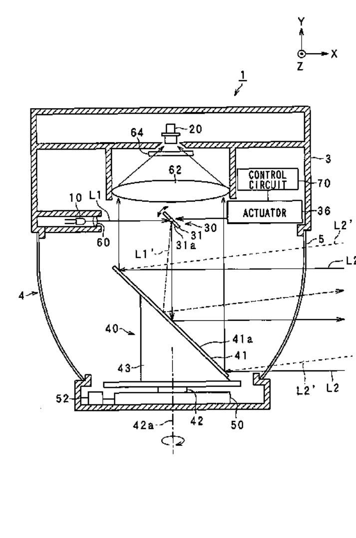
Primary Examiner—Thomas H Tarcza
Assistant Examiner—Luke D Ratcliffe
(74) *Attorney, Agent, or Firm*—Posz Law Group, PLC

(57) **ABSTRACT**

In a laser radar apparatus, a laser beam generator that generates a laser beam and an optical detector that detects reflected light that has been reflected by an object in a field to be observed. A deflection performing means, provided with one or more deflection means each rotatable on a given central axis thereof, for enabling the deflection means to deflect the laser beam to the field and to deflect the reflected light toward the optical detector. A drive means driven to rotate the deflection means. A direction changing means changes a direction of the laser beam from the deflection means is changed in a direction of the central axis. A control means controls an operation of the direction changing means.

43 Claims, 35 Drawing Sheets



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JP	A-H03-175390		7/1991
WO	WO 96/32662		10/1996

OTHER PUBLICATIONS

Office Action dated Jun. 12, 2009 from the European Patent Office in the corresponding EP Application No. 08152043.9-2220.

* cited by examiner

FIG. 1

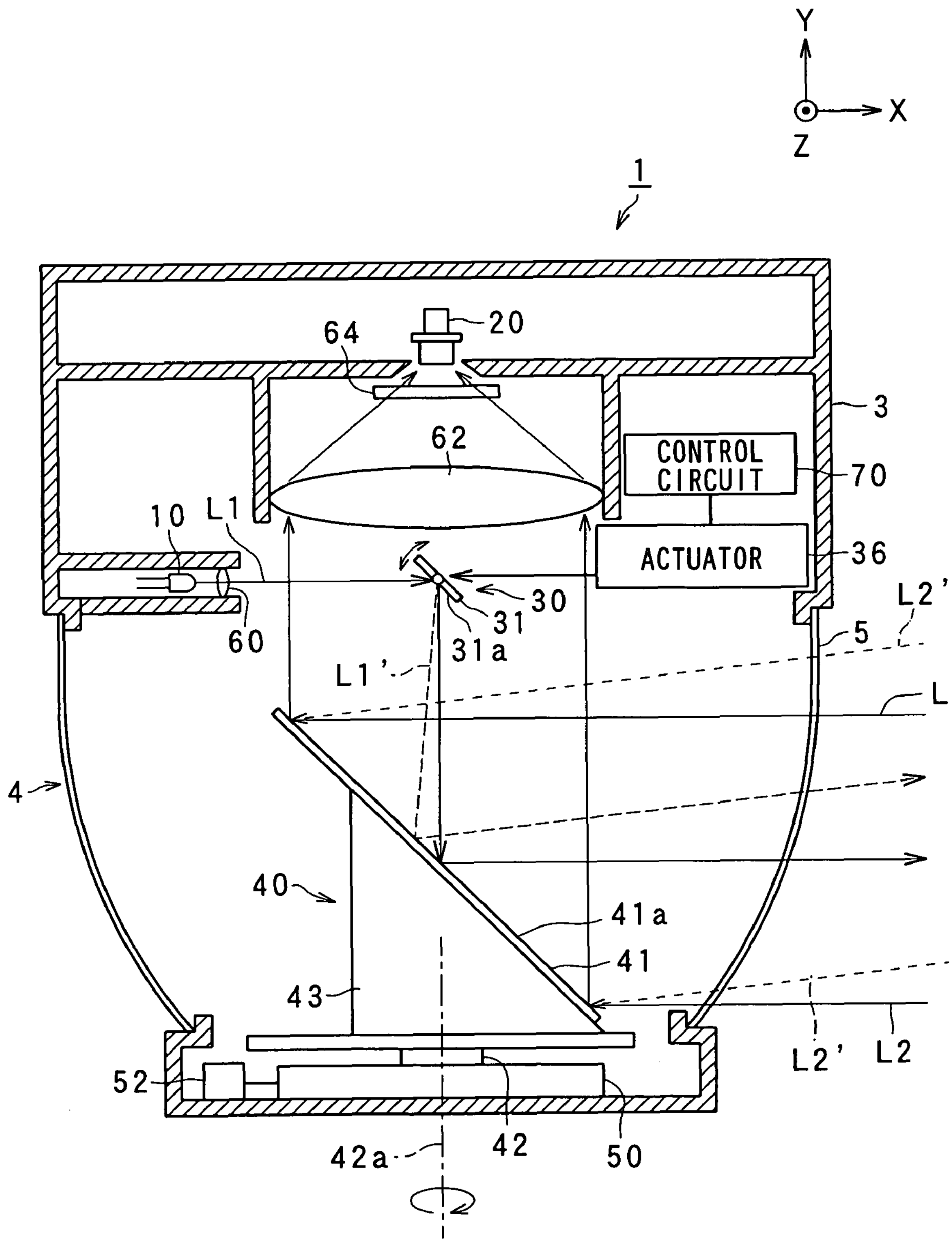

Y
X
Z
1
20
64
3
62
CONTROL CIRCUIT
70
10
L1
ACTUATOR
36
30
31
60
31a
L2'
5
L1'
L2
4
40
41a
41
43
L2'
L2
52
42
50
42a

FIG. 2

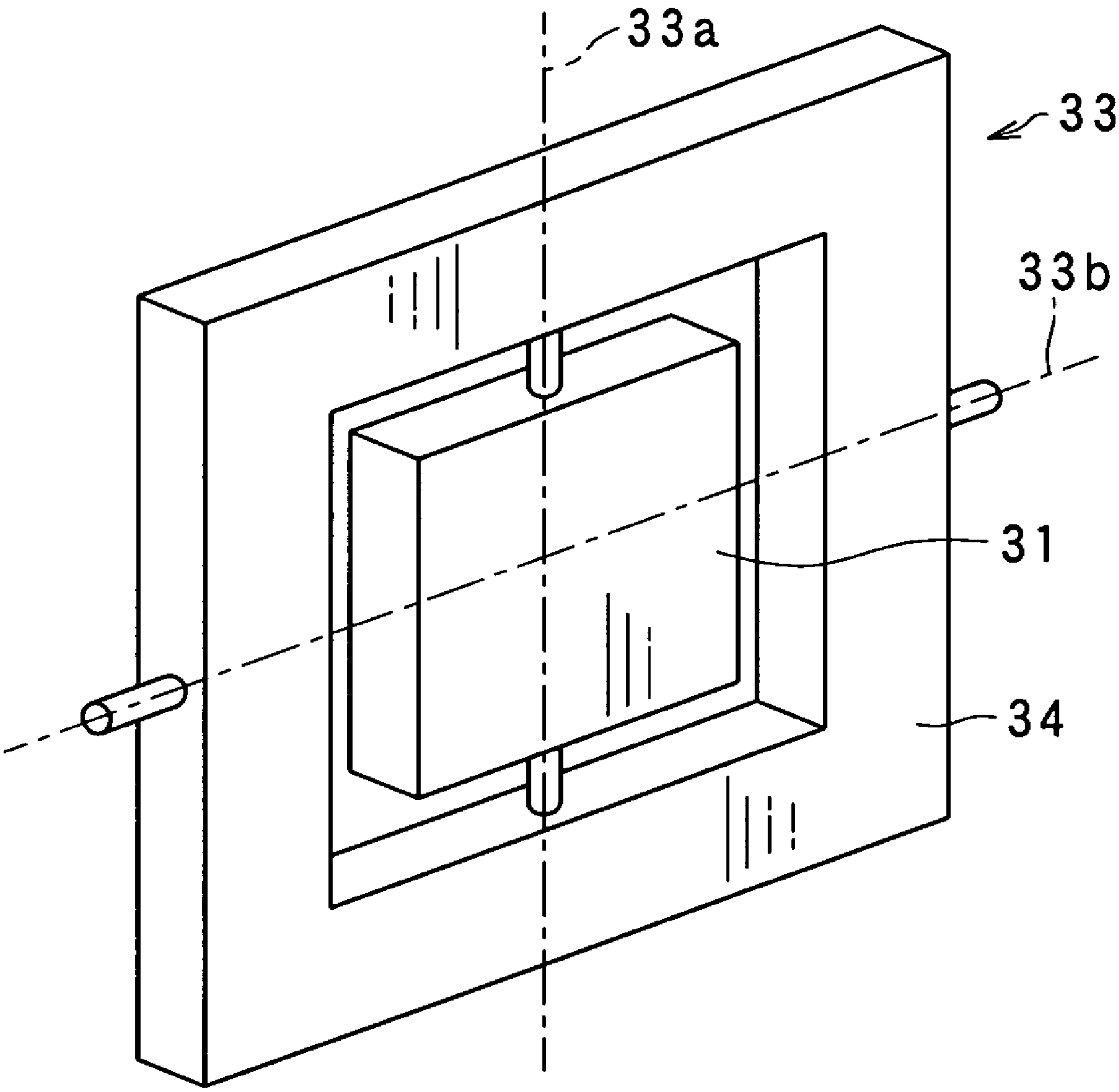
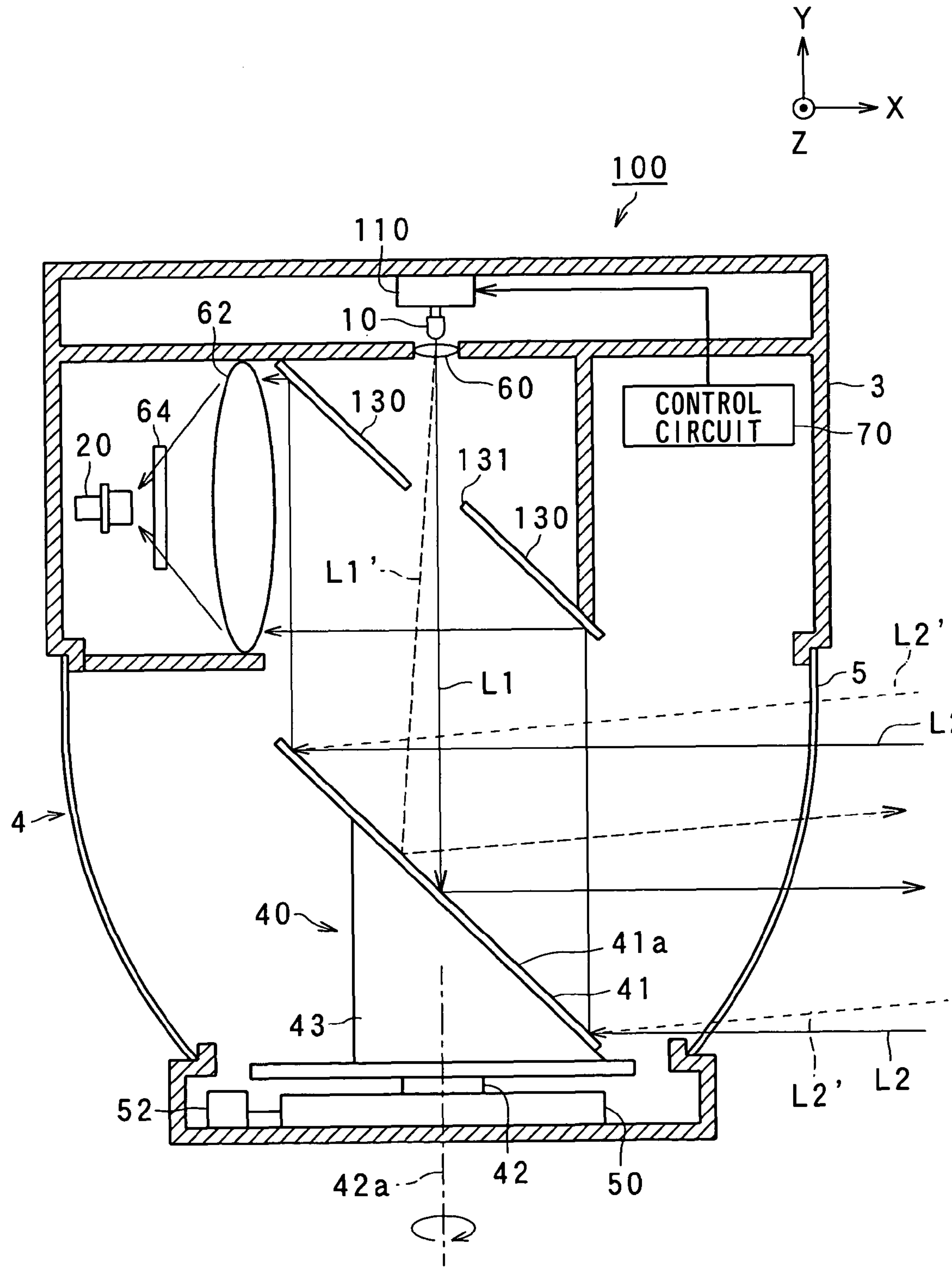


FIG. 3



Y
X
Z
100
110
10
62
60
130
3
64
CONTROL CIRCUIT
70
20
131
130
L1'
L2'
L1
5
L2
4
40
41a
41
43
L2'
L2
52
42a
42
50

FIG. 4

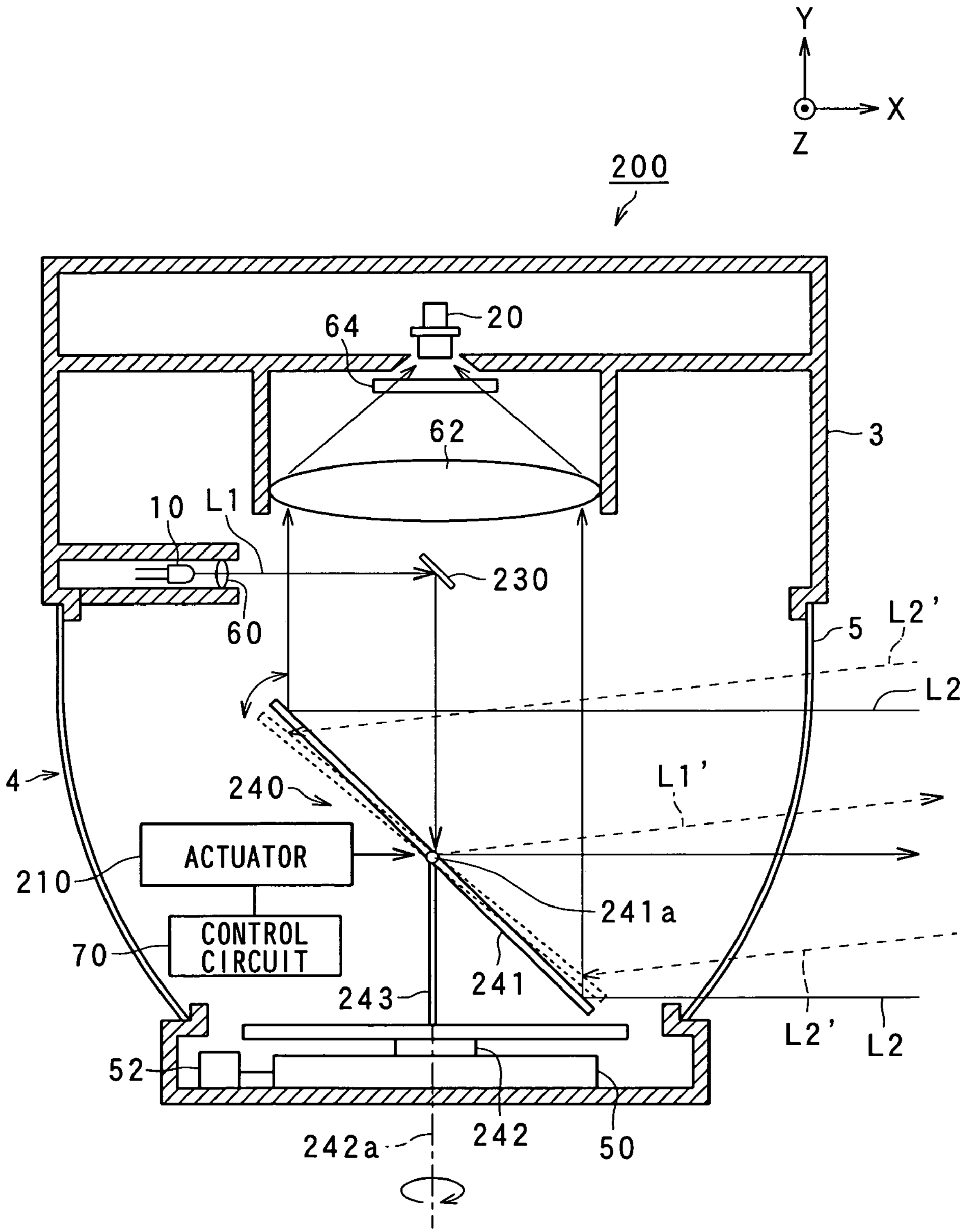
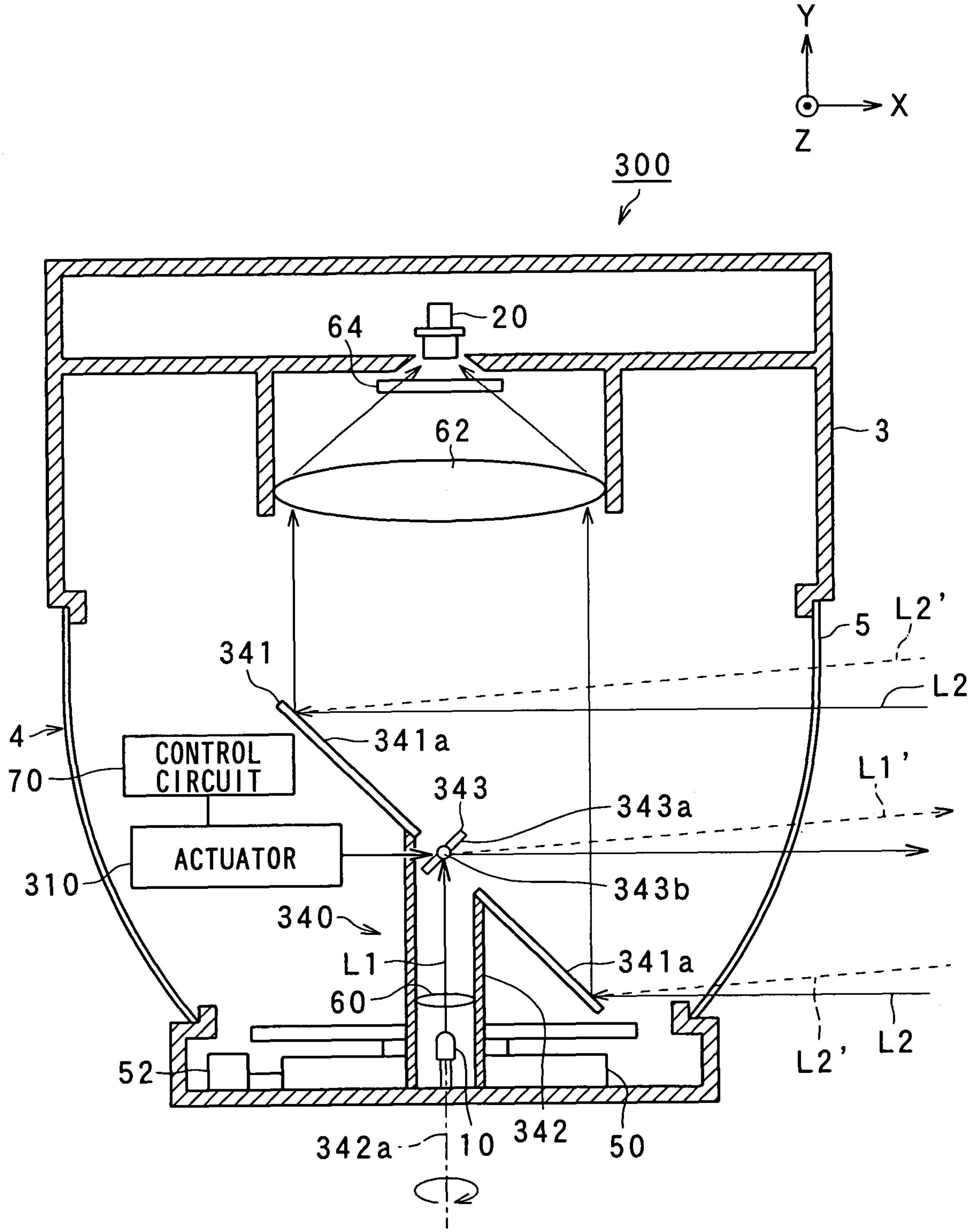
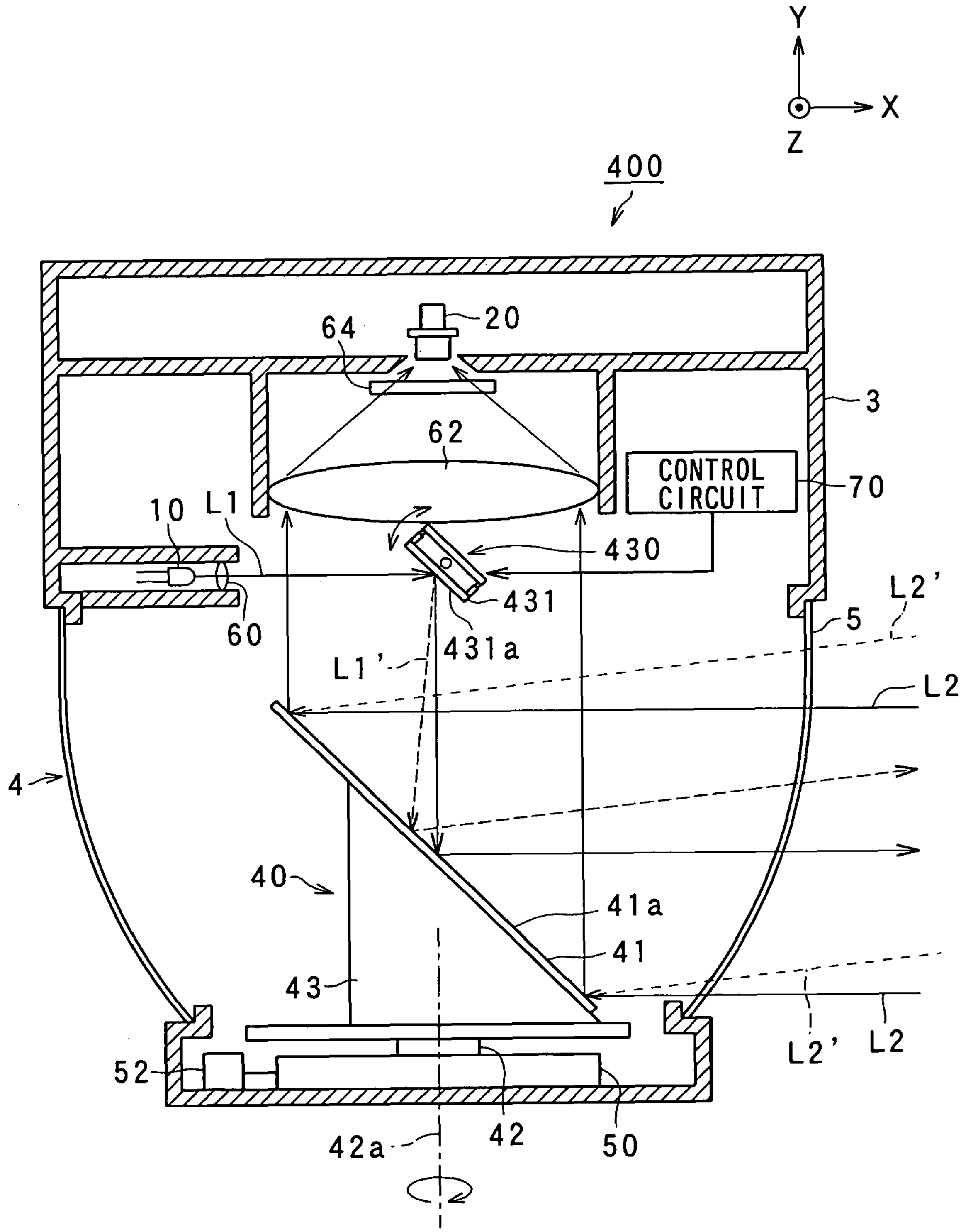

Y
X
Z
200
20
64
62
3
10
L1
230
60
5
L2'
L2
4
240
L1'
ACTUATOR
210
241a
CONTROL CIRCUIT
70
241
243
L2'
L2
52
242a
242
50

FIG. 5



Y
X
Z
300
20
64
62
3
5
L2'
L2
341
341a
4
CONTROL CIRCUIT
70
L1'
343
343a
ACTUATOR
310
343b
340
L1
341a
60
52
L2'
L2
342a
10
342
50

FIG. 6



Y
X
Z
400
20
64
62
3
CONTROL CIRCUIT
70
10
L1
430
431
60
431a
5
L2'
L1'
L2
4
40
41a
41
43
52
42
50
42a
L2'
L2

FIG. 7

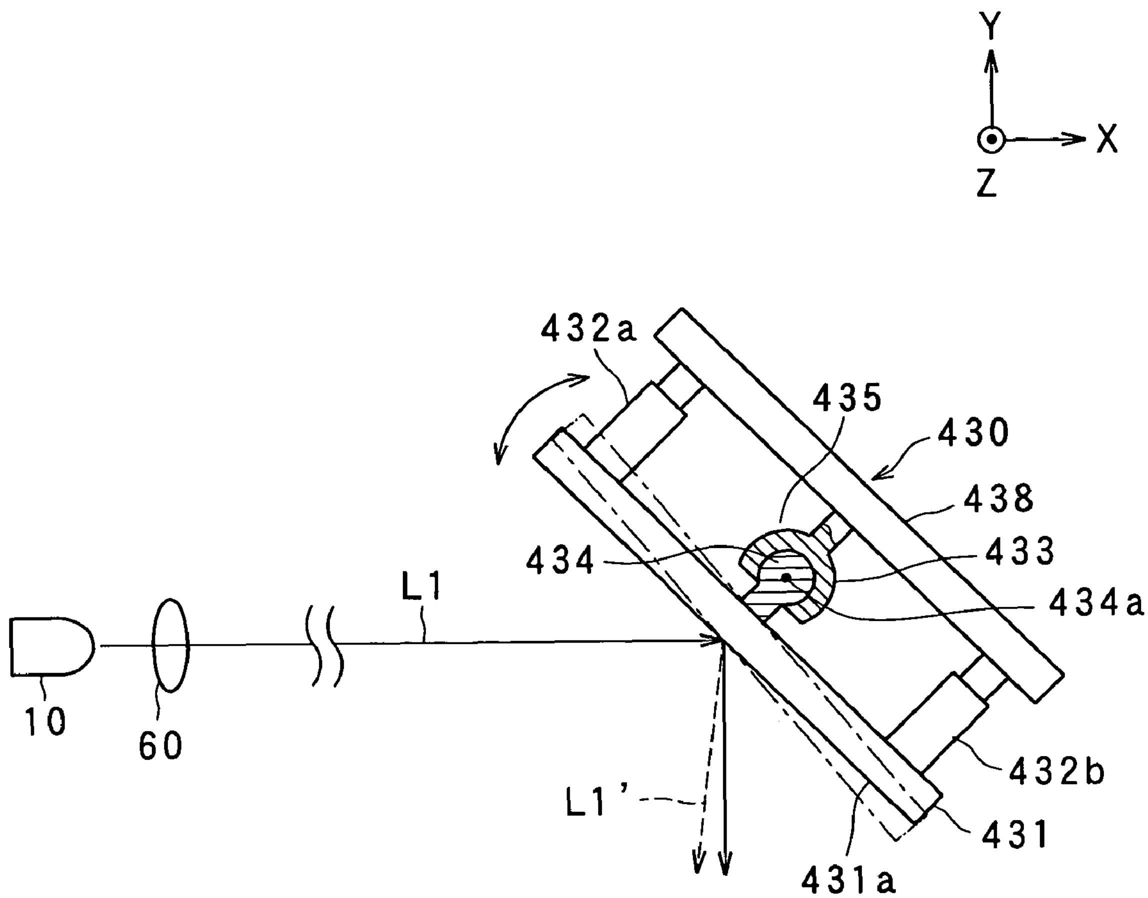


FIG. 8A

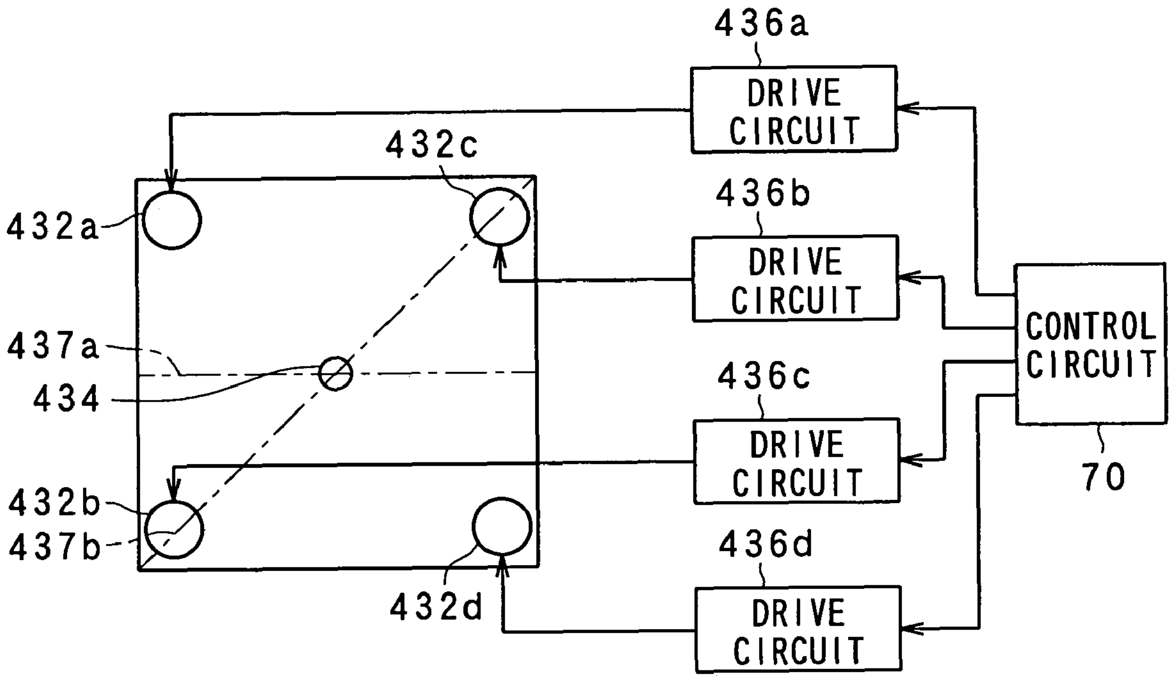

436a
DRIVE CIRCUIT
432c
436b
DRIVE CIRCUIT
432a
437a
434
CONTROL CIRCUIT
436c
DRIVE CIRCUIT
70
432b
437b
436d
432d
DRIVE CIRCUIT

FIG. 8B

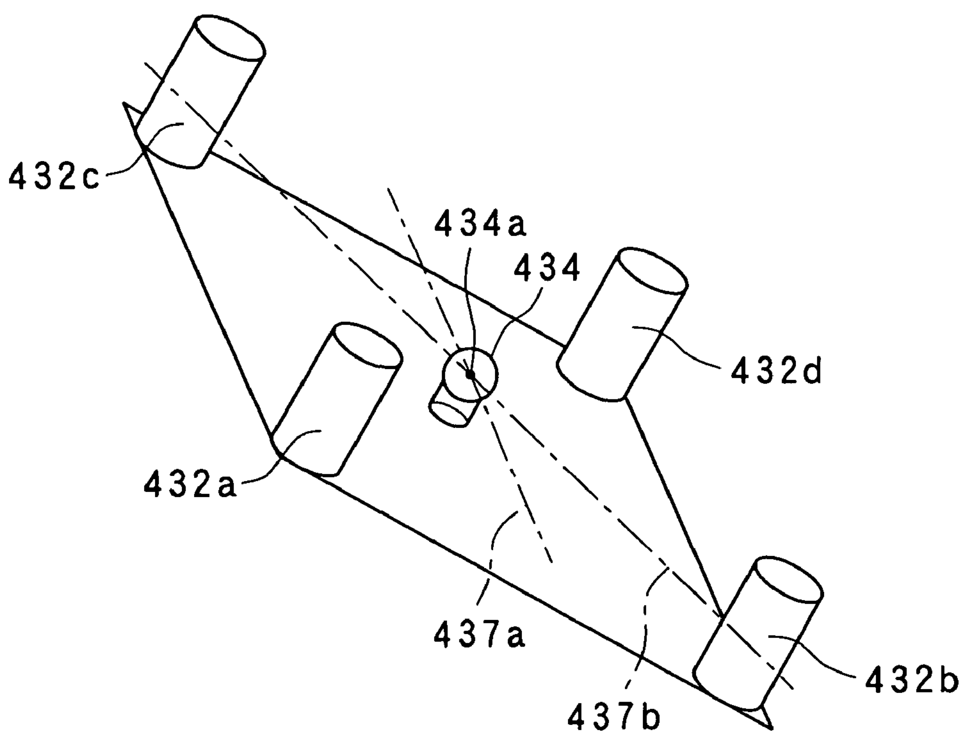

432c
434a
434
432d
432a
437a
437b
432b

FIG. 9

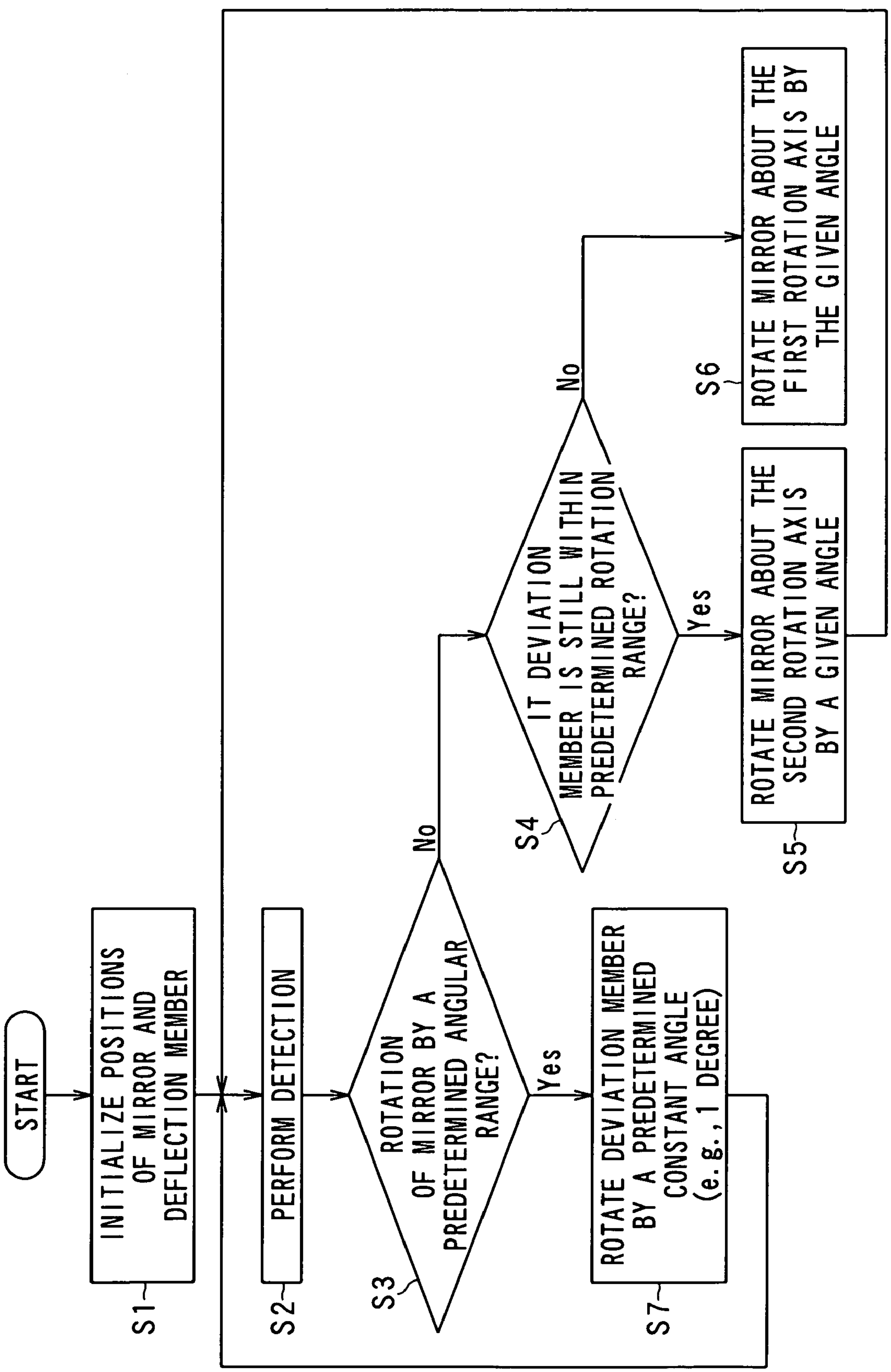

START
INITIALIZE POSITIONS OF MIRROR AND DEFLECTION MEMBER
S1
PERFORM DETECTION
S2
ROTATION OF MIRROR BY A PREDETERMINED ANGULAR RANGE?
S3
Yes
No
ROTATE DEVIATION MEMBER BY A PREDETERMINED CONSTANT ANGLE (e.g., 1 DEGREE)
S7
IT DEVIATION MEMBER IS STILL WITHIN PREDETERMINED ROTATION RANGE?
S4
Yes
No
ROTATE MIRROR ABOUT THE SECOND ROTATION AXIS BY A GIVEN ANGLE
S5
ROTATE MIRROR ABOUT THE FIRST ROTATION AXIS BY THE GIVEN ANGLE
S6

FIG.10

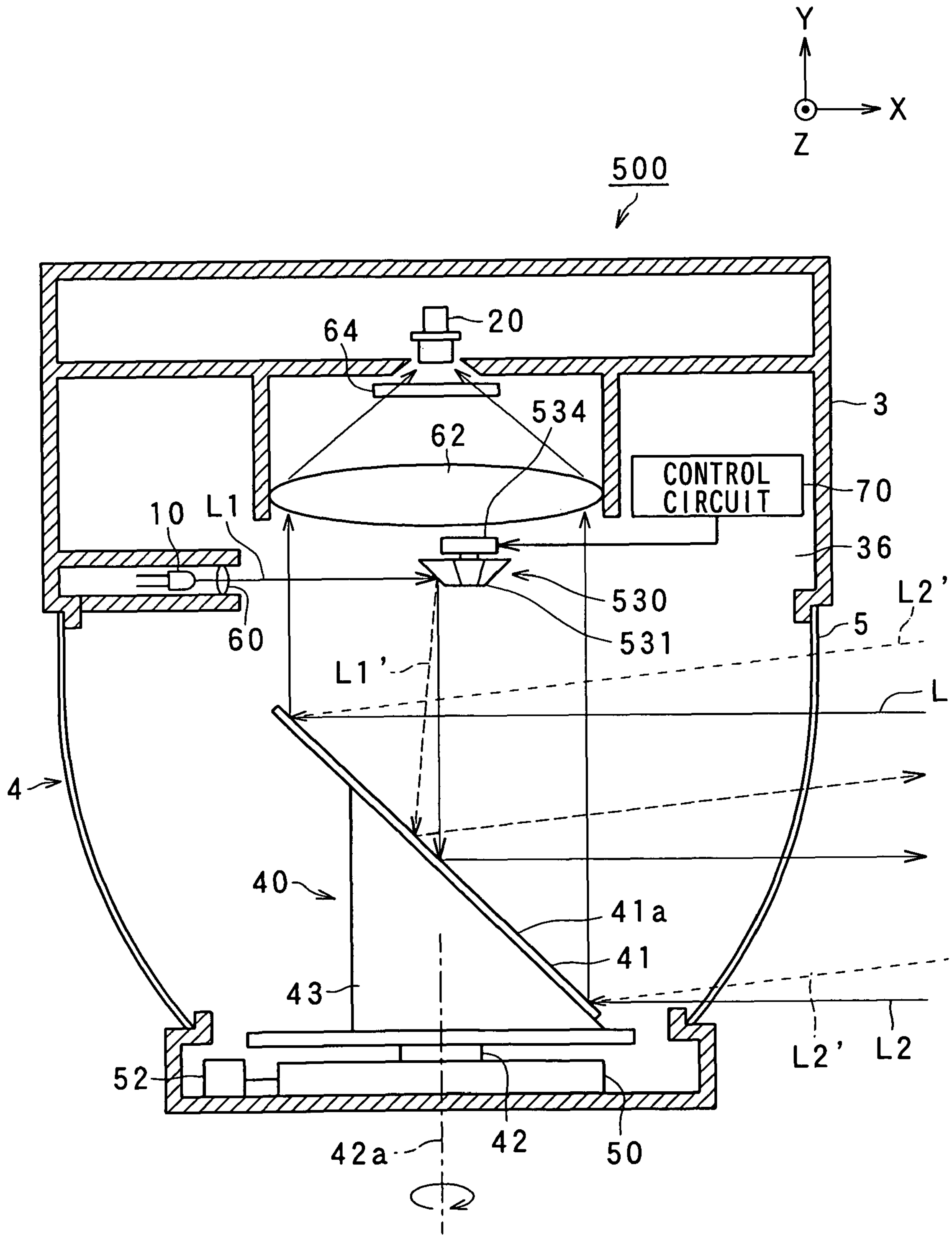

Y
X
Z
500
20
64
534
3
62
CONTROL CIRCUIT
70
10
L1
36
530
L2'
5
60
531
L1'
L2
4
40
41a
41
43
L2'
L2
52
42a
42
50

FIG.11A

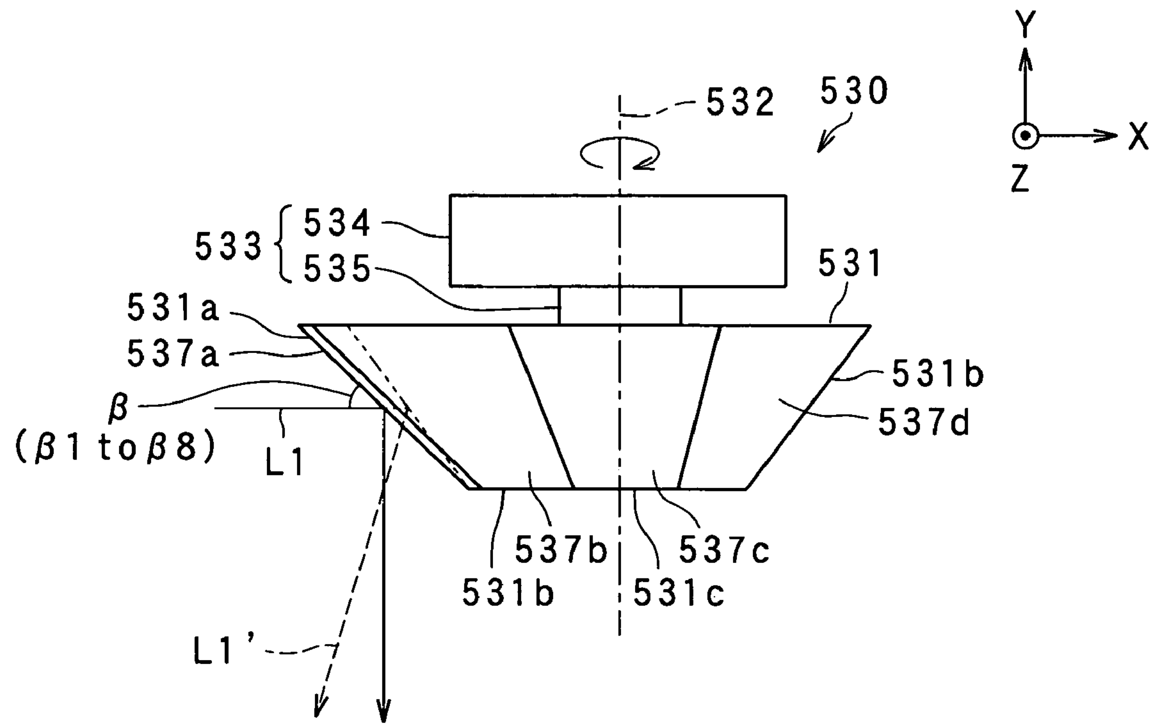


FIG.11B

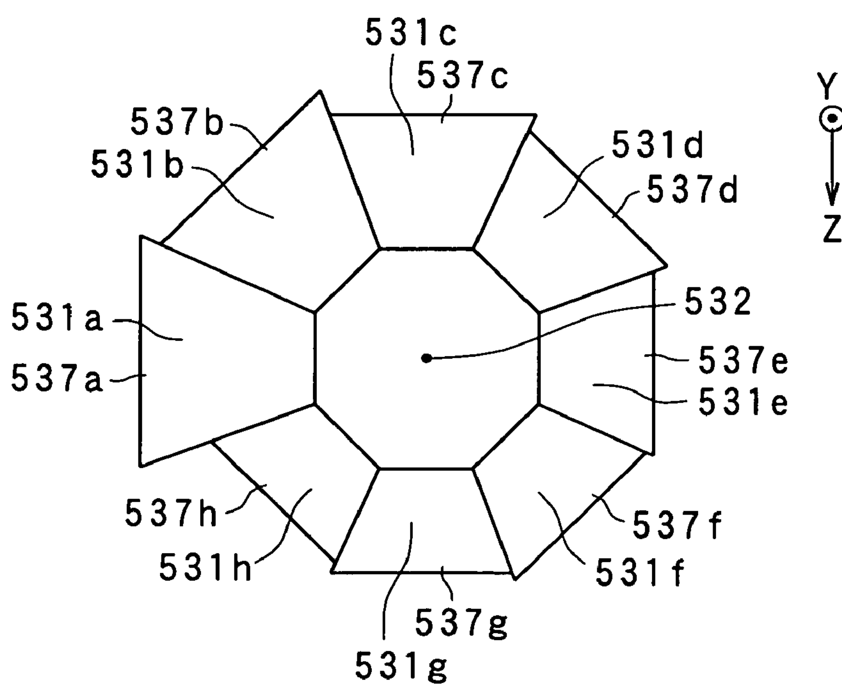


FIG. 12

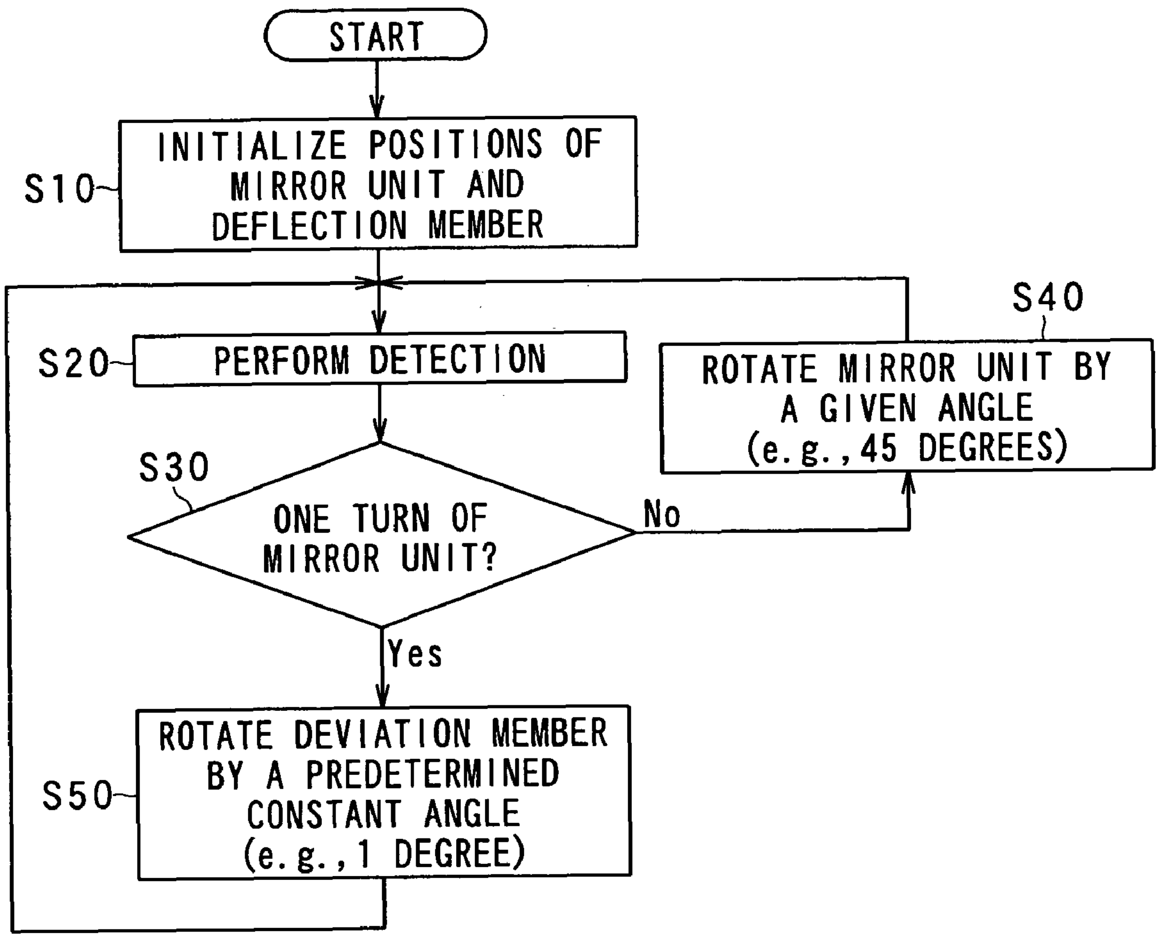

START
S10
INITIALIZE POSITIONS OF MIRROR UNIT AND DEFLECTION MEMBER
S20
PERFORM DETECTION
S30
ONE TURN OF MIRROR UNIT?
No
S40
ROTATE MIRROR UNIT BY A GIVEN ANGLE (e.g., 45 DEGREES)
Yes
S50
ROTATE DEVIATION MEMBER BY A PREDETERMINED CONSTANT ANGLE (e.g., 1 DEGREE)

FIG.13

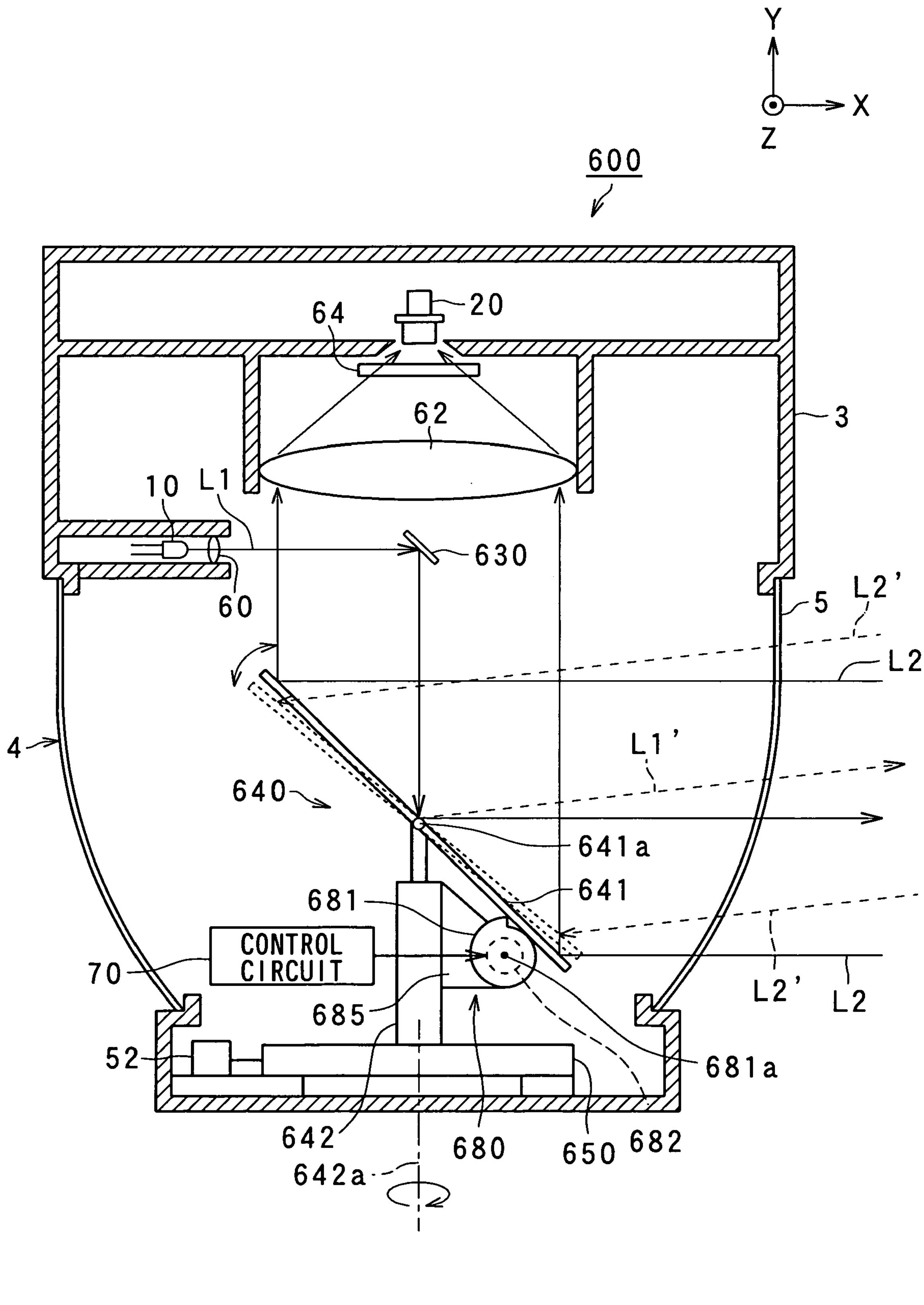

Y
X
Z
600
20
64
62
3
10
L1
630
60
5
L2'
L2
4
L1'
640
641a
641
681
CONTROL CIRCUIT
70
685
L2'
L2
52
681a
642
680
650
682
642a

FIG.14A

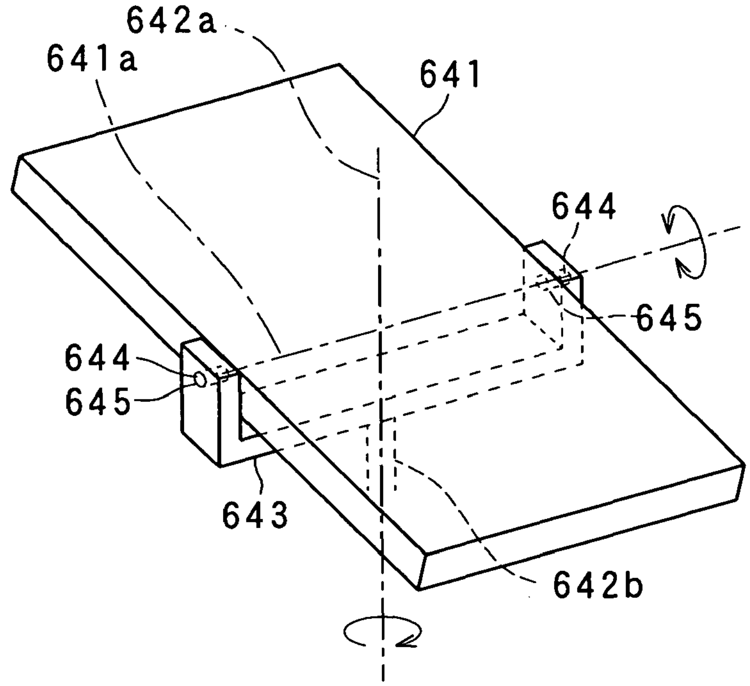


FIG.14B

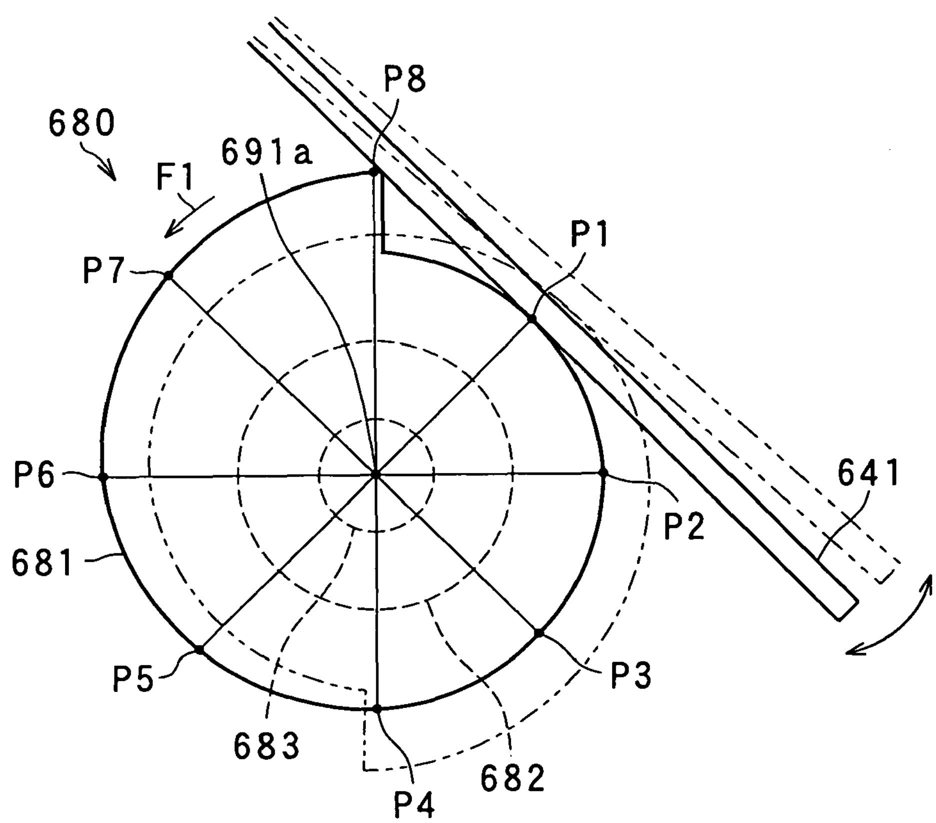


FIG.15A

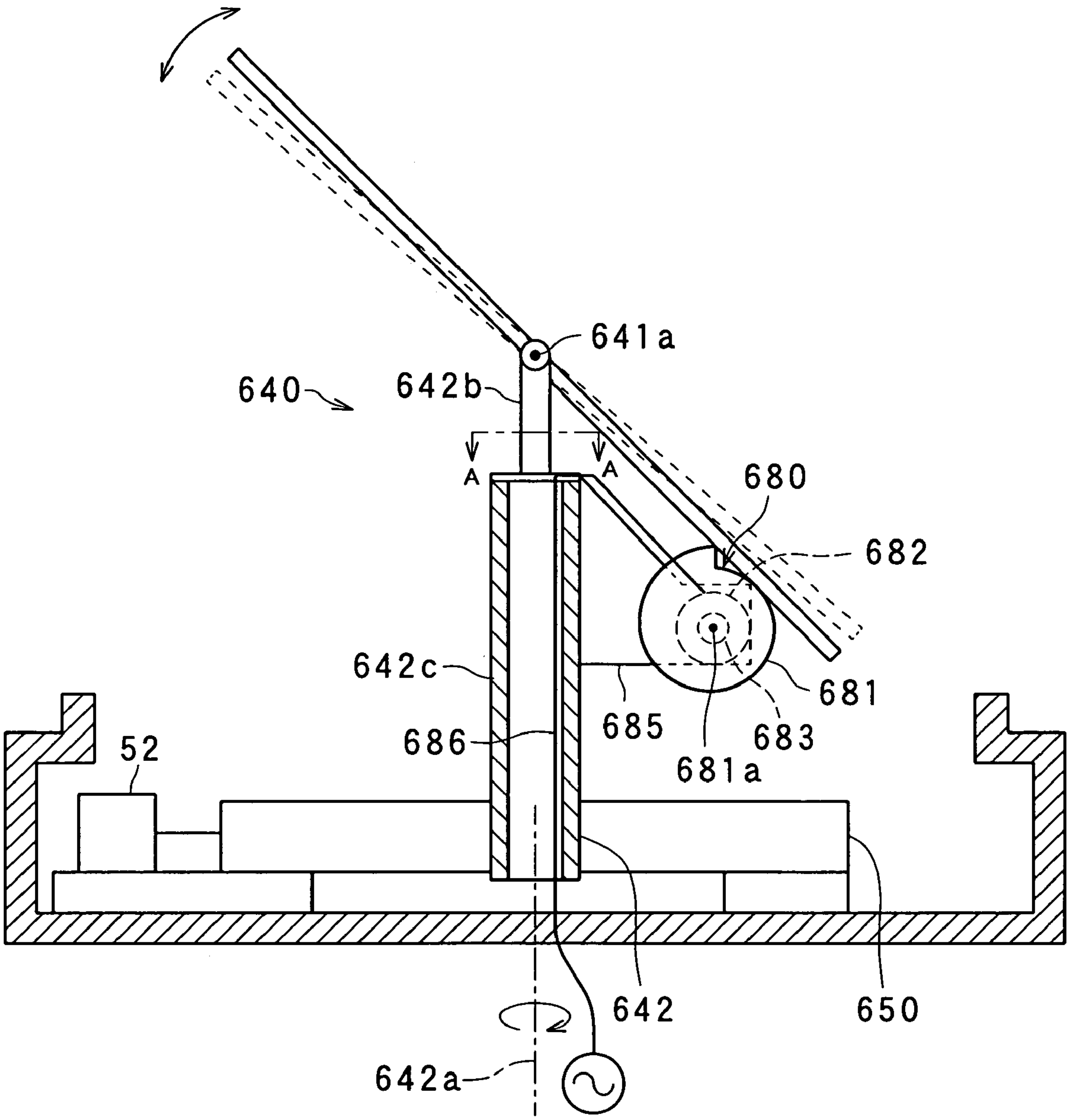


FIG.15B

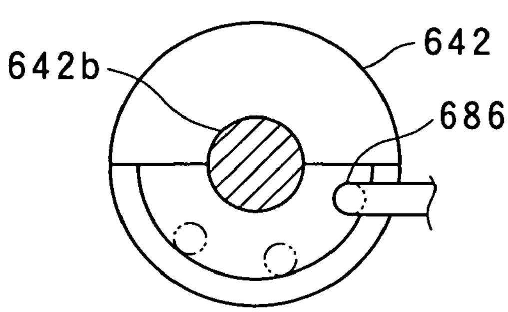


FIG. 16

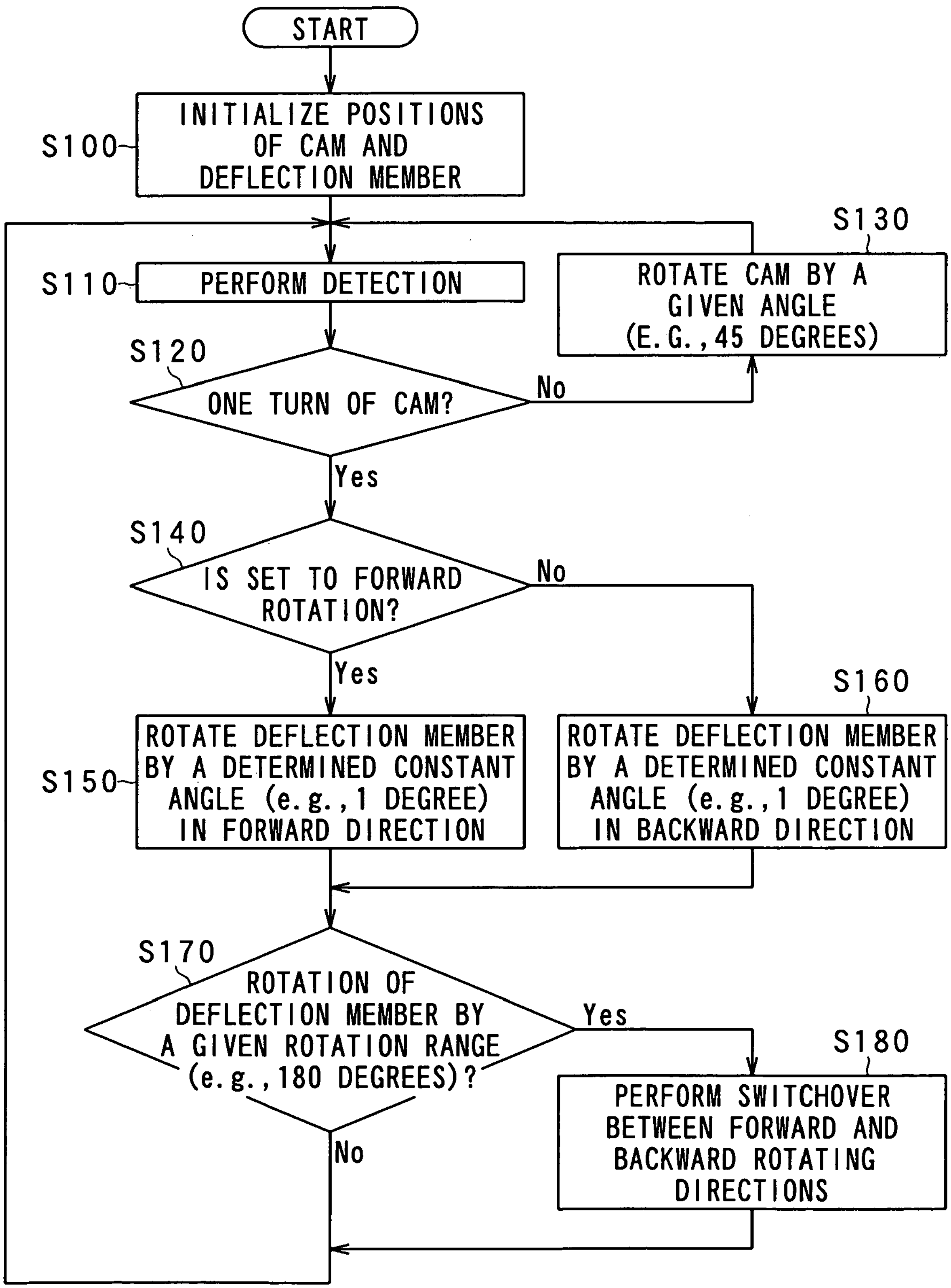

START
S100
INITIALIZE POSITIONS OF CAM AND DEFLECTION MEMBER
S110
PERFORM DETECTION
S120
ONE TURN OF CAM?
No
S130
ROTATE CAM BY A GIVEN ANGLE (E.G., 45 DEGREES)
Yes
S140
IS SET TO FORWARD ROTATION?
No
Yes
S150
ROTATE DEFLECTION MEMBER BY A DETERMINED CONSTANT ANGLE (e.g., 1 DEGREE) IN FORWARD DIRECTION
S160
ROTATE DEFLECTION MEMBER BY A DETERMINED CONSTANT ANGLE (e.g., 1 DEGREE) IN BACKWARD DIRECTION
S170
ROTATION OF DEFLECTION MEMBER BY A GIVEN ROTATION RANGE (e.g., 180 DEGREES)?
Yes
No
S180
PERFORM SWITCHOVER BETWEEN FORWARD AND BACKWARD ROTATING DIRECTIONS

FIG. 17

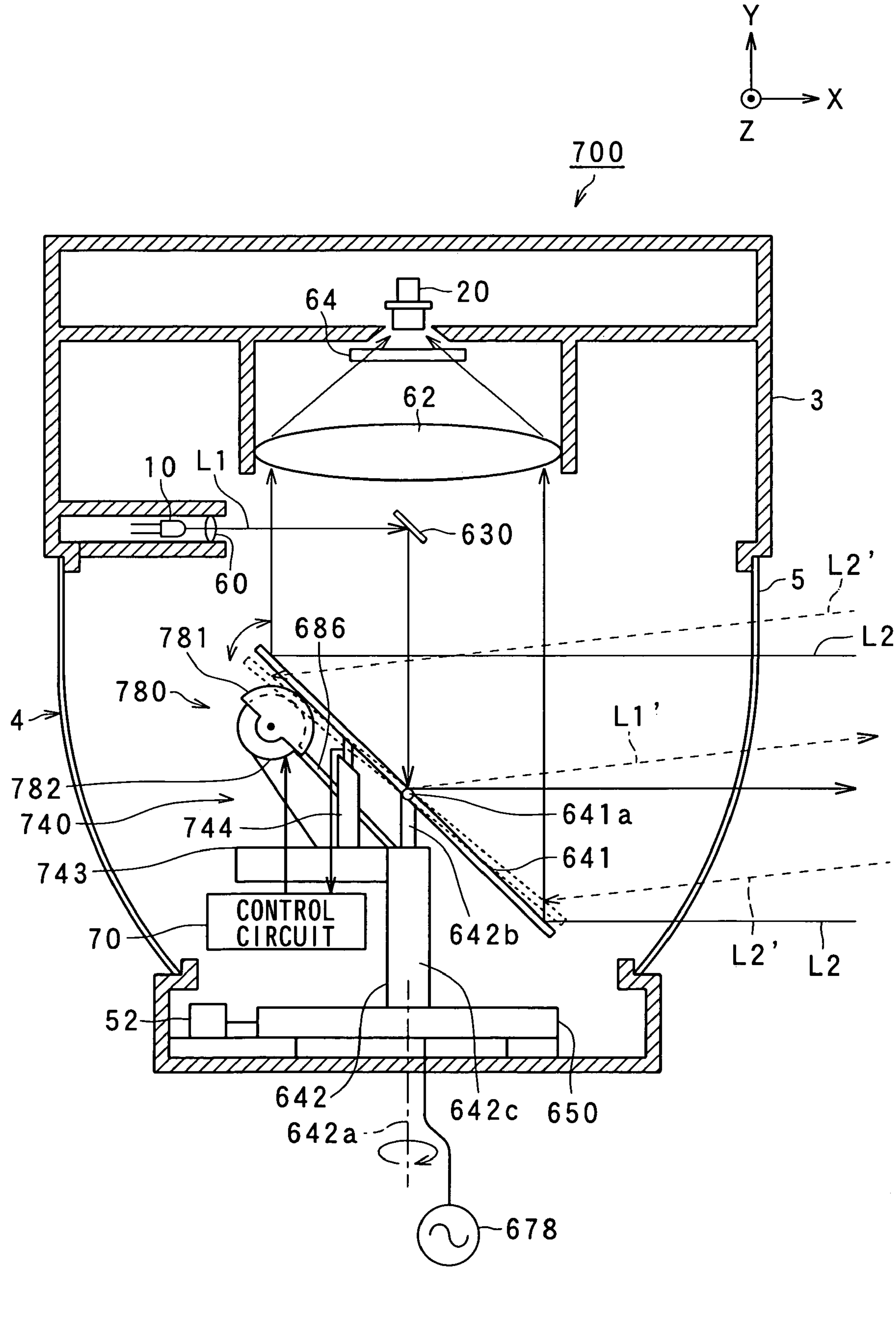

Y
X
Z
700
20
64
62
3
10
L1
630
60
5
L2'
L2
686
781
780
4
L1'
782
641a
740
744
641
743
CONTROL CIRCUIT
70
642b
L2'
L2
52
642
642c
650
642a
678

FIG.18A

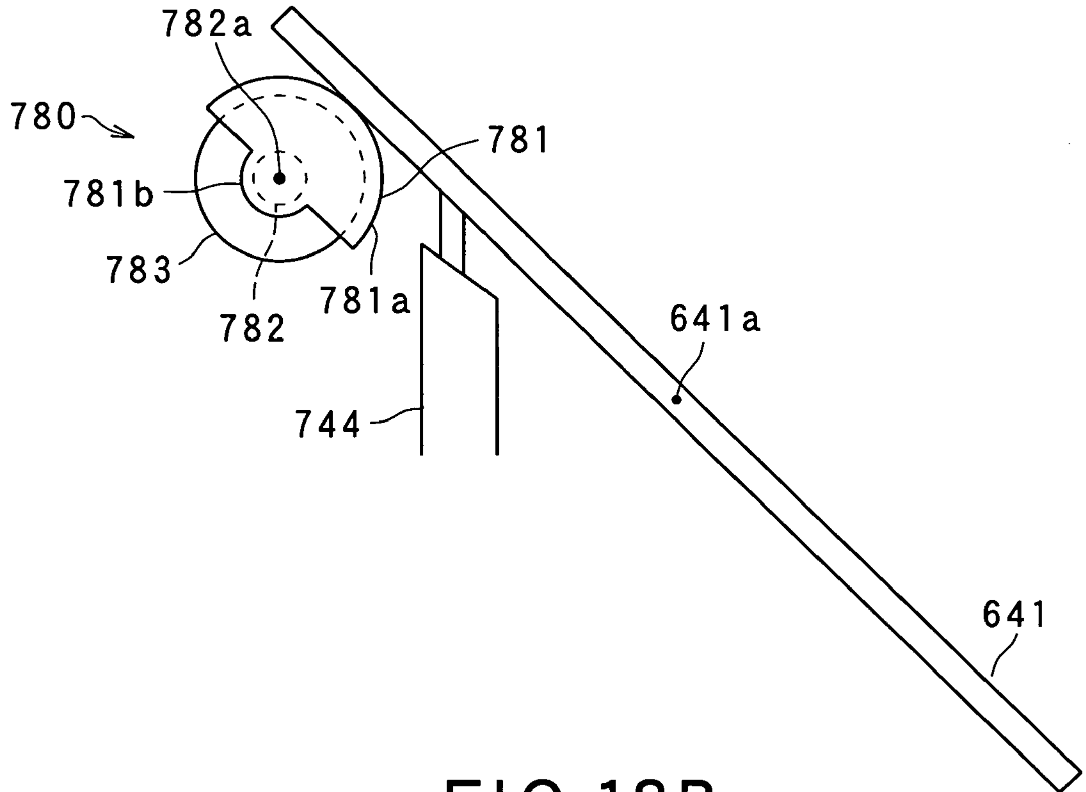


FIG.18B

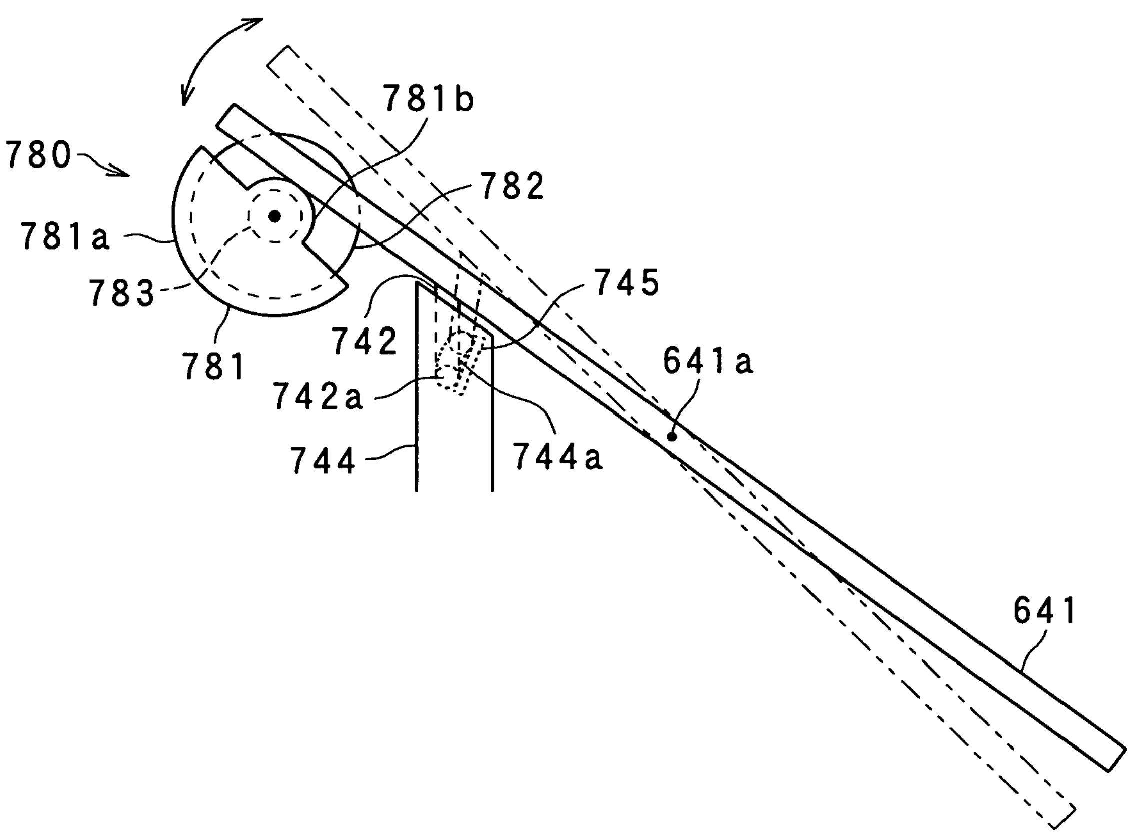


FIG. 19

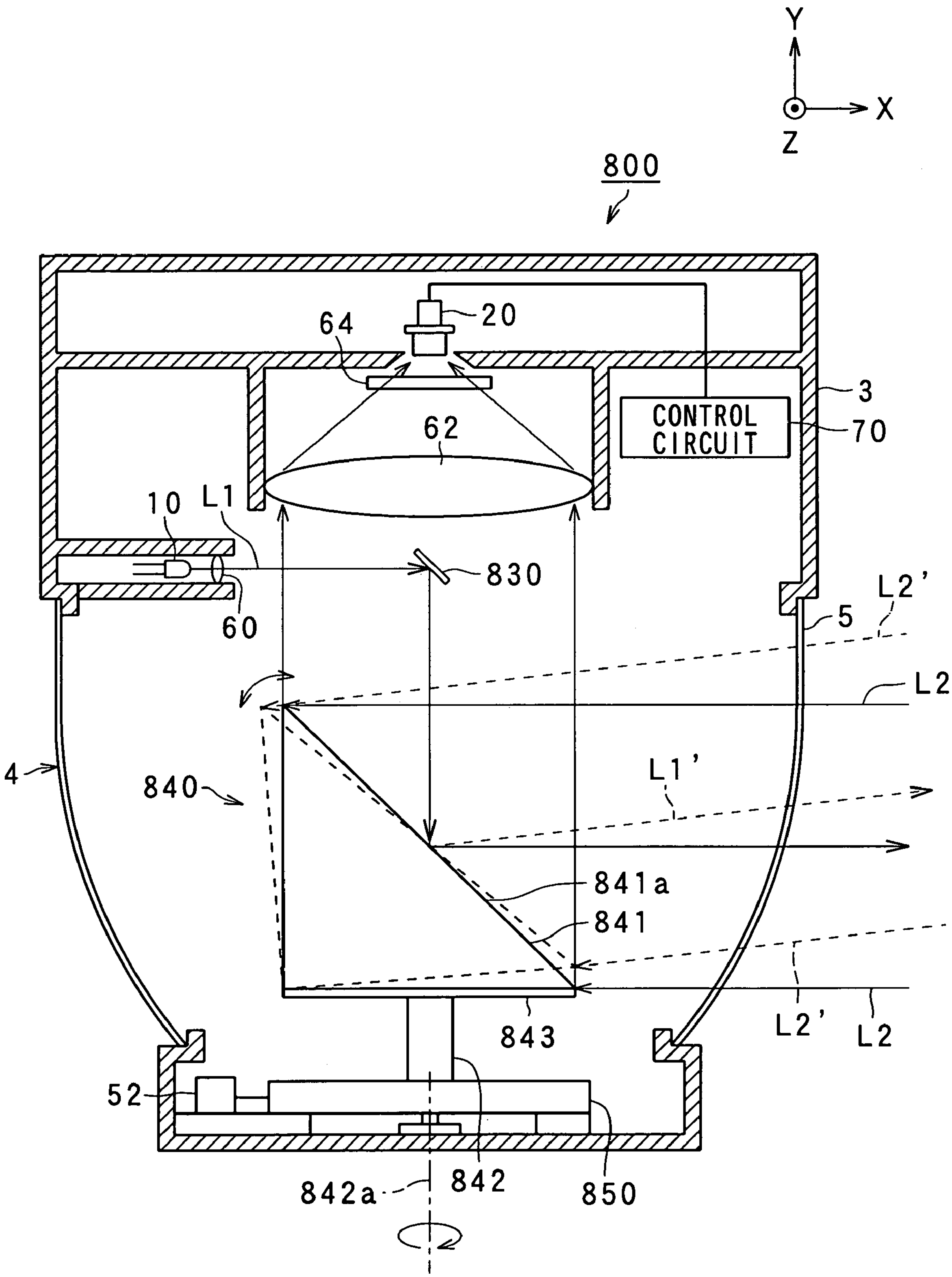

Y
X
Z
800
20
64
3
62
CONTROL CIRCUIT
70
10
L1
830
60
5
L2'
L2
4
840
L1'
841a
841
843
L2'
L2
52
842a
842
850

FIG. 20

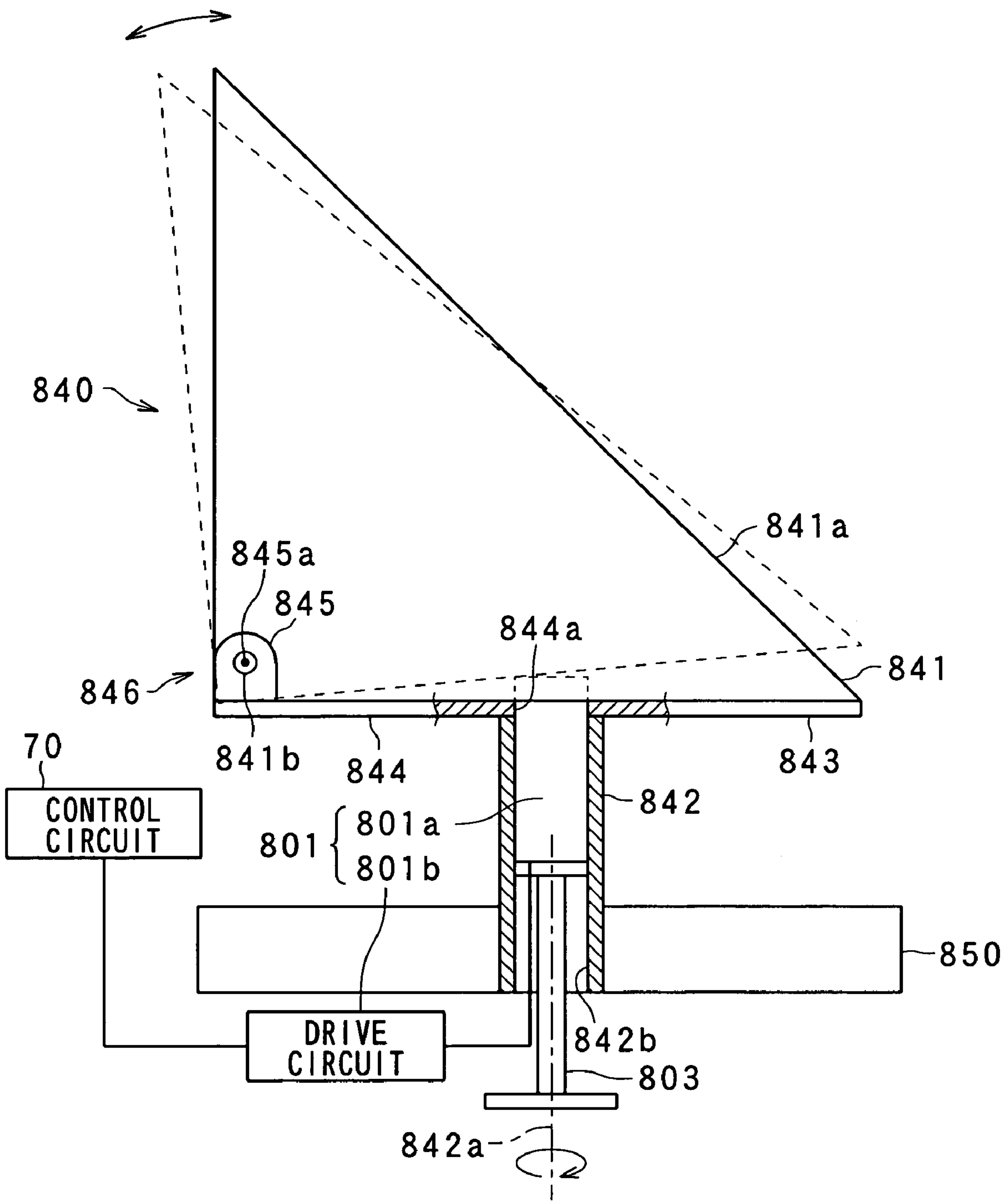

840
841a
845a
845
844a
841
846
70
841b
844
843
CONTROL CIRCUIT
842
801
801a
801b
850
DRIVE CIRCUIT
842b
803
842a

FIG. 21

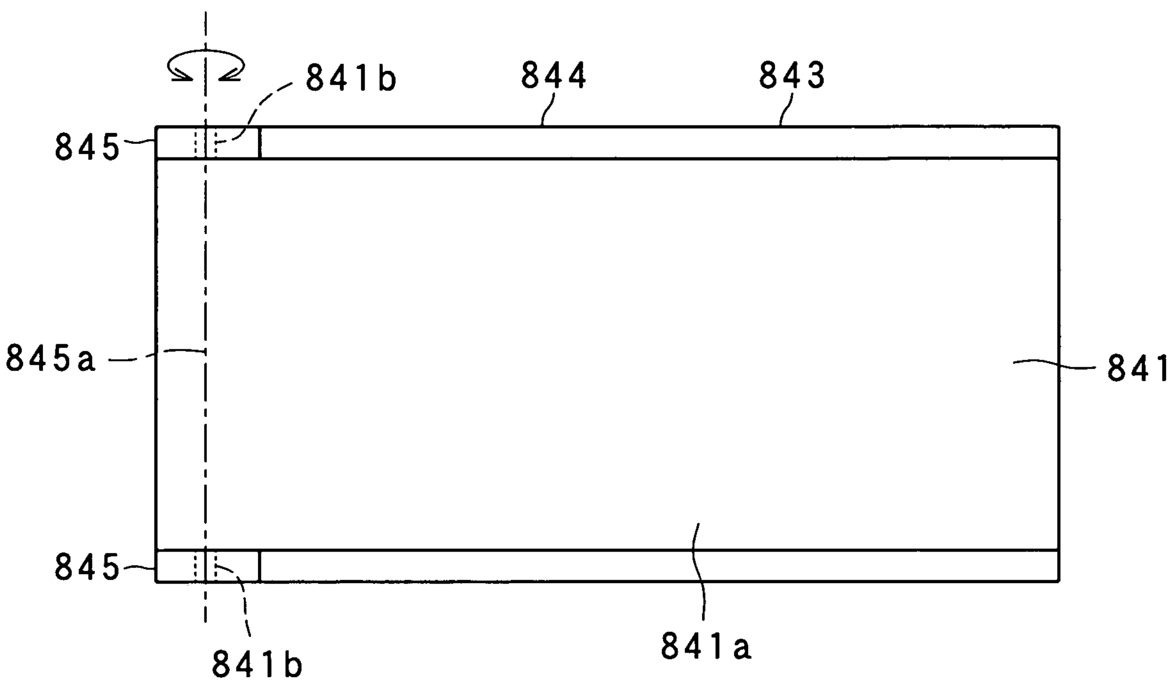
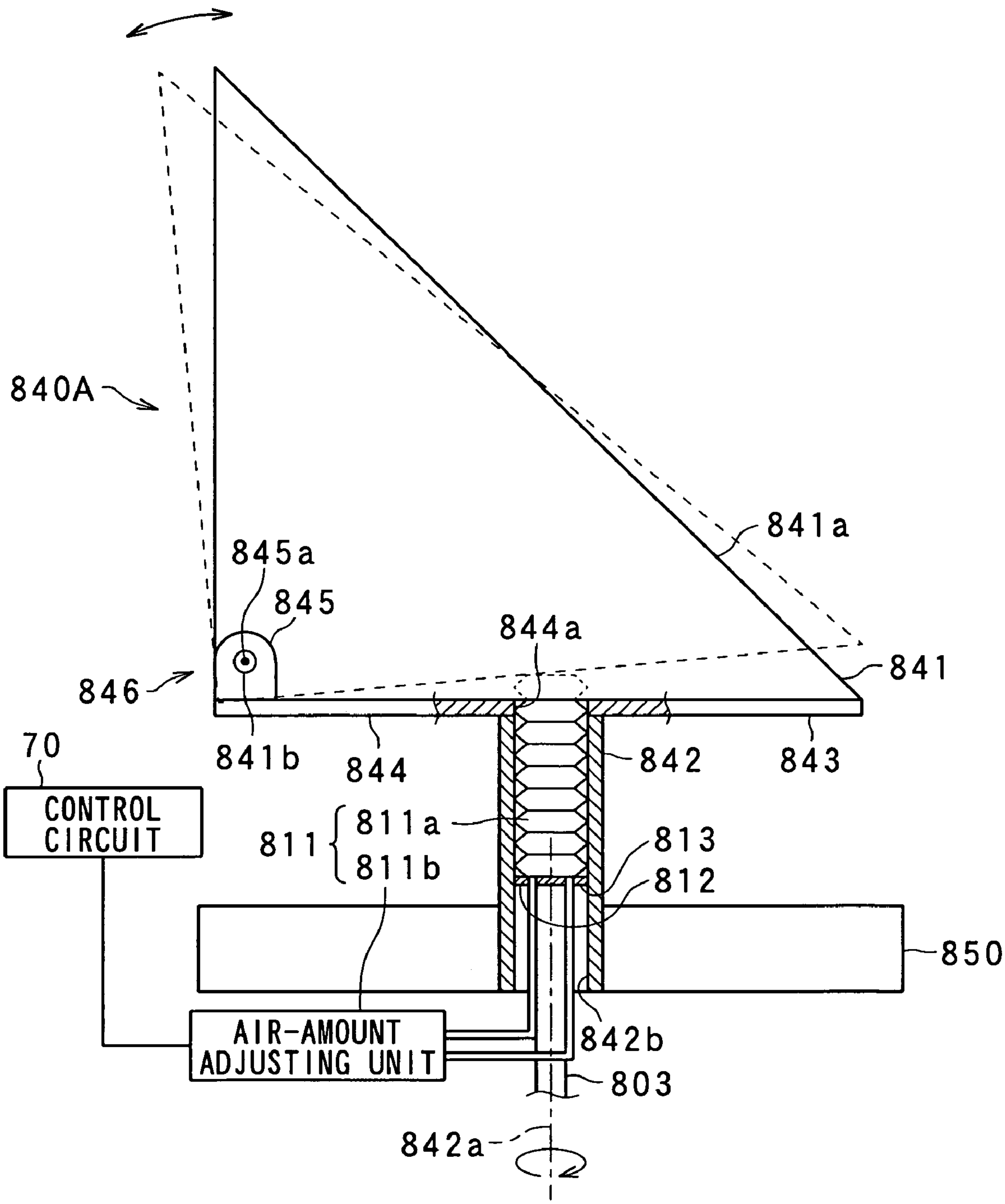


FIG. 22



840A
845a
845
846
841a
844a
841
841b
844
842
843
70
CONTROL CIRCUIT
811
811a
811b
813
812
850
AIR-AMOUNT ADJUSTING UNIT
842b
803
842a

FIG. 23

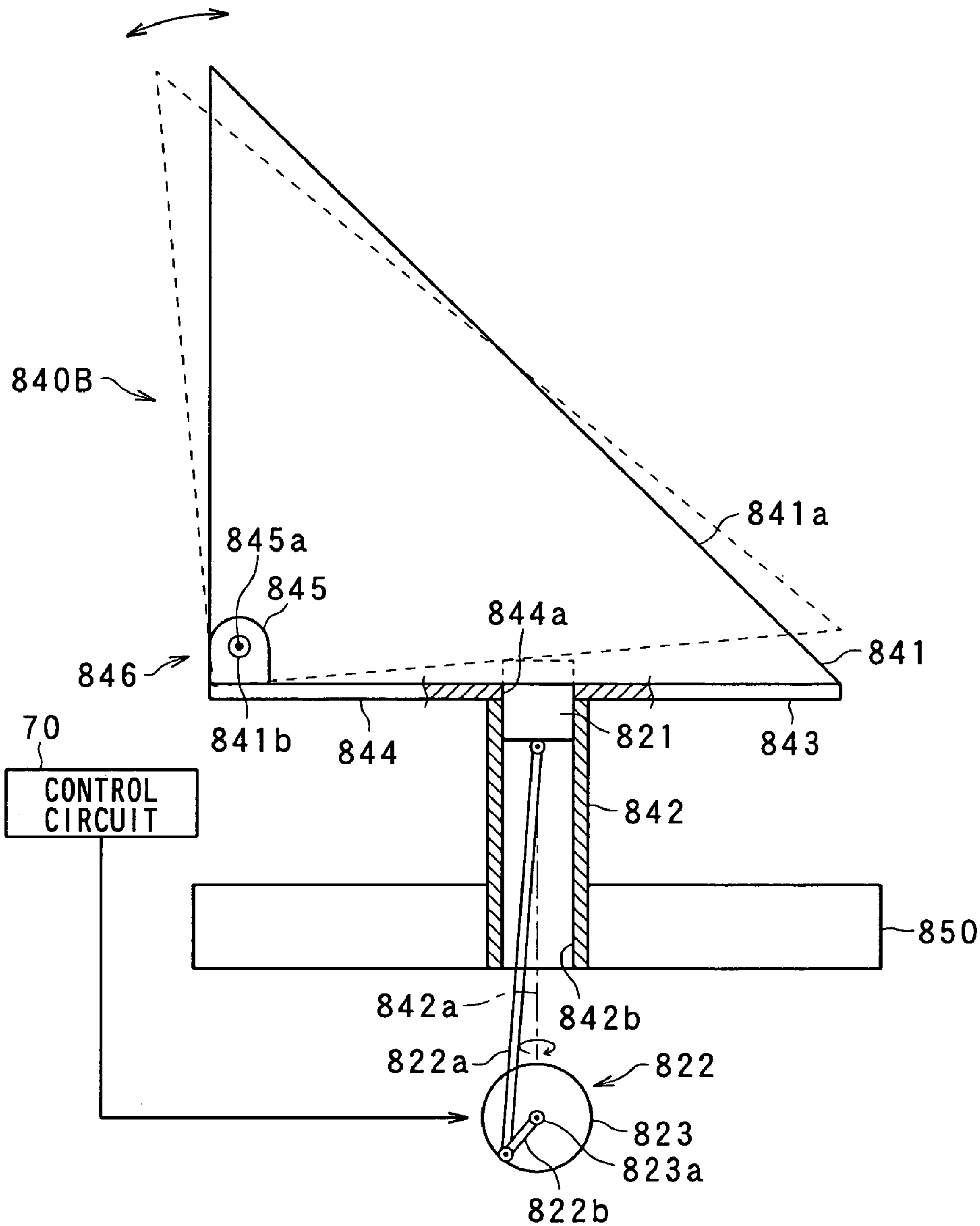

840B
841a
845a
845
844a
841
846
841b
844
821
843
70
CONTROL CIRCUIT
842
850
842a
842b
822a
822
823
823a
822b

FIG. 24

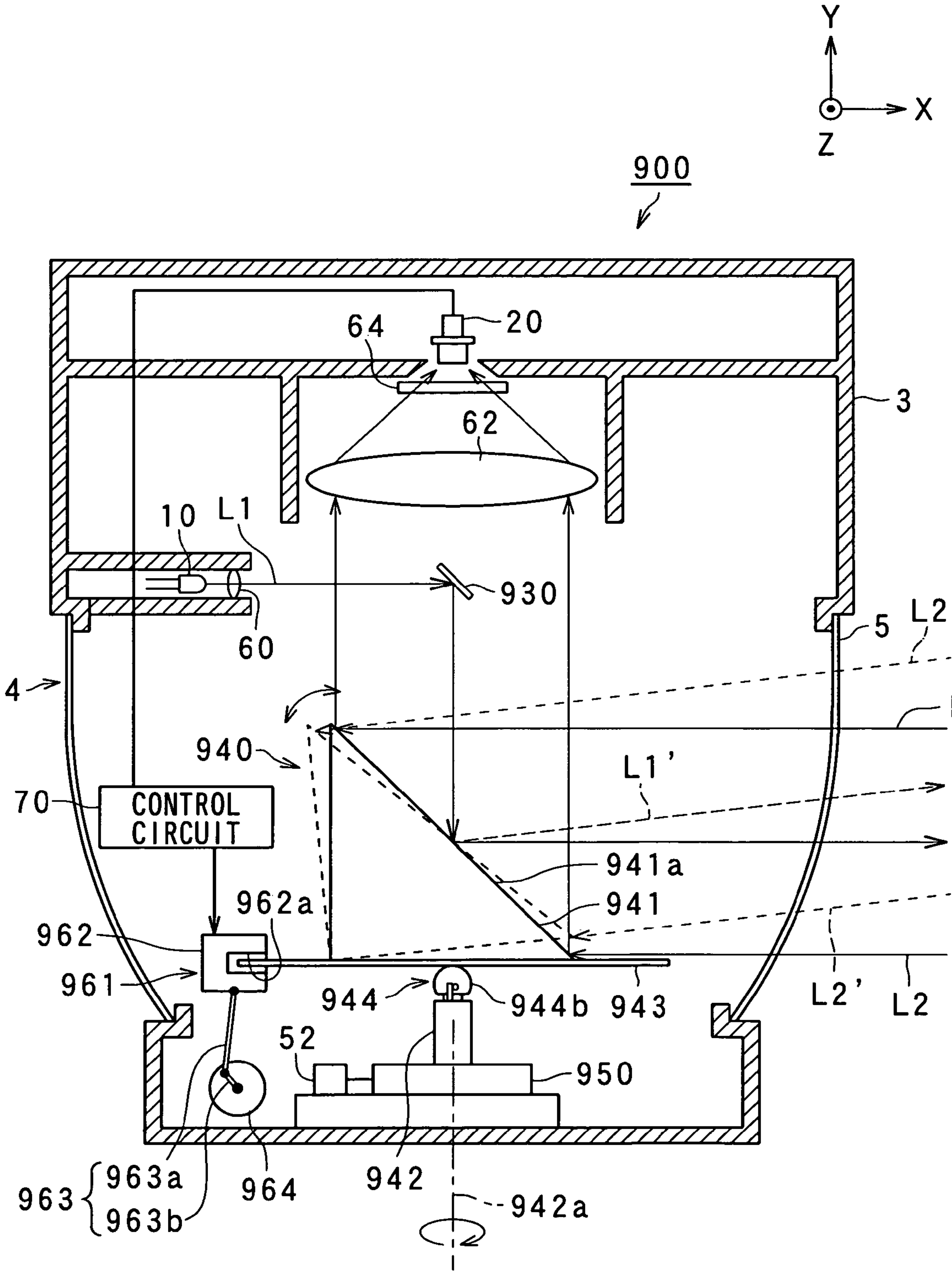

Y
X
Z
900
64
20
3
62
10
L1
930
60
5
L2'
4
L2
940
L1'
70
CONTROL CIRCUIT
941a
962a
941
962
961
944
944b
943
L2'
L2
52
950
963
963a
963b
964
942
942a

FIG. 25A

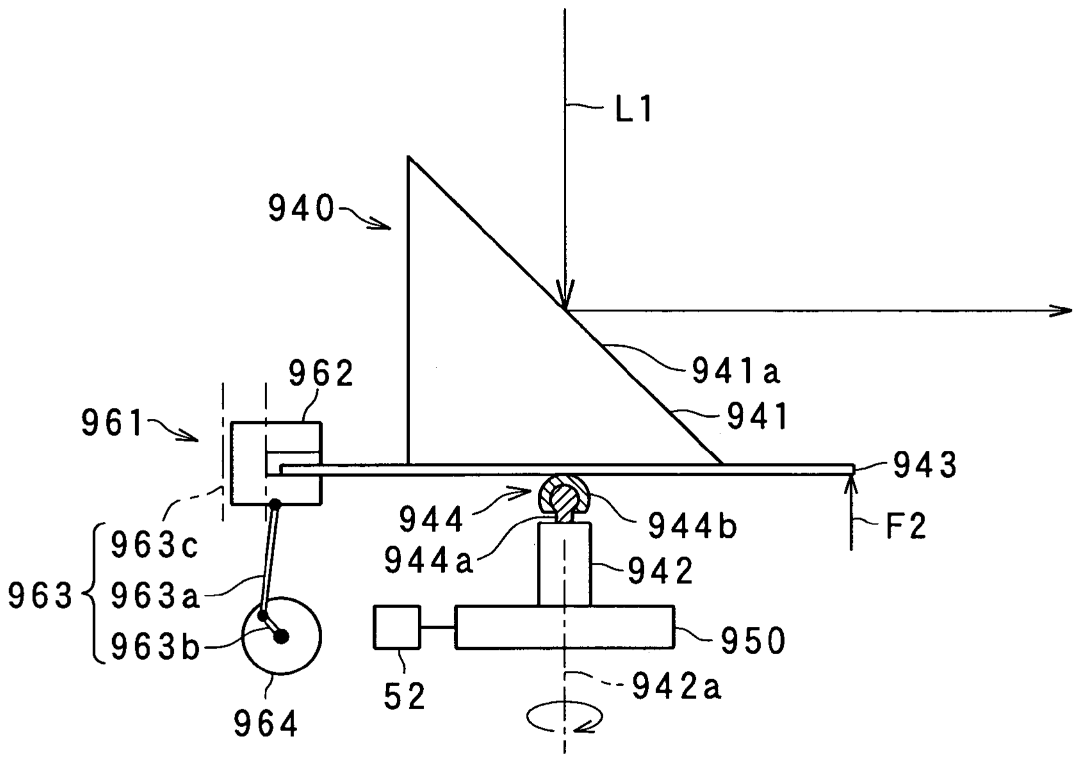


FIG. 25B

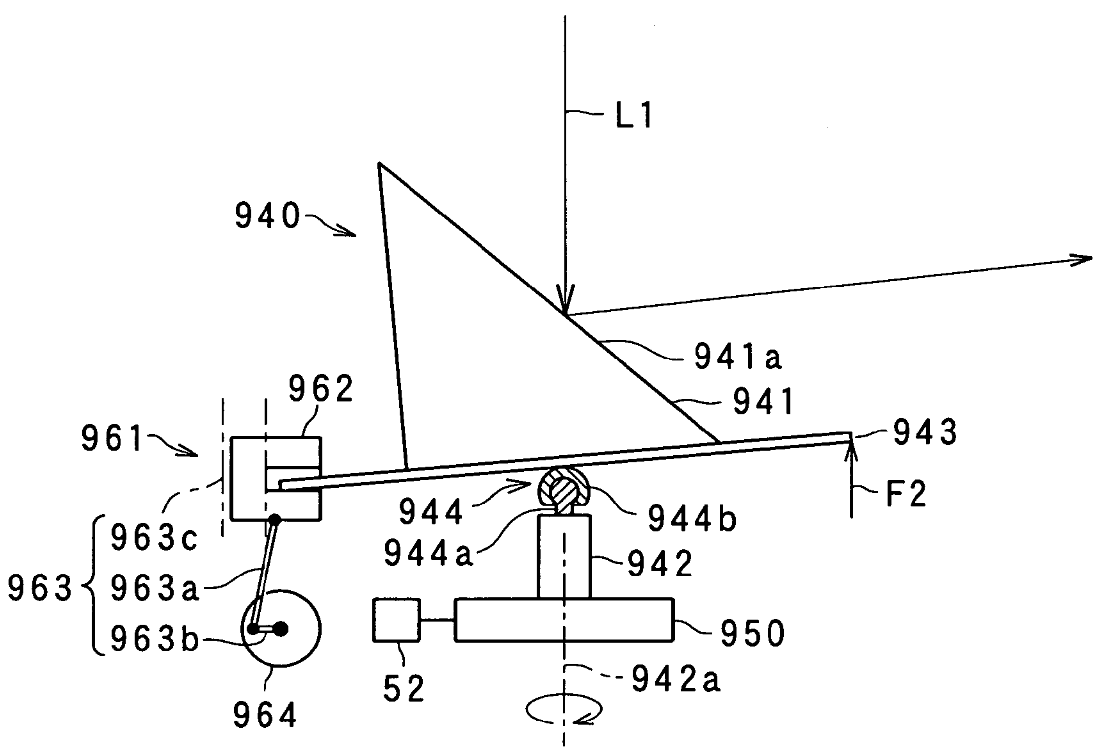


FIG. 26A

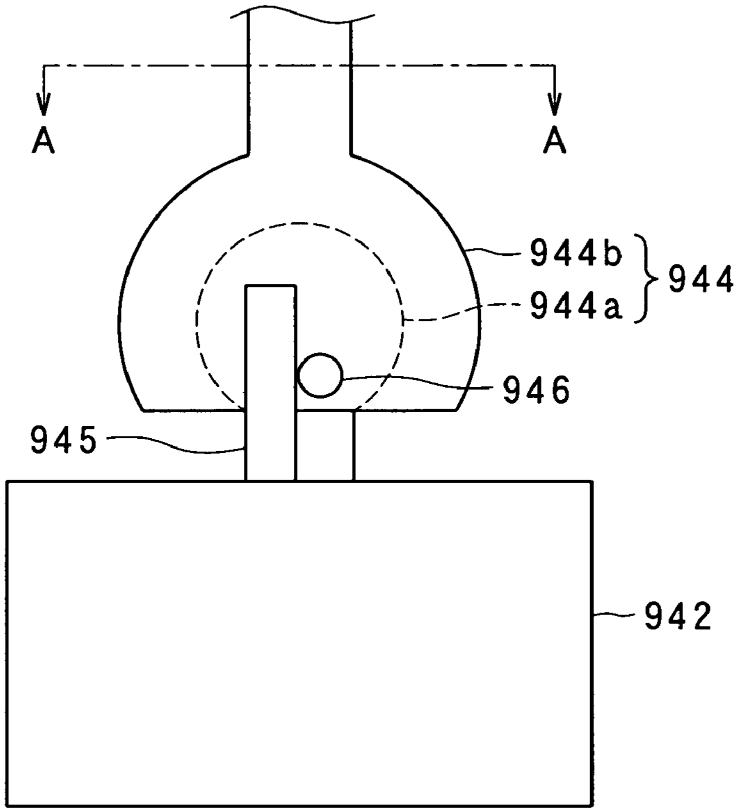


FIG. 26B

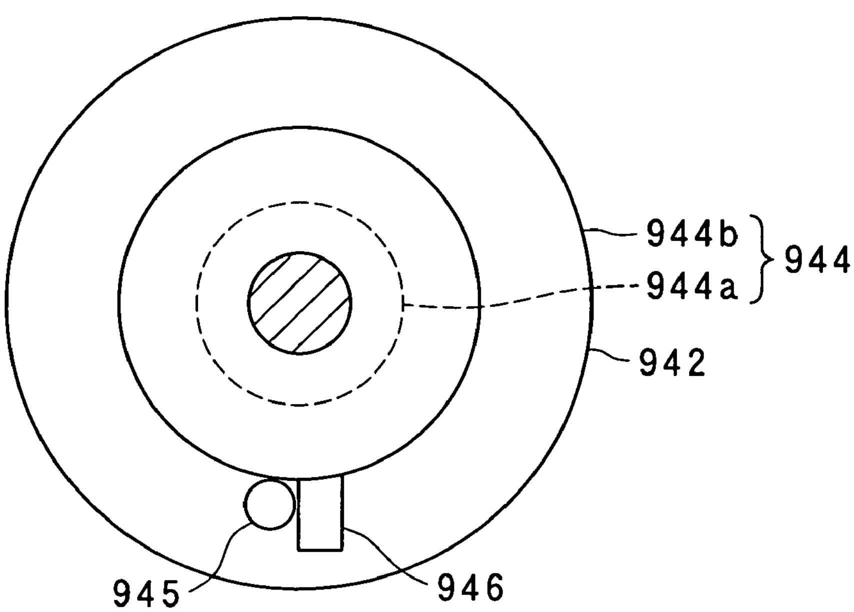


FIG. 27A

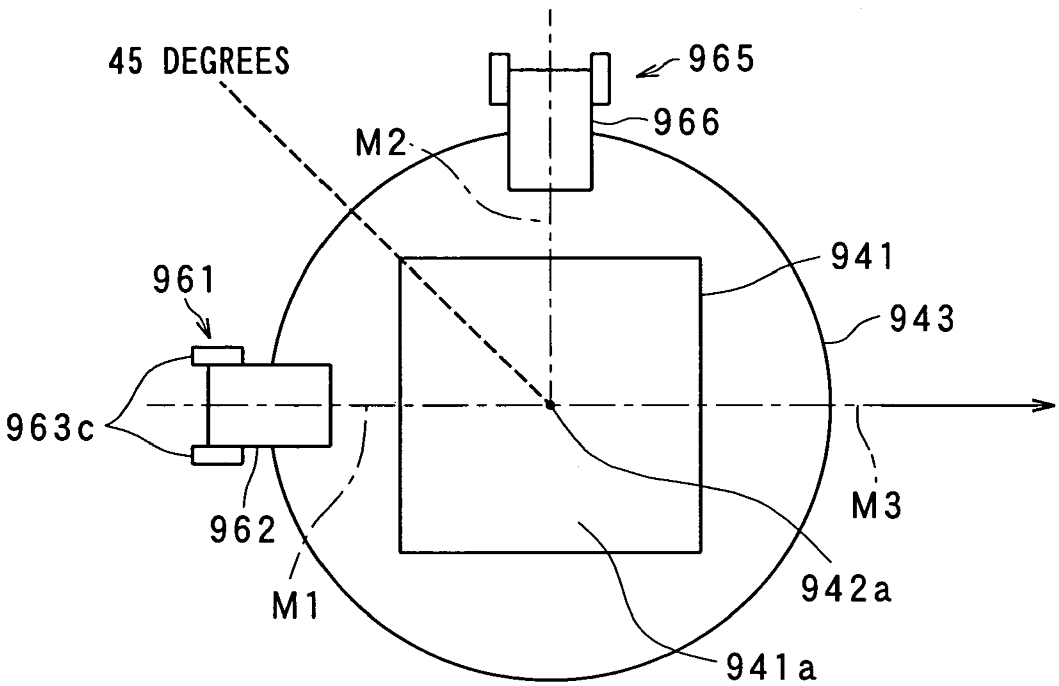


FIG. 27B

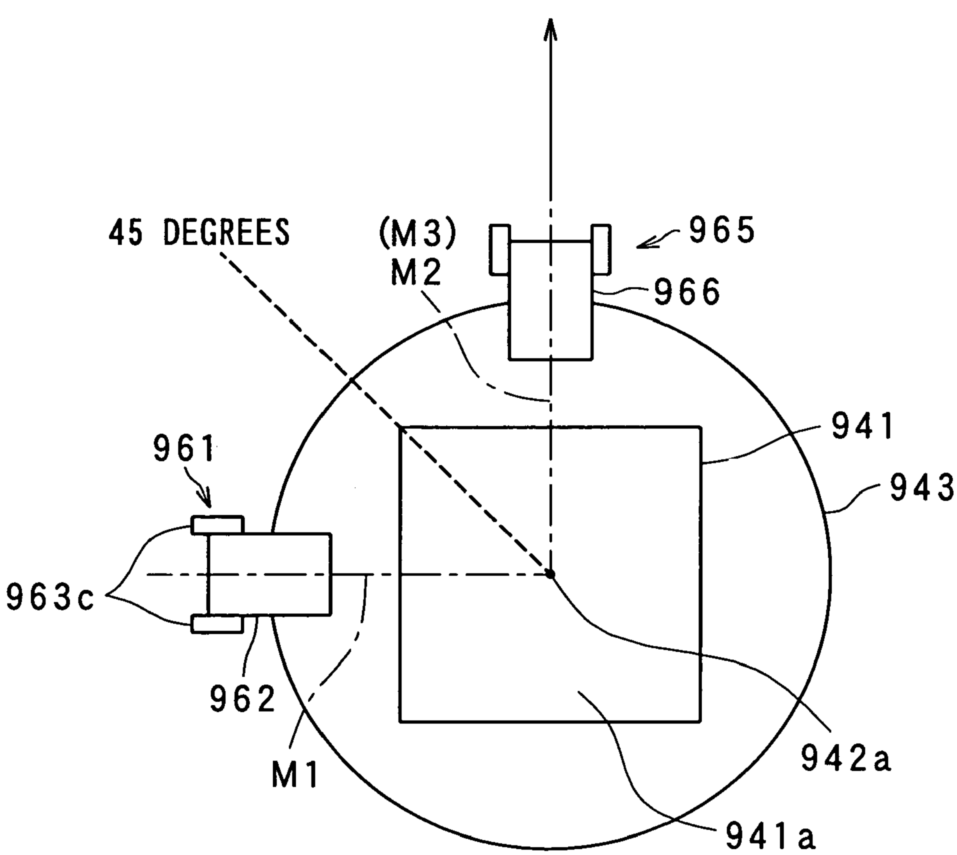


FIG. 28

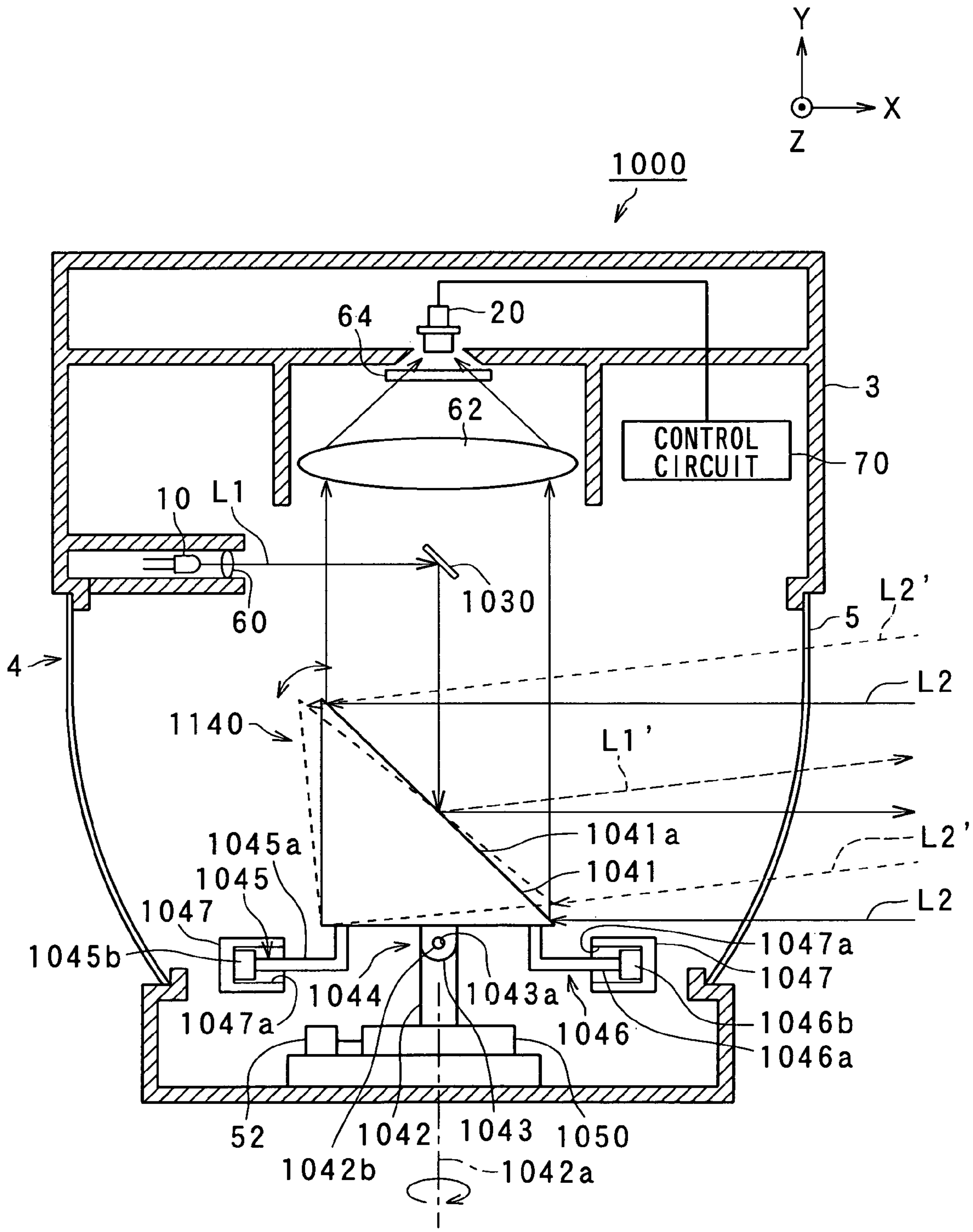

Y
X
Z
1000
64
20
3
62
CONTROL CIRCUIT
70
10
L1
1030
60
L2'
5
4
L2
1140
L1'
1041a
1045a
1045
1041
L2'
1047
L2
1045b
1047a
1047
1044
1043a
1047a
1046
1046b
1046a
52
1042
1043
1050
1042b
1042a

FIG. 29

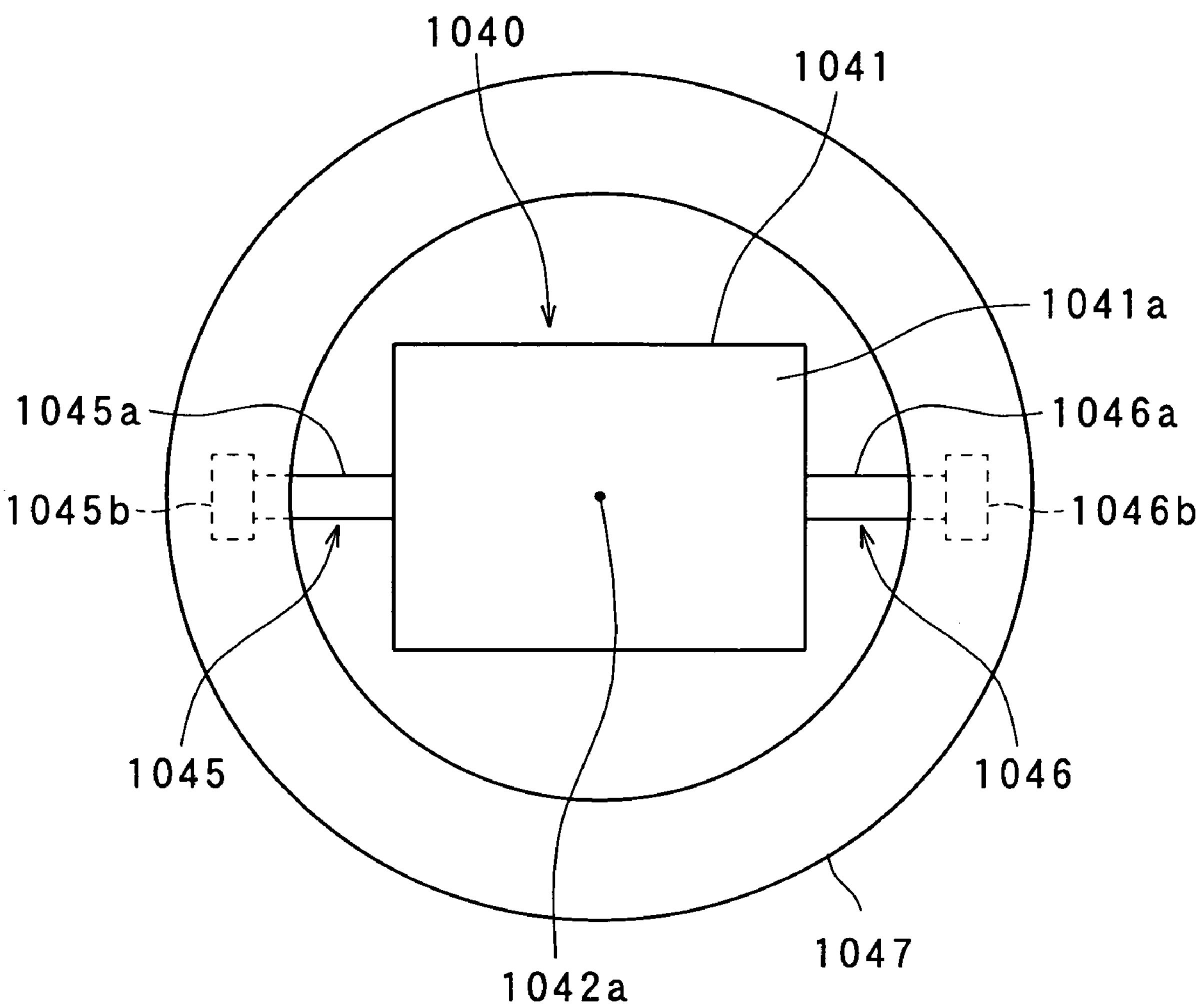

1040
1041
1041a
1045a
1046a
1045b
1046b
1045
1046
1047
1042a

FIG. 30

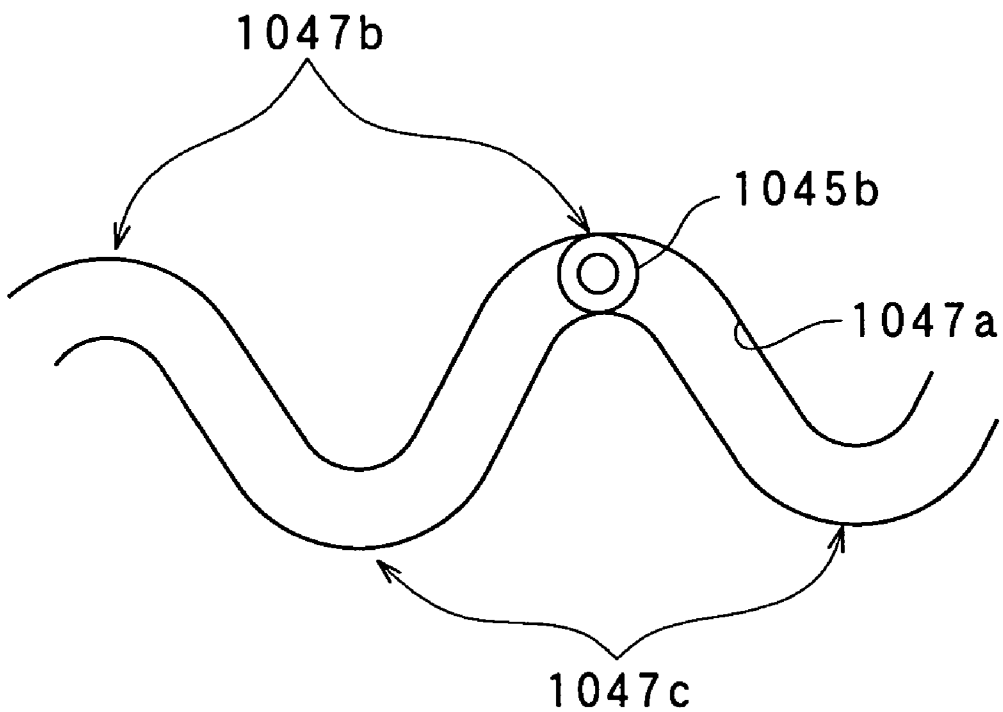


FIG. 31

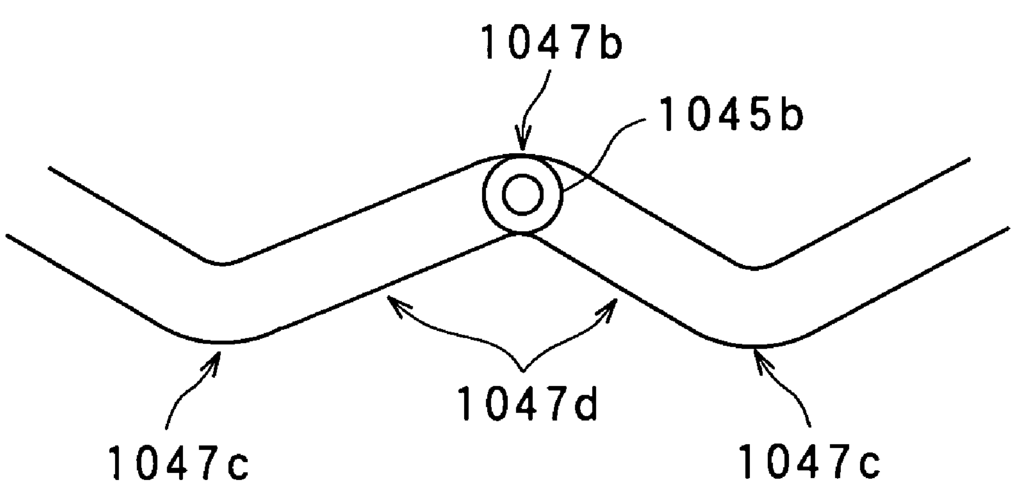
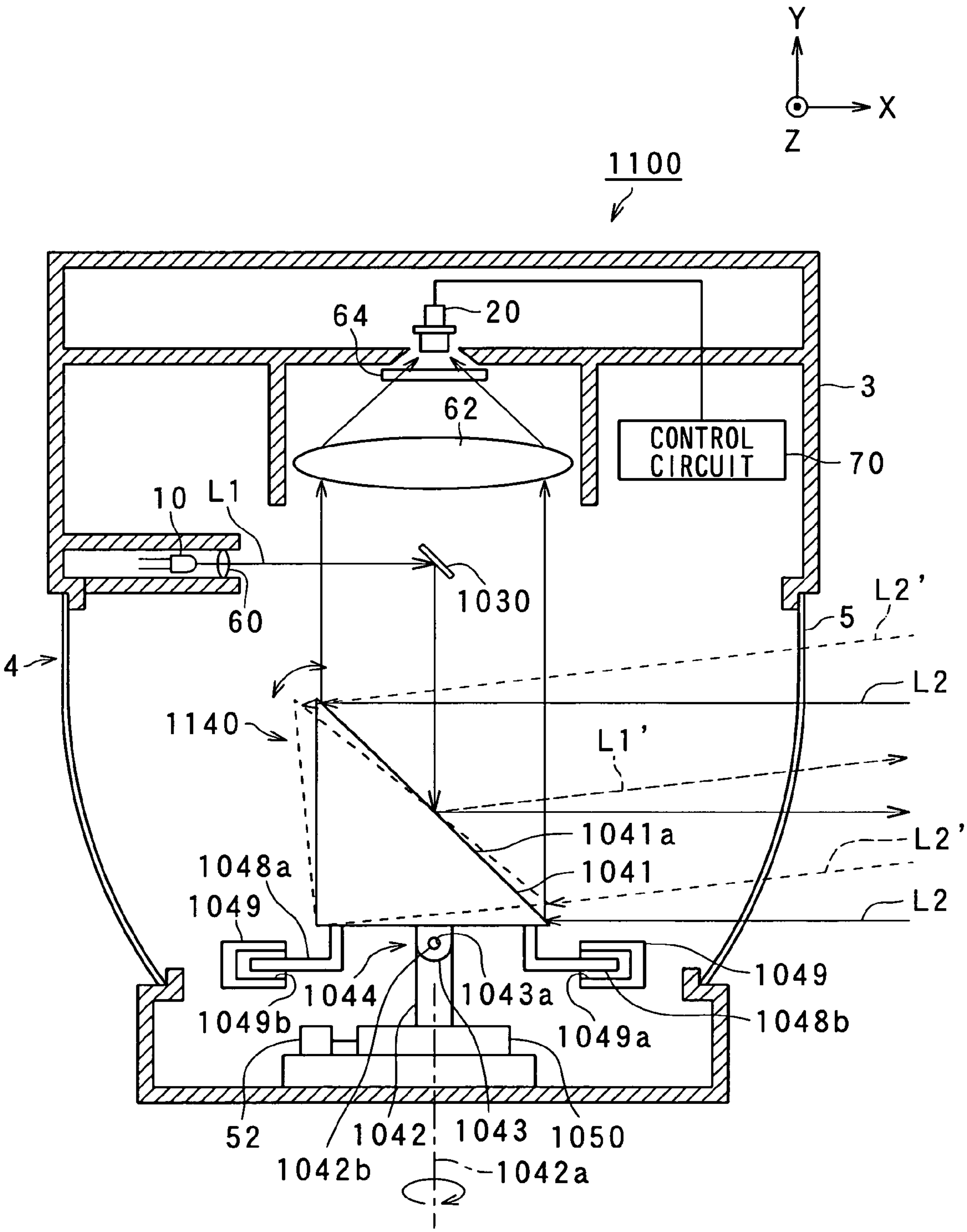
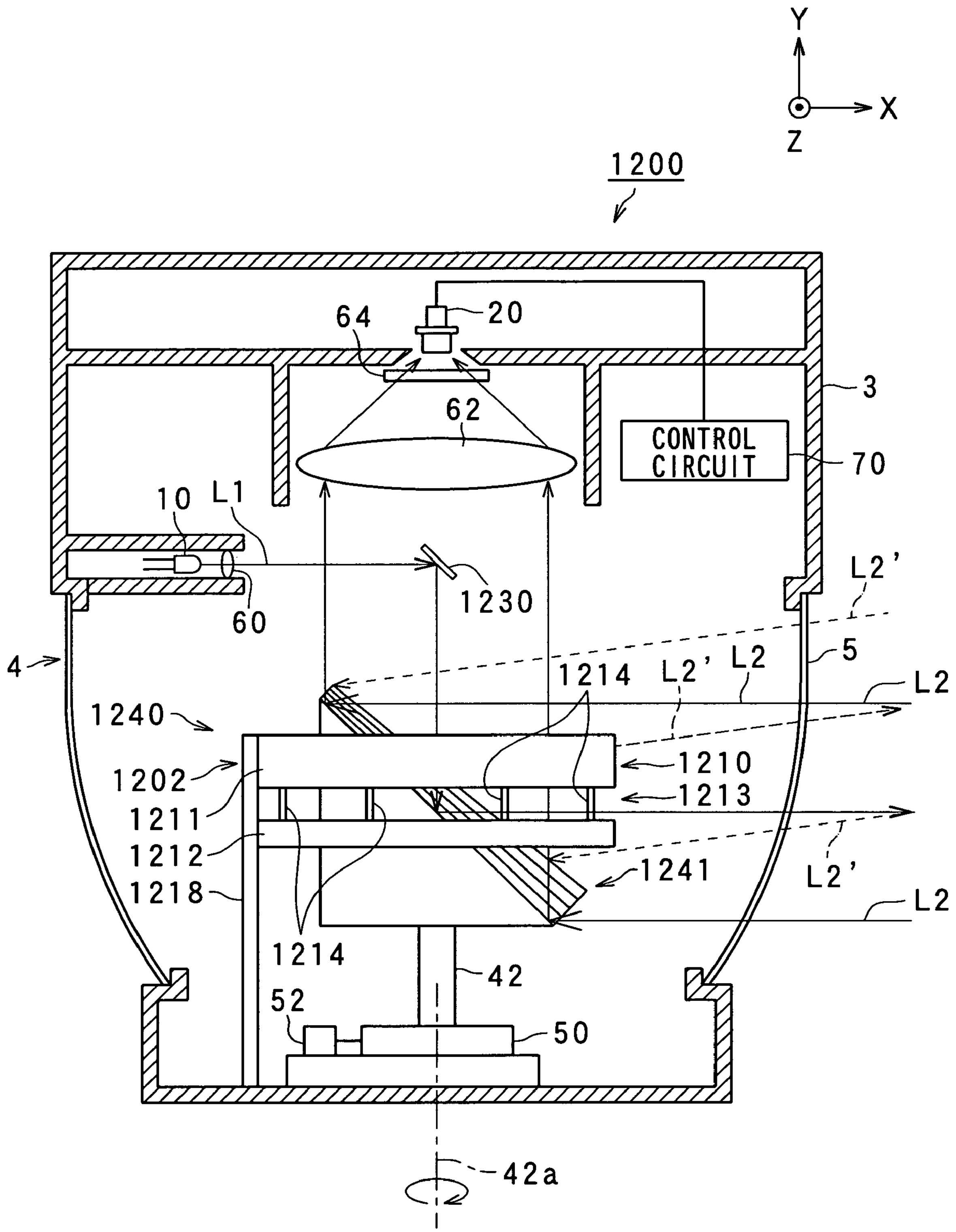


FIG. 32



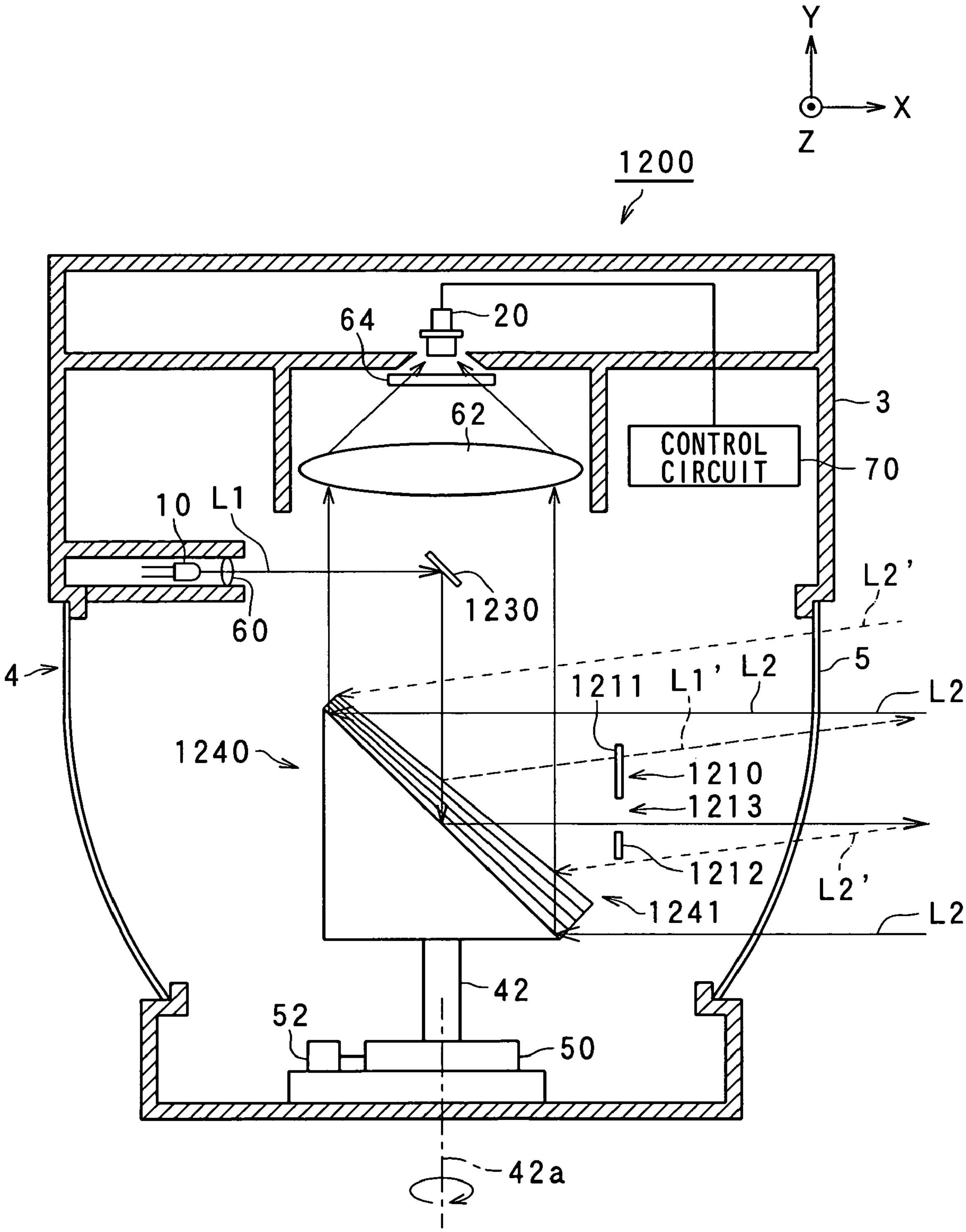
Y
X
Z
1100
64
20
3
62
CONTROL CIRCUIT
70
10
L1
60
1030
4
5
L2'
L2
1140
L1'
1041a
1048a
1041
L2'
1049
L2
1044
1043a
1049
1049b
1048b
1049a
52
1042
1043
1050
1042b
1042a

FIG. 33



Y
X
Z
1200
64
20
3
62
CONTROL CIRCUIT
70
10
L1
1230
60
L2'
4
5
1214
L2' L2
L2
1240
1202
1210
1211
1213
1212
1218
1241
L2'
L2
1214
42
52
50
42a

FIG. 34


Y
X
Z
1200
64
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3
62
CONTROL
CIRCUIT
70
10
L1
1230
60
L2'
4
5
1211
L1'
L2
L2
1240
1210
1213
1212
L2'
1241
L2
42
52
50
42a

FIG. 35

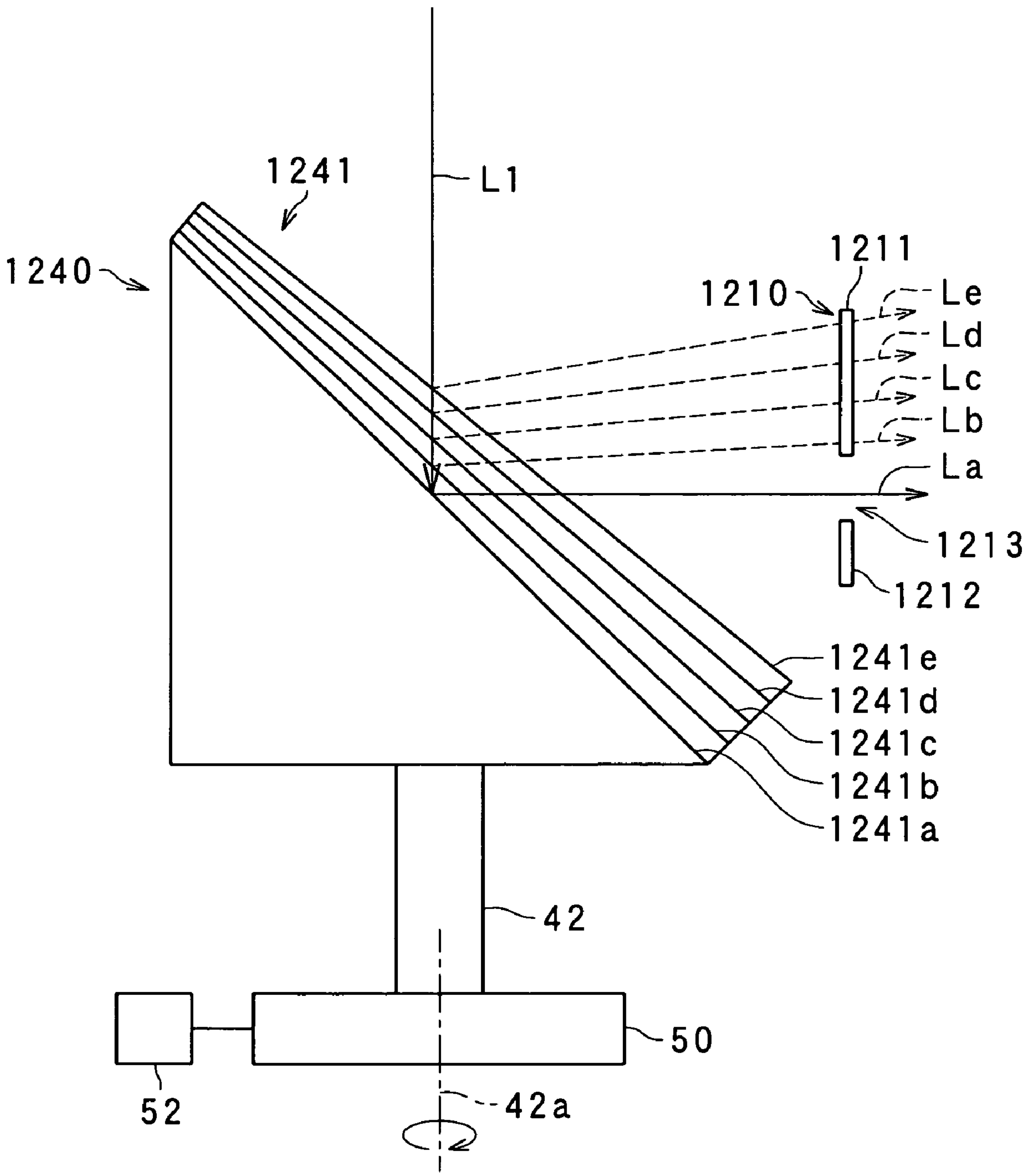

1241
L1
1240
1211
1210
Le
Ld
Lc
Lb
La
1213
1212
1241e
1241d
1241c
1241b
1241a
42
50
52
42a

FIG. 36A

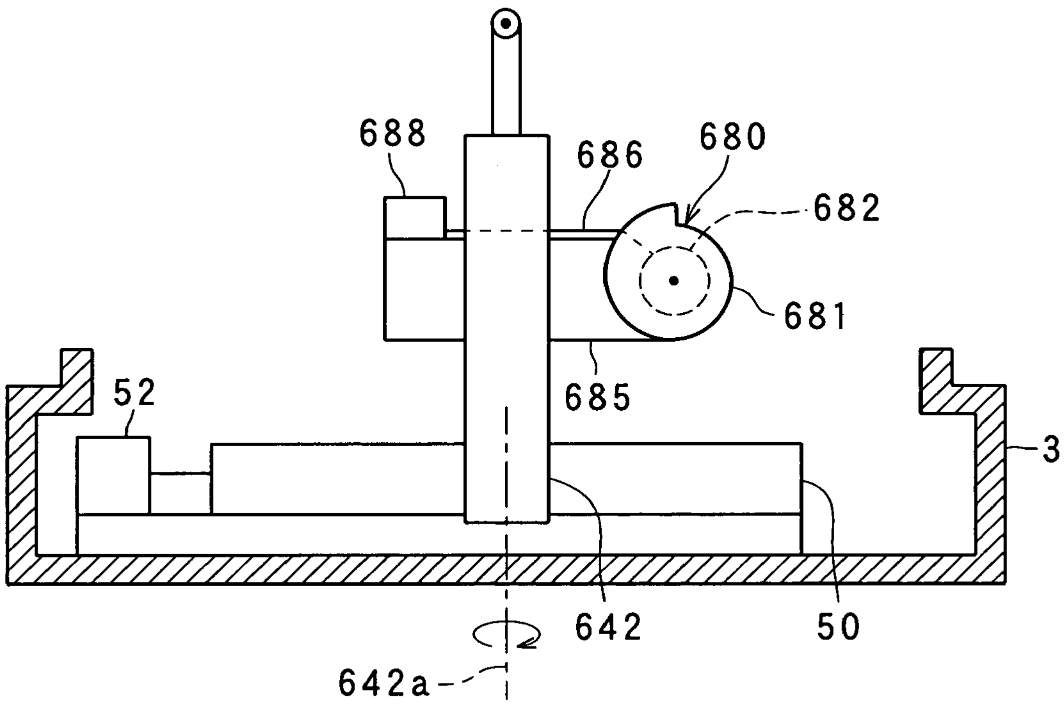
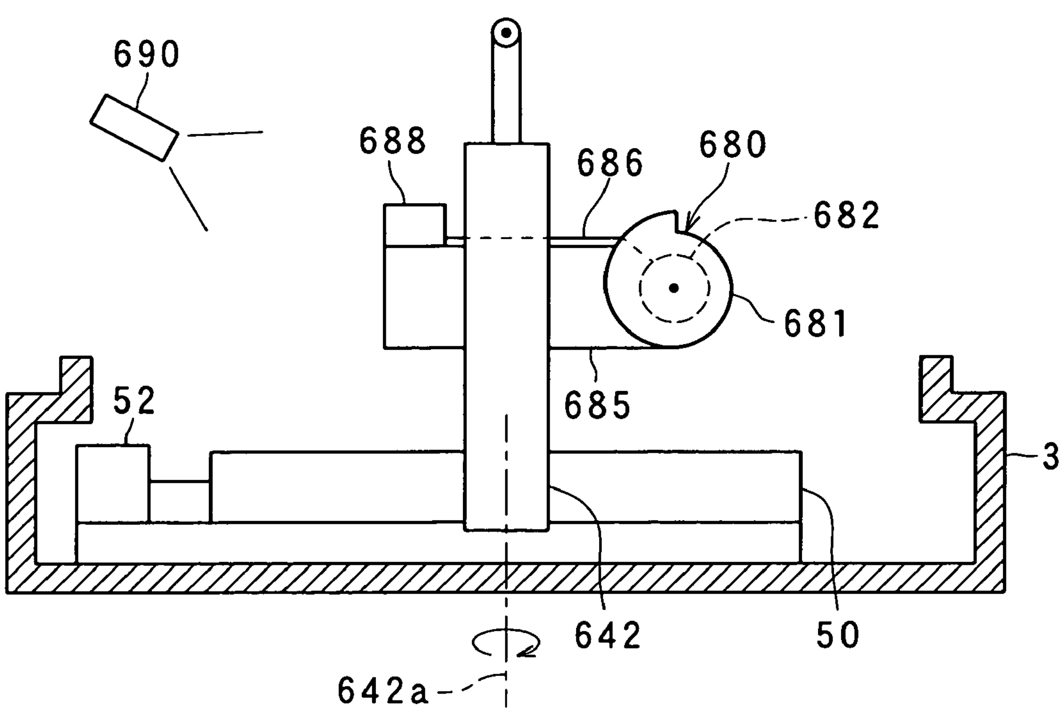


FIG. 36B



LASER RADAR APPARATUS FOR THREE-DIMENSIONAL DETECTION OF OBJECTS

CROSS REFERENCE TO RELATED APPLICATION

The present application relates to and incorporates by reference Japanese Patent application Nos. 2007-49970 filed on Feb. 28, 2007, 2007-248987 filed on Sep. 26, 2007, and 2007-316979 filed on Dec. 7, 2007.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a laser radar apparatus, and in particular, to a laser radar apparatus that uses a laser beam to detect the distance and direction of an object to be detected.

2. Description of the Related Art

A conventional laser radar apparatus is disclosed by Japanese Patent Publication No. 2789741. The apparatus disclosed by this publication is provided with a laser beam generator, a detector, and an optical isolator through which the laser beam is transmitted. The laser beam generator generates a laser beam and the optical isolator is located on the optical axis of the laser beam from the generator to reflect a reflected light toward the detector that detects reflected light from an object to be detected. In addition, a concave mirror is located on the optical axis of the laser beam such that the concave mirror rotates on its central axis along the optical axis direction of the laser beam. This concave mirror reflects not only the incident laser beam into the air but also the reflected light from the object to be detected toward the isolator, so that horizontal scanning can be performed over 360 degrees.

However, in the case of the technique according to the above publication, the 360-degree horizontal scanning, which is performed by rotating the concave mirror, is confronted with a drawback. As described, the horizontal scanning over 360 degrees makes it possible to detect the whole surrounding of the apparatus by scanning the whole angular detection range (scanning range on the laser beam). However, there is a problem that the detection range is limited to a planer range. Specifically, the laser beam that has been reflected specially from the concave mirror is obliged to scan a given planar (scanned planar), resulting in that regions which are outside the scanned planar cannot be scanned. That is, if objects are shifted from the scanned planar, the objects cannot be detected. In addition, even when the objects exist in the scanned planar, it is impossible to grasp the presence of the objects in the three-dimensional manner.

SUMMARY OF THE INVENTION

The present invention has been made in consideration of the foregoing situations, and it is an object of the present invention to provide the laser radar apparatus that has the capability of three-dimensionally scanning the surrounding field outside the apparatus to detect objects in the field.

In order to achieve the above objects, as one aspect of the present invention, there is provided a laser radar apparatus comprising: a laser beam generator that generates a laser beam; an optical detector that detects reflected light that has been reflected by an object in a field to be observed; a deflection performing means, provided with one or more deflection means each rotatable on a given central axis thereof, for enabling the deflection means to deflect the laser beam to the field and to deflect the reflected light toward the optical detector; a drive means that driven to rotate the deflection means; a direction changing means that changes a direction of the laser beam from the deflection means is changed in a direction of the central axis; and a control means that controls an operation of the direction changing means.

It is preferred that the direction changing means consists of a light deflection means adapted to deflect the laser beam from the laser beam generator toward the deflection means and configured to be swingable (i.e., configured to be able to swing), and the control means consists of a swing control means that controls a swing action of the light deflection means.

As another mode of the present invention, there is provided a laser radar apparatus comprising: a laser beam generator that generates a laser beam; an optical detector that detects reflected light that has been reflected by an object in a field to be observed; a deflection performing means, provided with a deflection means each rotatable on a given central axis thereof, for enabling the deflection means to deflect the laser beam to the field and to deflect the reflected light toward the optical detector; a drive means that rotates and drives the deflection means; wherein the deflection means comprise a plurality of reflection layers laminated one on another at an incident position of the laser beam and produced to reflect the laser beam at different directions, wherein, of the reflection layers, reflection layers other than a lowest reflection layer performs reflection and transmission of the laser beam, a laser beam selecting means that selects only a one laser beam from laser beams reflected by the plurality of reflection layers, the selected one laser beam being emitted into the field for detection of the object, and a control means that controls a selection carried out by the laser beam selecting means so that the selected laser beam is scanned in a direction of the central axis.

It is preferred that the reflection layers other than the lowest reflection layer are formed as half-silvered mirrors.

It is also preferred that the laser beam selecting means comprises a pair of annular light-shielding members arranged around the deflection means to be located along the direction of the central axis with a given space apart from each other so as to produce a slit therebetween, and a displacement means that displaces the pair of annular light-shielding members together, wherein the control means includes means for controlling a displacement to be carried out by the displacement means.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

FIG. **1** is a schematic diagram outlining the configuration of a laser radar apparatus according to a first embodiment of the present invention;

FIG. **2** is a perspective view showing a displacement mechanism used in the first embodiment;

FIG. **3** is a schematic diagram outlining the configuration of a laser radar apparatus according to a second embodiment of the present invention;

FIG. **4** is a schematic diagram outlining the configuration of a laser radar apparatus according to a third embodiment of the present invention;

FIG. **5** is a schematic diagram outlining the configuration of a laser radar apparatus according to a fourth embodiment of the present invention;

FIG. **6** is a schematic diagram outlining the configuration of a laser radar apparatus according to a fifth embodiment of the present invention;

FIG. **7** is a side view showing a light deflection member used in the fifth embodiment;

FIG. **8**A shows how to drive a mirror;

FIG. **8**B shows the mirror on which piezoelectric actuators are mounted;

FIG. **9** is a flowchart performed by a control circuit used in the fifth embodiment;

FIG. **10** is a schematic diagram outlining the configuration of a laser radar apparatus according to a sixth embodiment of the present invention;

FIGS. **11**A and **11**B show a light deflection member used in the sixth embodiment;

FIG. **12** is a flowchart performed by a control circuit used in the sixth embodiment;

FIG. **13** is a schematic diagram outlining the configuration of a laser radar apparatus according to a seventh embodiment of the present invention;

FIG. **14**A shows a deflection member used in the seventh embodiment;

FIG. **14**B shows a cam mechanism used in the seventh embodiment;

FIG. **15**A explains the operations of the deflection member and the cam mechanism;

FIG. **15**B is a sectional view showing wiring of a power line;

FIG. **16** is a flowchart performed by a control circuit used in the seventh embodiment;

FIG. **17** is a schematic diagram outlining the configuration of a laser radar apparatus according to an eighth embodiment of the present invention;

FIGS. **18**A and **18**B show the structures and operations a deflection member and an oscillation unit used in the eight embodiment;

FIG. **19** is a schematic diagram outlining the configuration of a laser radar apparatus according to a ninth embodiment of the present invention;

FIG. **20** explains a rotating deflection mechanism used in the ninth embodiment;

FIG. **21** is a plan view showing a deflection member;

FIG. **22** explains a rotating deflection mechanism according to a first modification of the ninth embodiment;

FIG. **23** explains a rotating deflection mechanism according to a second modification of the ninth embodiment;

FIG. **24** is a schematic diagram outlining the configuration of a laser radar apparatus according to a tenth embodiment of the present invention;

FIGS. **25**A and **25**B each explain the operations of a rotating deflection mechanism used in the tenth embodiment;

FIGS. **26**A and **26**B each explain a coupling mechanism by a side view and a sectional view, respectively;

FIGS. **27**A and **27**B each explain the rotation of a deflection member and the oscillating operations to the deflection member;

FIG. **28** is a schematic diagram outlining the configuration of a laser radar apparatus according to an eleventh embodiment of the present invention;

FIG. **29** is a plan view explaining the rotation of a deflection member and the guide for the rotation;

FIG. **30** explains a guide passage used in the eleventh embodiment;

FIG. **31** explains a guide passage according to a modification of the eleventh embodiment;

FIG. **32** is a schematic diagram outlining the configuration of a laser radar apparatus according to another modification of the eleventh embodiment;

FIG. **33** is a schematic diagram outlining the configuration of a laser radar apparatus according to a twelfth embodiment of the present invention;

FIG. **34** explains the laser beam emission and the reflected light reception in the twelfth embodiment;

FIG. **35** explains the selection of the laser beam to be emitted toward a field to be observed; and

FIGS. **36**A and **36**B each show modifications of wiring of the power line.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, referring to the accompanying drawings, preferred embodiments of the present invention will now be described.

First Embodiment

Referring to FIGS. **1** and **2**, a laser radar apparatus **1** according to a first embodiment of the present invention will now be described.

FIG. **1** outlines the configuration of the laser radar apparatus **1** according to the first embodiment.

As shown in FIG. **1**, the laser radar apparatus **1** is provided with a casing **3** and is configured to detect the distance from the object and the direction of the object. In the casing **3**, there are provided a laser diode **10** and a photodiode **20** receiving reflected light L**2** from an object to be detected. The laser diode **10** serves as one example of the laser beam generator and is configured to emit a pulsed laser beam L**1** in response to a pulsed current supplied from a not-shown drive circuit. The photodiode **20** serves as one example of the optical detector and is configured to detect the reflected light L**2** of the laser beam L**1**, which is reflected by the objects to be detected, and convert the reflected light L**2** into an electric signal. The reflected light L**2** from the object is composed of light taken from a predetermined angular range. In the example shown in FIG. **1**, the laser beam L**1** is emitted to pass along a path shown by the solid lines, so that the light taken between two lines L**2** composes the reflected light.

As shown in FIG. **1**, a lens **60** is arranged at a position on the optical axis of the laser beam L**1**. This lens **60** is composed of a collimation lens and converts the laser beam L**1** from the laser diode **10** into a collimated light.

On the optical path of the laser beam L**1** from the lens **60**, a swing mirror **31** is arranged which serves as the light deflection means. This swing mirror **31**, which corresponds to one example of the direction changing means, is configured to be swingable and to deflect the laser beam L**1** from the laser diode **10** toward a rotating deflection mechanism **40**. This swing mirror **31** changes the incident angle of the laser beam to a deflection member **41**, so that the direction of the laser beam from the deflection member **41** can be changed in the direction of a central axis **42***a*.

The swing mirror **31** is driven by a mirror driver based on multiple degrees of freedom. This kind of drive technique is known and can be achieved by using for example a galvanomirror, so that a detailed explanation for this technique is omitted here, but an outlined explanation is as follows. The mirror driver can be realized by employing a configuration where the swing mirror **31** is supported by for example a gimbal or a pivot bearing so as to allow the swing mirror **31** to rotate.

FIG. **2** exemplifies the swing mirror **31**, in which a displacement mechanism **33** for displacing the swing mirror **31** is shown. The displacement mechanism **33** is provided with a frame (not shown) arranged at a given location in the casing **3** and a mirror support frame **34** rotatably supported on this frame. The swing mirror **31** is supported by the mirror support frame **34** in such a manner that the swing mirror **31** is able to rotate on each of two directions consisting of a first axis **33***a* and a second axis **33***b* perpendicular to the first axis **33***a*. The swing mirror **31** has a reflection surface **31***a*. The support shown in FIG. **2** allows the reflection surface **31***a* of the swing mirror **31** to be controlled in terms of its three-dimensional position.

As shown in FIG. **1**, the directional relationships are defined such that the emitting direction of the laser beam L**1** from the laser diode **10** is assigned to an X-axis direction, the direction of the central axis **42***a* of the rotating deflection mechanism **40** to a Y-axis direction, and a direction perpendicular to both the X- and Y-axis directions to a Z-axis. Under this directional definition, an angle made between the reflection surface **31***a* and the XY plane is set to α, an angle made between the reflection surface **31***a* and the YZ plane is set to β, and an angle made between the reflection surface **31***a* and the XZ plane is set to γ. The angles α, β and γ can thus be decided freely by making a control circuit **70** control an actuator **36**.

The displacement mechanism **33** is configured to be driven by the actuator **36**, as outlined in FIG. **1**. The actuator **36** includes a first actuator and a second actuator. The first actuator is for example a motor that controls the mirror support frame **34** to a specified portion relative to the apparatus body. The second actuator is for example another motor to control a relative poison of the swing mirror **31** to the mirror support frame. The actuator **36** is able to respond to control from the control circuit **70**. That is, in response to control signals from the control circuit **70**, the first actuator sets the position of the mirror support frame **34** and the second actuator sets the position of the swing mirror **31** relatively to the mirror support frame **34**, with the result that the tilt angle of the swing mirror **31** relative to the laser beam L**1** can be decided. The control circuit **70** includes a microcomputer equipped with a CPU (central processing unit) and functions as the control means.

On the optical axis of the laser beam L**1** reflected by the swing mirror **31**, the rotating deflection mechanism **40** is arranged which shows one example of the rotation/deflection means. This rotating deflection mechanism **40** is provided with the deflection member **41** consisting of a mirror having a flat reflection surface **41***a*, a support base **43** supporting the deflection member **41**, an axial member **42** connected to the support base **43**, and a not-shown bearing rotatably supporting the axial member **42**. The deflection member **41** deflects not only the laser beam to the space but also the reflected light toward the photodiode **20**. This deflection member **41**, which consists of part of the rotating deflection mechanism **40**, is rotatable on the central axis **42***a* and functions as the deflection means.

In the present laser radar apparatus **1**, a deflection range provided by the deflection member **41** so as to deflect the reflected light, i.e., the area of the reflection surface **41***a*, is made to be larger than a deflection range given by the swing mirror **31** so as to deflect the laser beam, i.e., the area of the reflection surface **31***a* of the swing mirror **31**.

Furthermore, to rotate the rotating deflection mechanism **40**, a motor **50** is provided which functions as the drive means. The motor **50** is driven to rotate the axial member **42**, resulting in the rotation of the deflection member **41** connected to the axial member **42**. In this embodiment, the motor **50** is a stepping motor. Various types of stepping motors are available, in which the smaller the angle per step, the finer the angle control. As the motor **50**, drive means other than the stepping motor may be adopted. By way of example, a servo motor or a motor that rotates continuously may be employed. In the continuous-rotating motor, a pulsed laser beam is outputted in synchronization with the time when the deflection member **41** is orientated in a direction to be measured in its distance, whereby the detection is performed in a desired direction.

In the present embodiment, as shown in FIG. **1**, there is provided an angular sensor **52** to detect the angular position of the axial member **42** of the motor **50** (i.e., the angular position of the deflection member **41**). Any type of angle detecting means, such as a rotary encoder, may be usable, provided that the angular position of the axial member **42** is detected. In addition, the type of the motor **50** may also be limited to special ones.

On the optical path of the reflected light from the rotating deflection mechanism **40** to the photodiode **20**, a collecting lens **62** to collect the reflected light and direct it to the photodiode **20** is located. Further, between the collecting lens **62** and the photodiode **20**, a filter **64** is located. The collecting lens **62** functions as the light collecting means. The filter **64** is located at a given position on the optical path between the rotating deflection mechanism **40** in order to make the reflected light transmit the filter **64**, but to remove light other than the reflection light. The filter **64** thus functions as the light selecting means. To be specific, the filter **64** is composed by a wavelength selecting filter that makes it possible that only light having wavelengths belonging to a specific wavelength range which corresponds to the reflected light L**2** is allowed to pass through this filter.

In the present embodiment, the casing **3** accommodates therein the laser diode **10**, photodiode **20**, light deflection member **30**, lens **60**, rotating deflection mechanism **40**, motor **50** and others, with such components protected from dust and shocks. Around the deflection member **41** in the casing **3**, as part of the casing **3**, a light-passing portion **4** is arranged to enclose the deflection member **41**, but makes it possible to pass the laser beam L**1** and the reflected light L**2**. The light-passing portion **4** is formed into an annular shape. Thus this portion **4** covers a light transmission/reception view over an approximately 360 degrees. This light-passing portion **4** is sectioned by a light transmission plate **5** made of glass for example, which is oblique, over its circumstance, to a plane perpendicular to the light axis of the laser beam L**1** entering the deflection member **41**. That is, the laser beam L**1** deflected from the deflection member **41** always crosses the plate **5** at an oblique angle. Hence, thanks to this oblique crossing configuration, the light L**1** reflected from the light transmission plate **5** has a good resistance against optical noise components.

The present laser radar apparatus **1** will now be described from its operations.

When the pulsed current is supplied to the laser diode **10**, the laser diode **10** emits pulsed laser light whose duration agrees with the pulse width of the pulse current. This laser light is emitted as diffusion light with a certain level of spread angle, and converted into parallel light (i.e., laser beam L**1**) by passing the lens **60**. The produced laser beam L**1** is then reflected by the swing mirror **31** placed at the light deflection member **30** to enter the deflection member **41**, before being reflected by the deflection member **41** to be radiated to the space.

The laser beam L**1**, which has been reflected by the deflection member **41**, is then reflected by an object to be detected, if those objects exist. Part of the reflected light becomes reflected light L**2** returns to enter the deflection member **41**.

Thus the reflected light L**2** reflects from the deflection member **41** toward the photodiode **20**. This reflected light L**2** is then collected by the collecting lens **62** and is made to enter the photodiode **20** via the filter **64**.

The photodiode **20** responds to the light reception by outputting an electric signal whose voltage corresponds to the received reflected light L**2**, for instance. Hence, measurement of a time interval starting from the output of the laser beam L**1** from the laser diode **10** to the detection of the reflected light L**2** by the photodiode **20** provides a distance from the apparatus to each object. Additionally, the combination between the displacements of the swing mirror **31** and the displacement of the deflection member **41** makes it possible to calculate the direction of each object. In other words, when the angle α between the reflection plane **31***a* of the swing mirror **31** and the XY plane, the angle βbetween the reflection plane **31***a* and the YZ plane, and the angle γ between the reflection plane **31***a* and the XZ plane are known and the rotating angular position of the deflection member **41** is known, it is possible to uniquely decide the direction of the light beam L**1** emitting from the deflection member **41**, whereby the direction of each object can be calculated.

When the swing mirror **31** is made to be displaced in a controlled manner, the optical path of the laser beam changes as follows.

FIG. **1** exemplifies the rotating deflection mechanism **40** which is rotated until a given angle on its central axis **42***a*. In this rotated state, when the swing mirror **31** takes a swing attitude shown in FIG. **1**, the laser beam L**1** passes a path shown by solid lines, resulting in that the reflection light existing a range spatially sectioned by two solid lines shown by the reference L**2**. On the other hand, when the swing mirror **31** is swung so as to reflect the laser beam L**1** along a dashed line L**1'**, the incident angle of the laser beam L**1** to the deflection member **41** is changed from the former incident angle. Thus a displacement in the swinging attitude of the swing mirror **31** results in a change in the reflection angle of the laser beam at the swing mirror **31**, as exemplified by the dashed line L**1'**. This reflection angle change will cause the laser beam deflected by the deflection member **4** to change upward in the XY plane in FIG. **1**. In this case, the corresponding reflection light paths are also changed as shown by dashed lines L**2'**. The reflection light, which has been reflected by the deflection member **41**, enters the collecting lens **62** and is subjected to the process at the filter **64** and detection by the photodiode **20**, as described.

As described, in the laser radar apparatus **1** according to the present embodiment, the deflection member **41** is rotated on its given central axis **42***a* in a controlled manner, so that the laser beam L**1** to be emitted to the air and the reflected light L**2** from an object to the photodiode **20** are deflected throughout the 360 degrees along the XZ plane. In addition to this, the direction of the laser beam L**1** from the deflection member **41** is changed by the swing mirror **31** relative to the central axis **42***a*, that is, each of the planar directions each including the central axis **42***a* (in FIG. **1**, the XY plane). It is therefore possible that, in FIG. **1**, the laser beam L**1** is scanned (i.e., swung) in the XZ planar direction perpendicular to the central axis **42***a* as well as the XY planer direction including the central axis **42***a*. Hence the detection of the objects can be made three-dimensionally.

In the present embodiment, the swing mirror **31** is adopted, so that the laser beam L**1** from the deflection member **41** can be scanned along the XY planar direction without a complex configuration.

The deflection area of the deflection member **41**, in which the reflection light L**2** is deflected, is set to be larger than the deflection area of the swing mirror **31**, in which the laser beam L**1** is deflected. For this reason, the reflection light can be detected in a wider spatial range, thereby enhancing accuracy in the detection.

Moreover, the collection lens **60** is located on the optical path of the reflection light L**2** between the rotating deflection mechanism **40** and the photodiode **20**. Hence, without making the photodiode **20** lager in its size, the detection can be performed on the reflection light detected from a wider special range.

The filter **64** is located on the optical path of the reflection light L**2** between the rotating deflection mechanism **40** and the photodiode **20**. Hence noise components in the reflected light L**2** can be removed effectively.

Second Embodiment

Referring to FIG. **3**, a laser radar apparatus according to a second embodiment of the present invention will now be described.

In the second embodiment and successive embodiments, the similar or equivalent components to those in the first embodiment will be given the same reference numerals as those explained in the first embodiment for the sake of a simplified explanation.

The second embodiment concerns with a geometrical modification of the laser diode **10** and the photodiode **20**.

FIG. **3** shows an outlined configuration of a laser radar apparatus **100** according to the second embodiment, in which, as described later, there is provided a mirror **130**. The XYZ orthogonal coordinate system is given to the configuration shown in FIG. **3** such that the X- and Y-axis directions are assigned to the reflecting direction at the mirror **130** (i.e., the light receiving direction at the photodiode **20**) and the direction of the central axis **42***a* of the rotating deflection mechanism **40**, respectively.

In the present laser radar apparatus **100**, like the first embodiment, there are provided the laser diode **10**, the photodiode **20**, the deflection member **41** rotatable on its central axis **42***a*, the rotating deflection mechanism **40** for the deflection of the laser beam L**1** and the reflected light L**2** in the same way as the foregoing, and the motor **50** to drive the mechanism **40**.

The laser radar apparatus **100** is additionally provided with an emitting-direction deflection member **110** to change the emitting direction of the laser beam L**1** by displacing the laser diode **10** itself. This emitting-direction deflection member **110** functions as the direction changing means and the emitting-direction changing means. This deflection member **110** actions to change the incident direction of the laser beam L**1** to the deflection member **41**, so that the laser beam L**1** from the deflection member **41** can be scanned in its direction along the planar directions each including the central axis **42***a.*

The emitting-direction deflection member **110** can be realized by a variety of types of actuators as long as those actuators have the capability of changing the laser diode **10**. For instance, oscillating means such as oscillators may be adopted to oscillate the laser diode **10**. The laser diode **10** may be mounted in a displacement apparatus (such as the displacement mechanism **33** and the actuator **36**, shown in FIG. **2**) which is able to displace the laser diode at multiple degrees of freedom, in which the mounting plane is subjected to bidirectional rotation. In this configuration, the control circuit **70** is allowed to control the oscillation means and the displacement apparatus in terms of their amounts to be displaced, so that the control circuit functions as the displacement control means.

In the laser radar apparatus **100** according to the second embodiment, the laser beam (light) L**1** emitted from the laser diode **10** in the given direction is converted to the parallel light by the lens **60**. After passing the lens **60**, the laser beam L**1** enters the deflection member **41** without passing any components, and reflected to the air by this member **41**. The laser beam L**1**, which has been reflected by the deflection member **41**, is reflected by an object to be detected, before part of the reflected light L**2** returns to the deflection member **41**. The deflection member **41** reflects the returned reflected light L**2** toward the mirrors **130**. The reflected light L**2** then passes the mirror **130** to reach the photodiode **20**.

The mirror **130** is obliquely arranged between the laser diode **10** and the rotating deflection mechanism **40** and has a through-hole **131** to make the laser beam L**1** pass therethrough. The opening area given by the through-hole **131** is sufficiently small compared to all the reflection surface of the mirror **130**. The reflection light L**2** reflected by the deflection member **41** is again reflected by the reflection surface of the mirror **130**, which is other than the through-hole **131** toward the photodiode **20**. In this configuration, when the emitting direction of the laser diode **10** is changed to allow the laser beam to trace a path shown by the a dashed line L**1'** for example, the reflection light L**2** is controlled to pass along a path shown by a dashed line L**2'** and enter the photodiode **20**.

In the present embodiment, the collecting lens **62** stated in the first embodiment is also located on the optical path of the reflected light L**2** between the mirror **130** to the photodiode **20**. In addition, the filter **64** stated in the first embodiment is also located on the optical path between the mirror **130** and the photodiode **20**.

According to the present embodiment, the laser diode **10** and its associated components make it possible to change the direction of the laser beam L**1** from the deflection member **41** in each of the planar directions each including the central axis **42***a* (In FIG. **3**, the XY planar direction).

Third Embodiment

Referring to FIG. **4**, a laser radar apparatus according to a third embodiment of the present invention will now be described.

The third embodiment concerns with a geometrical modification of the laser diode **10** and the photodiode **20**.

FIG. **4** shows an outlined configuration of a laser radar apparatus **200** according to the third embodiment, in which, as described later, there is provided a rotating deflection mechanism **240** having a central axis **242***a*. The XYZ orthogonal coordinate system is given to the configuration shown in FIG. **4** such that the X- and Y-axis directions are assigned to the emitting direction of the laser beam L**1** from the laser diode **10** and the direction of the central axis **242***a* of the rotating deflection mechanism **240**, respectively.

In the present laser radar apparatus **200**, like the first embodiment, there are provided the laser diode **10** and the photodiode **20**.

The present laser radar apparatus **200** differs from the laser radar apparatus **1** according to the first embodiment in the configuration of the rotating deflection mechanism **240**. This mechanism **240** has a deflection member **241** produced as a mirror and rotatable on both the given central axis **242***a* and a given axis **241***a* perpendicular to the central axis **242***a*.

Practically, the rotating deflection mechanism **240** is equipped with a support base **243** including a pillar portion which supports the deflection member **241**, a shaft member **242** supporting the support base **243**, and an actuator **210** such as a motor. The deflection member **241** is rotatably supported by the support base **243** such that the member **242** is rotatable on the axis **241***a* along the XZ plane. The actuator **210** is used to drive the rotation angle relative to the support base **243** in a controlled manner. The displacement given by the actuator **210** is controlled by the control circuit **70**. The support base **243** is connected to the shaft member **242** driven by the motor **50** stated in the same way as that in the first embodiment.

In the present laser radar apparatus **200**, the deflection member **241** provides the function to deflect not only the laser beam L**1** to the air but also the reflected light L**2** toward the photodiode **20**. Further the actuator **210** is able to tilt the whole deflection member **241** about the axis **241***a* perpendicularly crossing the central axis **242***a*. This tilt action makes it possible that the incident direction of the laser beam L**1** to the deflection member **241** is controlled to change the direction of the laser beam L**1** from the deflection member **241** along each of the planar directions each including the central axis **242***a*. The actuator **210** tilting the deflection member **241** serves as both the direction changing means and the tilt means and the control circuit **70** serves as both the control means and the tilt control means.

In the present embodiment, the collecting lens **62** is located on the optical path of the reflected light L**2** between the rotating deflection mechanism **240** and the photodiode **20** so as to collect the reflected light L**2** onto the photodiode **20**. The filter **64** is located as well in the same manner as that in the first embodiment.

It is therefore possible that the present embodiment provides the configuration to change the direction of the laser beam L**1** along each of the planar directions each including the central axis **242***a*, without making the configurations other than the changing means complex.

Fourth Embodiment

Referring to FIG. **5**, a laser radar apparatus according to a fourth embodiment of the present invention will now be described.

The fourth embodiment concerns with a geometrical modification of the laser diode **10** and the photodiode **20**.

FIG. **5** shows an outlined configuration of a laser radar apparatus **300** according to the fourth embodiment, in which, as will be described later, there is provided a rotating deflection mechanism **340** having a central axis **342***a*. The XYZ orthogonal coordinate system is given to this configuration shown in FIG. **5** such that the X- and Y-axis directions are assigned to the central axis **342***a* and the direction perpendicular to the central axis **342***a*.

Like the first embodiment, the laser radar apparatus **300** according to the fourth embodiment is provided with the laser diode **10**, the photodiode **20**, and the rotating deflection mechanism **340**.

The rotating deflection mechanism **340** is different from that explained in the first embodiment. This mechanism **340** functionally includes a cylindrical shaft **342**, the changing means which is composed of a first deflection member **343** and a second deflection member **341**. The first deflection member **343** is configured as a mirror and to deflect the laser beam L**1** from the laser diode **10**, thus the first deflection member **343** functions as the first deflection member. Likewise, the second deflection member **341** is configured as a mirror and to deflect to the reflected light L**2** from an object, thus the second deflection member **341** functions as the second deflection means.

The second deflection member **341** is fixedly arranged on the top of the cylindrical shaft **342** in a tilted attitude, as shown in FIG. **5**, while the first deflection member **343** is tiltably supported on the top of the cylindrical shaft **342**. The cylindrical shaft **342**, to which the central axis **342***a* is given, is rotatable on the central axis **342***a* and driven to rotate by the motor **50**, so that the first deflection member **343** and second deflection member **341** are rotatable on the central axis **342***a*.

Specifically, the first deflection member **343** is tiltable independently of the second deflection member **341**. The first deflection member **343** is supported by a not-shown bearing on the top of the cylindrical shaft **342** and is able to be displaced in rotation directions around an axis **343***b* perpendicular to the central axis **342***a*. In addition, the first deflection member **343** is driven by an actuator **310** in FIG. **5**. The type of the actuator **310** is not limited to a particular one. For example, the actuator **310** may be a component including a motor to rotate the member **343** for the control of its rotated angle. An alternative actuator may be applied to the deflection member **343** which is partly composed of a magnetic member and configured to have a coil on the cylindrical shaft **342**. The coil is subjected to the supply of current to generate electromagnetic force that displaces the first deflection member **343** in a controlled manner.

In the present laser radar apparatus **300**, the first deflection member **343**, which composes part of the deflection means, realizes the function of deflecting the laser beam L**1** to the air. Furthermore, the second deflection member **341**, which composes part of the deflection means, realizes the function of deflecting the reflected light L**2** toward the photodiode **20**.

The actuator **310** operates to rotate the first deflection member **343** on the axis **343***b* perpendicular to the central axis **342***a* of the first deflection member **343**. This makes it possible that the incident direction of the laser beam L**1** to the first deflection member **343** is changed and the direction of the laser beam L**1** from the first deflection member **343** is changed along each of the planar directions each including the central axis **342***a* (in the case of FIG. **5**, along the XY plane). Thus the actuator **310** serves as the direction changing means and the tilt means, while the control circuit **70** serves as the control means and the tilt control means.

In the present embodiment, the second deflection member **341** has a reflection area **341***a* which functions as a deflection area to deflect the reflected light L**2** at this member **341**, while the first deflection member **343** has a reflection area **343***a* which functions as a deflection area to deflect the laser beam L**1** at this member **343**. The second deflection member **341** is larger in the deflection area than the first deflection member **343**.

Further, as illustrated in FIG. **5**, on the central axis **342***a* of the rotating deflection mechanism **340**, the laser diode **10** and the photodiode **20** are arranged to be faced to each other with the deflection member **343** therebetween. In this geometrical configuration, the laser beam L**1** is generated by the laser diode **10** which is located within the inner space of the cylindrical shaft **342**. The laser beam L**1** is then reflected by the first deflection member **343** to be directed to the spatial field for scanning. The laser beam L**1** is reflected by objects in the scanning spatial field to yield reflection light L**2**. This reflection light L**2** returns to the apparatus and is reflected by the second deflection member **341** to be directed toward the photodiode **20**. In this beam and light transmission paths, when the deflection member **343** is displaced, the path of the laser beam is changed to, for example, another path shown by a dashed line L**1'**. Responsively to this path change, the reflected light comes to the second deflection member **341** along another path shown by a dashed line L**2'**.

Like the first embodiment, the collecting lens **62** and the photodiode **20** are located in turn on the optical path of the reflected light L**2** between the rotating deflection mechanism **340** and the photodiode **20**.

In this way, only selectively displacing part of the deflection means makes it possible to change the emitting direction of the laser beam.

In addition, the deflection area of the second deflection member **341**, which deflects the reflected light, is larger than that of the first deflection member **343**, which deflects the laser beam. Therefore, the reflected light can be detected in a wider view, thus enhancing accuracy in the detection.

The laser diode **10** and the photodiode **20** are opposed to each other with the deflection member **343** located therebetween on the central axis of **342***a* of the rotating deflection mechanism **340**. Hence the arrangement can be done effectively, being less in the space.

Fifth Embodiment

Referring to FIGS. **6-9**, a laser radar apparatus according to a fifth embodiment of the present invention will now be descried.

FIG. **6** outlines the configuration of a laser radar apparatus **400** according to the fifth embodiment.

As shown in FIG. **6**, the laser radar apparatus **400** is provided with the casing **3**, light-passing portion **4**, light transmission plate **5**, laser diode **10**, lens **60**, photodiode **20**, filter **64**, collecting lens **62**, rotating deflection mechanism **40**, motor **50**, rotation angle sensor **52**, and control circuit **70**, which are the same as those in the first embodiment. As shown, the Y-axis direction is given to the direction of the central axis **42***a* of the deflection member **41**, while the X-axis is given to the emission direction of the laser beam from the laser diode **10**.

Like the apparatus explained in the first embodiment, the laser radar apparatus **400** includes the laser diode **10**, photodiode **20**, rotating deflection mechanism **40** provided with the deflection member **41** having the central axis **42***a*, and motor **50**, which are operative in the same manner as those in the first embodiment.

The laser radar apparatus **400** is provided with a light deflection member **430** in place of the swing mirror **30** in the first embodiment. This light deflection member **430**, which functions as the direction deflection means and light deflection means, receives the laser beam from the laser diode **10** and deflects it toward the rotating deflection mechanism **40**. This member **430** is configured to be swingable. Thus, the light deflection mechanism **430** is able to change the incident direction of the laser beam L**1** to the deflection member **41**, so that the direction of the laser beam L**1** from the deflection member **41** can be changed in the Y-axis direction, that is, along each of the planar directions including the central axis **42***a* (in the case of FIG. **6**, along the XY plane).

As shown in FIGS. **7**, **8**A and **8**B, the light deflection member **430** is provided with a square mirror **431** reflecting the laser beam, a support mechanism **435** swingably supporting the mirror **431** (i.e., supporting the mirror **431** in a manner that the mirror can be swung), and four piezoelectric actuators **432***a*, **432***b*, **432***c* and **432***d*. These piezoelectric actuators are provided to drive the mirror **431** supported by the swing mechanism **435**. The mirror **431** corresponds to part of the deflection member deflecting the laser beam and the piezoelectric actuators **432***a*, **432***b*, **432***c* and **432***d* are one example of the actuator according to the present invention.

Any of the four piezoelectric actuators **432***a*, **432***b*, **432***c* and **432***d* is known, which is able to extend and contract in response to voltage to be applied. The square mirror **431** has a frontal reflection surface **421** and a rear surface opposed to the reflection surface. One end of each piezoelectric actuator is secured to the rear surface of the mirror **431** at each of the four corners (specific positions) thereof. The other end of each piezoelectric actuator is fixedly secured to a support plate **438**. The support plate **438** is fixed to the casing **3** to be positioned in place within the space enclosed by the casing **3**. The respective piezoelectric actuators **432***a*, **432***b*, **432***c* and **432***d* are fixed on this support plate **438** are extended and contracted depending on the voltage applied to each actuator. Hence, this extension and contraction allows the mirror **431** to have a tilt to the support plate **438**, as exemplified by a chain double-dashed line in FIG. **7**.

The control circuit **70**, which functions as the control means and the swing control means, is provided to control the drive of the piezoelectric actuators **432***a*-**432***d*. This drive is for the tilt of the mirror **431**, that is, the swung state of the light deflection member **430**. As illustrated in FIG. **8**A, the respective piezoelectric actuators **432***a*, **432***b*, **432***c* and **432***d* are electrically connected to piezoelectric-actuator drive circuits **436***a*, **436***b*, **436***c* and **436***d*, respectively. These drive circuits **436***a*-**436***d* is given a command signal from the control circuit **70**. The command signal indicates an amount to be controlled with regard to the displacement of each actuator. In reply to this command signal, each drive circuit **436***a* (-**436***d*) provides each piezoelectric actuator **432***a* (-**432***d*) with voltage according to the command signal value, i.e., the amount to be controlled.

In addition, the swing mechanism **435** is provided with a ball joint that coupling the mirror and the support plate **438**. The ball joint, which has a spherical bearing stud and socket, comprises a spherical portion **434** coupled to the mirror **431** and a spherical shell portion **433** coupled to the support plate **438**. Both the spherical portion **434** and the spherical shell portion **433** are jointed with each other such that the spherical portion **434** provides a center **434***a* fixed located at the same position and the spherical portion **434** contained in the spherical shell portion **433** can be rotated in multiple ways.

Accordingly, the swing mechanism **435** allows the tilted state of the mirror **431** to the laser beam L**1** to be changed depending on the extended and contacted states of the piezoelectric actuators **432***a*-**432***d*, in the state where the distance between the reflection surface **431***a* and the center **434***a* of the spherical portion **434** is kept constant any time. Hence the extension and contraction of each piezoelectric actuator **432***a* (-**432***d*) is controlled by the control circuit **70**, with the result that the tilting attitude of the mirror **431** to the laser beam L**1** is controlled.

The detection process for objects, which is carried out by the laser radar apparatus **400**, will now be detected.

FIG. **9** is a flowchart which explains the detection process, which is also carried out by the control circuit **70**. In other words, the control circuit **70** is responsible for detecting objects as a processor as well as controlling the actuators **432***a*-**432***d* and motor **50** as a controller. To realize these functions, computer readable programs for those functions are installed in the control circuit **70** in advance.

The detection process explained by FIG. **9** starts responsively to the power-on operation or a predetermined user's operation to the control circuit, for instance. First, the mirror **431** and the deflection member **41** are positionally located at their initial positions (step S**1**). In the present embodiment, those initial positions are indicated by solid lines in FIGS. **6** and **7**. Thus the motor **50** and the piezoelectric actuators **432***a*-**432***d* are controlled to enable the mirror **431** to take such an initial tilt position. As a modification, this initial setting of both the deflection member **41** and the mirror **431** may be set to their initial tilt positions during a waiting state before staring up the detection process. In this case, the process at step S**1** can be omitted.

In this initial positioning state (or the current positioning state at the second and successive calculation timings), the detection process of objects is performed (step S**2**). Concretely, the control circuit **70** orders the photodiode **10** to emit a laser beam and reads out an electric signal from the photodiode **20**. Then the control circuit **70** determines whether or not there are objects in the current scanning direction decided by the current extension and contraction of the piezoelectric actuators **432***a*-**432***d* (that is, the current tilt of the mirror **431**). When the electric signal from the photodiode **20** shows an amplitude higher than a given level, the control circuit **70** will calculate a distance from each object on the basis of a time interval between the laser beam emission from the laser diode **10** to the reflected light reception at the photodiode **20**. Additionally, using the current extension and contraction of the piezoelectric actuators **432***a*-**432***d*, the direction (orientation) of the laser beam L**1** emitted from the deflection member **41** is calculated. The calculated distance and direction can be outputted to a not-shown display for visual observation.

The control circuit **70** then determines whether or not the mirror **431** has rotated by a predetermined angular range (step S**3**). In the present embodiment, under the control of the control circuit **70**, the motor **50** is able to rotate the deflection member **41** every predetermined constant angle (for example, every one degree). Every time the deflection member **41** is rotated every predetermined constant angle (i.e., every one degree), the mirror **431** is subjected to the rotation through a "given angular range." Hence, at each rotated position of the motor **50**, that is, the deflection member **41**, the scanning is made by the laser beam L**1** through a given lateral view range in the X-axis direction including the central axis **42***a*. When the determination at step S**3** reveals the completion of rotation by the given angular range, that is, the scanning in the X-axis direction has been completed (YES at step S**3**), the processing is made to proceed to step **57**.

Meanwhile, when the determination at step S**3** reveals the non-completion of rotation through the given angular range, that is, the scanning in the X-axis direction has not been completed (NO at step S**3**), the processing is shifted to step S**4**. At this step S**4**, it is determined whether or not the deflection member **41** is still within a "predetermined rotation range." In the present embodiment, the predetermined rotation range is set to a rotation range in which the angle α made between an imaginary straight line in parallel with the emitting direction of the laser beam from the laser diode **10** and an imaginary plate in parallel with the reflection surface **41***a* of the deflection member **41** is less than a given threshold. When the deflection member **41** exists to fall into the predetermined rotation range, the determination at step S**4** is YES, so that the processing is shifted to step S**5**. In contrast, the determination at step S**4** is NO, the processing is shifted to step S**6**.

When performing the swing control, the control circuit **70** controls the swing of the light deflection member **430** based on the rotated position of the deflection member **41**. That is, in cases where the deflection member **41** is not within the predetermined rotation range, the angle α is over the given threshold (for example, 10 degrees), whereby the determination NO comes out at step S**4**. Thus, at step S**6**, the control circuit **70** controls the extension and contraction of the piezoelectric actuators **432***a*-**432***d* so as to rotate the mirror **431** by a predetermined angle about a first rotation axis **437***a* extending in the Z-axis direction, with the reflection surface **431***a* still being perpendicular to the XY plane. Thus, the direction of the laser beam L1 from the mirror **431** to the deflection member **41** is changed along the XY plane, as shown in FIG. **7**, where the mirror **431** is rotated from the rotated position shown by the solid line to a new rotated position shown by the two-dot chain line about the first rotation axis **437***a*. At this new rotated position, the laser beam passes as shown by a broken line L1' (refer to FIGS. **6** and **7**).

For rotating the mirror **431** about the first rotation axis **437***a*, the four piezoelectric actuators **432***a*-**432***d* are controlled as follows. When the piezoelectric actuators **432***a* and **432***c* are extended, the remaining two piezoelectric actuators **432***b* and **432***d* are made to contract by an amount corresponding to the extended amount. In contrast, when piezoelectric actuators **432***b* and **432***d* are extended, the remaining two piezoelectric actuators **432***a* and **432***c* are made to contract by an amount corresponding to the contracted amount. In both cases, the amounts of extension/contraction of the two piezoelectric actuators **432***a* and **432***c* are set to be the same and those of the remaining two piezoelectric actuators **432***b* and **432***d* are also set to be the same.

On the other hand, in cases where the deflection member **41** is within the predetermined rotation range, the piezoelectric actuators **432***a*-**432***d* are controlled to extend and contract so as to rotate the mirror **431** by a given angle about a second rotation axis **437***b* crossing the first rotation axis **437***a* (step S**5**; refer to FIGS. **5**A and **8**B). The second rotation axis **437***b* crosses with all the XY plane, YZ plane and ZX plane, and in the present embodiment, set as an axis along a diagonal line of the mirror **431**. By rotating the mirror about the second rotation axis **437***b*, the direction of the laser beam from the mirror **431** toward the deflection member **41** can be changed along a plane crossing the XY plane.

In cases where the mirror **431** is rotated about the first rotation axis extending in the Z-axis direction, changes of the laser beam emitting from the deflection member **41** are made smaller in the direction of the central axis **42***a* (longitudinal direction), as the foregoing angle α becomes smaller. Thus, in the present embodiment, when the deflection member **41** is within the predetermined rotation range, the mirror **431** is subject to rotation about the second rotation axis **437***b* along the diagonal line, instead of rotation about the first rotation axis **437***a*. Hence, even if the angle α becomes smaller, it is secured that the laser beam can be changed largely in the longitudinal direction along the central axis **42***a*. For this control, for example, the amount of extension/contraction of the piezoelectric actuators **432***b* and **432***c* are made to be the same, the piezoelectric actuator **432***d* (or **432***a*) is made to contract by an amount corresponding to the extension of the piezoelectric actuator **432***a* (or **432***d*).

Returning to FIG. **9**, when being shifted to step S**7**, by the control circuit **70**, the motor **50** is driven to further rotate the deflection member **41** by the predetermined constant angle (one degree). After this, the processing is returned to step S**2**, so that at the new rotated state of the deflection member **41**, the foregoing processing on steps S**2**-S**7** is repeated, thereby scanning in the longitudinal direction again. Incidentally, the predetermined constant angle, on which the deflection member **41** rotates step by step, is not limited to one degree, but may be larger or smaller than one degree.

As described, in the present embodiment, the mirror **431** supported by the swing mechanism **435** is driven by the piezoelectric actuators **432***a*-**432***d* and the drive is controlled by the control circuit **70**. Thus the swinging action of the mirror **431** to deflect the laser beam can be controlled at higher accuracy. Further, the light deflection member **430** can be made compact.

In addition, controlling the four piezoelectric actuators **432***a*-**432***d* at the four corners of the mirror **431** leads to the attitude control of the mirror **431**. This control simplifies the swing control configuration for the mirror **431**, so that the structure is made compact.

The ball joint is used to rotatably couple the mirror **431** and the support plate **438** supporting the mirror **431**. This contributes to stably supporting the mirror **431** and smooth swinging actions of the mirror **431**.

Further, based on the rotated positions of the deflection member **41**, the swing control is the light deflection member **430** is changed. Thus the swing control can be made proper depending on the rotated positions of the deflection member **41**.

Like the first embodiment, the collecting lens **62** is arranged, whereby the reflection light can be utilized for the object detection in a wider view, without making the detecting means larger in its size.

The filter **64** is also arranged as shown in the first embodiment, whereby the noise in the reflected light can be removed effectively.

Sixth Embodiment

Referring to FIGS. **10**-**12**, a laser radar apparatus according to a sixth embodiment of the present invention will now be described.

As shown in FIG. **10**, a laser radar apparatus **500** according to the present embodiment includes the casing **3**, light-passing portion **4**, light transmission plate **5**, laser diode **10**, lens **60**, photodiode **20**, filter **64**, collecting lens **62**, rotating deflection mechanism **40**, motor **50**, rotation angle sensor **52**, and control circuit **70**, which are the same or similar as or to the members described in the first embodiment. The XYZ orthogonal coordinate system is also applied to this apparatus **500**.

In this apparatus **500**, instead of the light deflection member **30** explained in the first embodiment, another light deflection member **530** is provided as shown in FIG. **10**. This member **530** functions as the direction deflecting means and light deflection means.

FIGS. **11**A and **11**B detail the light deflection member **530**. As shown, this member **530** is provided with a mirror unit **531** and a rotation mechanism **533** which is able to displace the mirror unit **531**. The rotation mechanism functions as a displacement mechanism. The mirror unit **531** is provided with a plurality of mirrors **531***a*-**531***h*, which are combined together into one unit. The mirror unit **531** is configured to be rotatable on a rotation axis **532** which is parallel with the central axis **42***a* (i.e., the Y-axis direction) of the rotating deflection mechanism **40**. The plurality of mirrors have flat reflection surfaces **537***a*-**537***h*, respectively, and are arranged around the rotation axis **532** to establish a ring-like form. The tilt angles of the respective reflection surfaces **537***a*-**537***h* to the rotation axis **532** are different from each other.

The rotation mechanism **533**, which is produced to rotate the mirror unit **531** on the rotation axis **532**, comprises a motor **534** and an shaft member **535** coupling the motor **534** and the mirror unit **531**. The motor **534** is of any type of motor including a stepping motor, as long as its rotated position can be controlled. In this rotation mechanism **533**, the mirror unit **531** is driven to locate, in turn, the plural mirrors **531***a*-**531***h* at a beam-incident position onto which the laser light L**1** from the laser diode **10** comes. As described, since the reflection surfaces **537***a*-**537***h* of the mirrors **531***a*-**531***h* which are located at the beam-incident position are different from each other, the laser beams are reflected at mutually different angles on the reflection surfaces.

The control circuit **70**, which functions as the control means, controls the drive of the rotation mechanism **533** to sequentially locate the mirrors **531***a*-**531***h* at the beam-incident position. When being located at the beam-incident position, each of the reflection surfaces **537***a*-**537***h* is set to be perpendicular to the XY plane.

The tilt angles of the reflection surfaces **537***a*-**537***h* can be set in various modes. In the present embodiment, the first mirror **531***a* is adopted as a reference mirror. That is, the reflection surface **537***a* of this first mirror **531***a* has an angle β**1** of 45 degrees relative to the laser beam L**1**, when the mirror **531***a* is located at the beam-incident position. The reflection surface **537***b* of the second mirror **531***b* has an angle β**2** (e.g., 47 degrees) larger than the angle β**1** relative to the laser beam L**1**, when the mirror **531***b* is located at the beam-incident position. Likewise, the reflection surface **537***c* of the second mirror **531***c* has an angle β**3** (e.g., 49 degrees) larger than the angle β**2** relative to the laser beam L**1**, when the mirror **531***c* is located at the beam-incident position. In this way, the angles of the respective reflection surfaces **537***a*-**537***h* of all the eight mirrors **531***a*-**531***h* differ from each other relative to the incident laser beam L**1**.

Hence, in the present laser radar apparatus **500**, the reflecting directions of the laser beam L**1** from the mirrors **531***a*-**531***h* are also different from each other. The control circuit **70** controls the drive, i.e., the rotation of the mirror unit **531** in a predetermined speed, so that the direction of the reflected laser beam L**1** from the mirror unit **531**, that is, the incident direction toward the deflection member **41**, is changed. This means that the direction of the laser beam L**1** deflected (reflected) by the deflection member **41** is changed in the lateral direction (i.e., the Y-axis direction) along the central axis **42***a*. Thus, a lateral field outside the apparatus can be scanned by the laser beam L**1**.

FIGS. **10** and **11**A explain this scanning. In those figures, a solid line shows the reflection of the laser beam L**1** by the mirror **531***a*, while a dashed line (L**1**') shows the reflection of the laser beam L**1** by the next mirror **531***b*.

Referring to FIG. **12**, the detection process carried out by the control circuit **70** will now be descried.

First, the control circuit **70** starts by locating the mirror unit **531** and the deflection member **41** at their initial positions, respectively (step S**10**). Hence, the initial positions pictorially shown by the solid line in FIGS. **10** and **11**A are realized by controlling the drive of both motors **534** and **50**. Incidentally, this positional initialization step can be performed before the detection process, but in the waiting state for the detection process.

Then the control circuit **70** performs the detection of objects in the current scanning state (including the initial scanning state) provided by the current driven state of the motors (step S**20**). This processing is almost similar to that described in step S**2** in FIG. **9**, except that, instead of the light deflection member **430**, the current setting state (the current mirror angle) of the mirror unit **531** is taken into the calculation of a direction along which the laser beam L**1** travels (i.e., the direction in which an object exists).

The control circuit **70** then determines whether or not the mirror unit **531** has been rotate one turn. In the present embodiment, under the control of the control circuit **70**, the motor **50** rotates the deflection member **41** every predetermined constant angle (i.e., 1 degree). Accordingly, whenever the deflection member **41** has rotated by the constant angle, the mirror **531** is rotated by one turn so that the plural mirrors **531***a*-**531***h* are subjected, in sequence, to be located at the beam-incident position and to reception of the laser beam L**1**. Thus the direction of the laser beam reflected by the mirror unit **531** is changed in turn at intervals. In this way, at every stepping angle of the motor **50**, the laser beam L**1** emitted from the apparatus scans the outer field in the lateral Y-axis direction.

When the mirror unit **531** has finished it one turn, the determination at step S**30** is YES, and the processing is shifted to step S**50**. Meanwhile, the determination is NO at step S**30**, the processing is shifted to step S**40**, where the control circuit **70** controls the drive of the mirror unit **531** to be rotated by the given angle (in the present embodiment, 45 degrees), thus locating the next mirror at the beam-incident position. The processing then returns to step S**20** to repeat the detection process at the new scanning angle.

Meanwhile, at step S**50**, the control circuit **70** controls the drive of the motor **50** to further rotate the deflection member **41** by the constant angle (in the present embodiment, 1 degree), before returning the processing to step S**20**. Thus, at the next rotation angle along the XY lateral plane, the new longitudinal Y-axis directional view in the outside filed is scanned for detecting objects.

In the present embodiment, the angle of 1 degree is exemplified as the predetermined constant angle, but this is not a decisive list. This predetermined constant angle, which corresponds to each rotation step of the deflection member **41**, may be smaller or larger than 1 degree. In addition, the number of mirrors arranged to the mirror unit **531** is not limited to eight, but may be smaller or larger than eight.

In the present embodiment, the mirror unit **531** is driven and controlled such that the plural mirrors **531***a*-**531***h* are located in sequence at the beam-incident position of the laser beam L**1** from the laser diode **10**. Hence the direction of the laser beam L**1** to the deflection member **41** can be changed using the relatively compact mirror structure. Simply controlling the mirror unit **531** so as to sequentially locate the mirrors **531***a*-**531***h* makes it possible to change the incident direction of the laser beam toward the deflection member **41**. Thus, without employing a complex control, the laser beam L**1** emitted from the apparatus can be scanned in the lateral Y-axis direction in the outside field.

In addition, rotating the mirror unit **531** results in switchovers among the plural mirrors at the beam-incident position of the laser beam L**1**, whereby the switchover action can be speeded up and performed with accuracy.

The deflection member **41** is rotated, step by step, every predetermined constant angle, and at each stepping angle of the deflection member **41**, all the plural mirrors **531***a*-**531***h* are located in sequence at the beam-incident position for scanning the longitudinal direction. It is not necessary to the deflection member **41** largely at a time, but the three-dimensional scanning can be made reliably for three-dimensionally detecting objects in the outer filed. Thus, the rotating deflection mechanism **40** and motor **50** are suppressed from being loaded heavily.

Seventh Embodiment

Referring to FIGS. **13**-**16**, a laser radar apparatus according to a seventh embodiment of the present invention will now be described.

As shown in FIG. **13**, a laser radar apparatus **600** according to the present embodiment includes the casing **3**, light-passing portion **4**, light transmission plate **5**, laser diode **10**, lens **60**, photodiode **20**, filter **64**, collecting lens **62**, rotation angle sensor **52**, and control circuit **70**, which are the same or similar as or to the members described in the first embodi-

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which the laser beam L1 travels (i.e., the direction in which an object exists). That is, the control circuit **70** calculates the emitting direction (scanning direction) of the laser beam L1 from the deflection member **641** on the basis of information showing the rotated positions of both the motors **682** and **650**. The distance from the object is also calculated by the control circuit **70** in the same way stated already. The calculated distance and direction is presented by a not-shown display or other means.

After the detection step S**110**, the processing is made to proceed to the determination whether or not the cam **681** has been finished its one turn (step S**120**). Like the forgoing, the motor **650** is driven by the control circuit **70** to rotate the deflection member **641***a* predetermined constant angle (1 degree in the present embodiment). And at each rotated angle of the deflection member **641**, the motor **682** is driven to rotate the cam **681** one turn. In other words, whenever the deflection member **641** is rotated by the constant angel on the central axis **642***a* (the Y-axis direction), the laser beam L1 scans the external field in the longitudinal direction (the Y-axis direction).

When it is determined that the cam **681** has finished its one turn (YES at step S**120**), it is recognized that the longitudinal scanning has been finished at the current rotated position of the motor **650** (i.e., the deflection member **641**) along the XY plane. Thus the processing is shifted to step S**140**. Meanwhile it is determined that the cam **681** has not been finished its one turn yet (NO at step S**120**), the processing is shifted to step S**130**, where the control circuit **70** controls the motor **682** to rotate the cam **681** by a given angle (in the present embodiment, 45 degrees). Then the processing is returned to step S**110**, where at the new tilt angle of the deflection member **641**, the detection is repeated.

At step S**140**, it is determined whether or not the motor **650** is currently set to the forward rotation (step S**140**). In the present embodiment, when being viewed in FIG. **14**B, the rotation in the clockwise direction is set to the forward rotation, while the rotation in the counterclockwise direction is set to the backward rotation. When being set to the forward rotation, the processing is shifted to step S**150**, where the deflection member **641** is rotated forward by the predetermined constant angle (1 degree). In contrast, when the rotation is set to the backward rotation, the processing is shifted to step S**160**, where the deflection member **641** is rotated backward by the predetermined constant angle. Incidentally, the rotation of this motor **650** is set to the forward rotation by default setting, but is switched to the opposite one at step S**180** described later.

On completion of the process at step S**150** or S**160**, it is determined at step S**170** whether or not the deflection member **641** has been rotated by a given rotation range (in the present embodiment, a angular range of 180 degrees) in either the forward rotation or the backward rotation. If the determination is made such that the deflection member **641** has completed the rotation through the given rotation range on the central axis **642***a*, the processing is shifted to step S**180** for performing a setting switchover process. This switchover process is prepared for a switchover to the backward rotation if the current setting is the forward rotation and for a switchover to the forward rotation if the current setting is the backward rotation. Information indicating the forward/backward rotation is always kept at a memory in the control circuit **70**, and the determination at step S**140** uses the information. In consequence, by controlling the drive of the motor **650**, the rotating deflection mechanism **640** is driven to reciprocate the deflection member **641** by the given rotation range.

When the determination at step S**180** is NO, the processing is returned to step S**110**, where the newly rotated angle of the deflection member **641** at step S**150** or S**160** is subjected to the scanning and detection of objects.

The predetermined constant angle is not always limited to 1 degree, but may be smaller or larger than this angle. The rotation step angle of the cam **681** is also not always be limited to 45 degrees, but may be smaller or larger than this angle.

In this way, in the present embodiment, the deflection member **641** is tiltably supported, and oscillated by the cam mechanism **680** to be oscillated by a given tilting angle range in a controlled manner. Hence, the deflection member **641** can be supported stably and controlled in its tilt action.

Furthermore, the cam mechanism **680** and the motor **682** compose the oscillation means which is controlled by the control circuit **70**. Thus the oscillation means can be produced in a relatively simplified and compact structure, while still oscillating the deflection member **641** reliably.

The oscillation means (the cam mechanism **680** and the motor **682**) and the deflection member **641** are unified and rotated together, and the motor **682** is powered by the external power supply which is not rotated together with such unified unit. Thus the rotated portion including the deflection member **641** can be simplified in its construction. Additionally, the power line **686** electrically connects the motor **682** and the external power supply and the deflection member **641** is reciprocated by the given rotation range. Therefore, though the oscillation means is adopted, this means is powered well from the external power supply.

Eighth Embodiment

Referring to FIGS. **17**-**18**A and **18**B, a laser radar apparatus according to an eighth embodiment of the present invention will now described.

FIG. **17** shows an outlined configuration of a laser radar apparatus **700** according to the present embodiment. The laser radar apparatus **700** is provided with a rotating deflection mechanism **740** including an oscillation unit **780**, instead of the foregoing rotating deflection mechanism **640**. The remaining components are the same or identical to those employed by the seventh embodiment, so the explanation will center on the oscillation unit **780**.

The laser beam L1 from the laser diode **10** is reflected substantially at the right angle by the mirror **630**, and is radiated to a central area of the deflection member **641** of the rotating deflection mechanism **740**. In this mechanism **740**, the deflection member **641** is rotatable on both the central axis **642***a* and the axis **641***a* perpendicular to the central axis **642***a*. The deflection member **641** acts as the deflection means for the incident light beam L1 and the incident reflected light from objects, which are the same as the described. The deflection member **641** is driven by the motor **650** to rotate.

As shown in FIG. **18**A, the oscillation unit **780**, which functions as the oscillation means, is provided with a rotation member **781** and a motor **782** rotating the rotation member **781** on the rotation shaft **783** of the motor **782**. The rotation member **781** consists of two parts, but unified together so as to be rotatable on the rotation shaft as an axis. Such two parts are a large-radius part **781***a* of which radium is larger and a small-radium part **781***b* of which radium is smaller. As shown in FIG. **18**A, the large-radium part **781***a*, which can come in contact with an end of the deflection member **641**, and lifts up the end for the support when the contact is achieved. In contrast, as shown in FIG. **18**B, the small-radium part **781***b*, which can come in contact with the end of the deflection member **641**, and lifts down the end for the support when the contact is achieved.

Thus, the rotation of the motor **782** allows the oscillation unit **780** to realize a switchover between two stages. In one state, the large-radium part **781***a* supports the end of the deflection member **641** at a higher spatial position, as shown in FIG. **18**A. In the other stage, the small-radium part **781***b* supports the end of the deflection member **641** at a lower spatial position, as shown in FIG. **18**B. Thus the end of the deflection member **641** oscillates up and down. Since the deflection member **641** is supported to be rotatable on the axis (shaft) **641***a* located at the longitudinal center thereof, the oscillation of the end of the deflection member **641** permits the whole deflection member **641** to move in the tilting direction. The oscillation unit **780** is part of the direction changing means and the tilt means.

The drive of the motor **782** is controlled by the control circuit **70**, so that the oscillation of the end of the deflection member **641** is controlled by the control circuit **70**. Various motors such as a stepping motor or DC motors can be applied to the motor **782**.

Furthermore, as shown in FIG. **18**B, a extending member **742** is extended from the lower face of the deflection member **641**. This extending member **742** is displacably engaged with a guide member **744** fixed to a frame **743** on the shaft member **642**. Specifically, a protrusion **742***a* is formed on the end of the extending member **742**, and a guide groove **744***a* is obliquely formed in the guide member **744**. The protrusion **742***a* is fit with the guide groove **744***a* and guided therealong. The extending member **742** and the guide member, which function as a limiting means, are to limit the supported end of the deflection member **641** from oscillating outside a given oscillation range. In FIG. **17**, the extending member **742** and the guide member **744** are omitted from being depicted.

To detect the tilt of the deflection member **641**, a sensor **745** is placed. This sensor **745** is a known position sensor to detect the poison of the protrusion **742***a*. Because the position of the protrusion **742***a* is found, the tilt of the deflection member **641** can be decided uniquely, the tilt of the deflection member **641** can be detected by detecting the position of the protrusion **742***a*.

The oscillation unit **780** is rotated together with the deflection member **641** and powered by the commercial power supply **687** placed externally so as not to rotate. The power line **686** also electrically connects the commercial power supply **687** and oscillation unit **780** for the power transmission. The power line **686** is arranged in the same way as that explained in the previous embodiment. The remaining configurations are also the same as those in the previous embodiment.

In the present embodiment, the deflection member **641** is rotated every predetermined constant angle (for example, 1 degree) on the central axis **642***a*, so that the longitudinal (Y-axis directional) laser beam scanning in the external field is made at each rotated angle position. The longitudinal scanning is carried out by making the oscillation unit **780** oscillate the deflection member **641**.

In other words, when the deflection member **641** is oscillated, the deflection member **641** changes its tilt positions between two tilted states shown by solid lines and dashed lines in FIG. **17**. When the photodiode **20** detects the reflected light, the control circuit **70** reads a signal from the position sensor **745** to understand the tilt of the deflection member **641**.

The control circuit **70** constantly monitors the rotated position of the motor **650**, and understands it when the photodiode **20** detects the reflected light. Hence, by the control circuit **70**, on the basis of both the signal from the signal from the sensor **745** and the rotated position of the motor **650**, the direction of an object calculated. The distance from the object to the apparatus is also calculated in the same way as described.

In the present embodiment, the rotating deflection mechanism **740** is provided, so the laser beam L**1** can be scanned three-dimensionally in the external field outside the present laser radar apparatus **700**.

In particular, the deflection member **641** is tiltably supported by the tilt member and the given position (the end) of the deflection member **641** is oscillated by the oscillation unit **780** in a controlled manner under the control of the control circuit **70**. Thus the deflection member **641** is held stably and the tilt of the deflection member **641** is controlled reliably.

Further, the limit means limits the deflection member **641** from oscillating through the given oscillation range. Thus it is not necessary to change the incident direction of the laser beam to the deflection member beyond a necessary angle range, while still controlling the emitting direction of the laser beam from the deflection member **641** through the necessary desired angular range in the longitudinal direction, that is, the Y-axis direction along the central axis **642***a*.

The oscillation unit **780**, which is able to rotate together with the deflection member **641**, can be powered from the external power supply positionally fixed. Thus, as to this powering system, the advantages stated in the previous embodiment are gained in the present embodiment.

Ninth Embodiment

Referring to FIGS. **19-21**, a laser radar apparatus according to a ninth embodiment of the present invention will now described.

The present embodiment concerns another modification of how the deflection member is supported.

FIG. **19** outlines the configuration of a laser radar apparatus **800** according to the present embodiment. As shown, the present laser radar apparatus **800** is provided with a mirror **830**, a rotating deflection mechanism **840** and a motor **850**, in place of the mirror **630**, the rotating deflection mechanism **740**, and the motor **650** explained in the seventh and eighth embodiments. The control circuit **70** is also provided, but components to be controlled by this control circuit **70** and how to control such components are different from the previous configuration.

Of the replaced components, the motor **850** is coupled with a shaft member **842** which is different from the previous one.

The rotating deflection mechanism **840** has a central axis **842***a* on which this mechanism **840** is rotatable. In the same manner as the previous ones, the Y-axis is given to the direction of this central axis **842***a* and the same XYZ orthogonal coordinate system as that described is assigned to this apparatus **800**.

The rotating deflection mechanism **840** is provided with a deflection member **841**. Thus, the laser beam L**1** emitted from the laser diode **10** in the X-axis direction is reflected almost perpendicularly by the mirror **830**, and enters a central part of the deflection member **841** functioning as the deflection means. This member **841** is also rotatable on the central axis **842***a*. The deflection member **841** referents (i.e., deflects) the incident laser beam L**1** toward a field observed outside the apparatus **800** and receives reflected light L**2** from objects in the field. The deflection member **841** also reflects (i.e., deflects) the reflected light L**2** toward the photodiode **20**. The rotating deflection mechanism **840** is driven to rotate by the motor **850**. The motor **850** and the control circuit **70** are combined to form the drive means to rotate the deflection member **841**.

In the present laser radar apparatus **800**, the rotating deflection mechanism **840** differs largely from that in the first embodiment, though its shape is similar to that in the first embodiment. As shown in FIGS. **20** and **21**, this rotating deflection mechanism **840** is provided with the foregoing deflection member **841** which is a mirror, a support base **843** supporting the deflection member **841** thereon and a cylindrical shaft member **842** coupled with the support base **843**. The deflection member **841** has a reflection surface **841***a* oblique to the central axis **842** serving as the rotation center of the deflection member **841**. The deflection member **841** is rotatably supported by the support base **843** so as to be rotatable about a rotation center shifted from the central axis **842***b*.

The cylindrical shaft member **842**, which is formed as the rotation shaft or a shaft coupled the rotation shaft of the motor **850**, is cylindrical and an end coupled with the support base **843**. The support base **843** is provided with a square plate member **844** and a pair of bearings **845** disposed on both width-directional ends at one length-directional end of the plate member **844**. The plate member **844** is arranged perpendicularly to the central axis **842***b*. A hole **844***a* is formed at a position of the plate member **844** therethrough, in which the position is subjected to coupling with the cylindrical shaft member **842** so as to make the hole **844***a* communicate with a cylindrical bore **842***b* of the shaft member **842**. A piezoelectric actuator **801** is arranged within the bore **842***b* to protrude upward therefrom.

On both width-directional sides of the deflection member **841**, two protrusions **841***b* are fixedly formed to protrude outward. The protrusions **841***b* are held by the bearings **845**, so that deflection member **841** is rotatable around a rotation shaft **845***a*. The bearings **845** and the protrusions **841***b* compose a rotating deflection mechanism **846**, which functions as the tilt mechanism tiltably supporting the deflection member **841** around the rotation shaft **845***a*. The deflection member **841** and the support base **843**, which are coupled with each other by the rotating deflection mechanism **846**, can be rotated as one unit by the rotation of the cylindrical shaft member **842** driven by the motor **850**.

The piezoelectric actuator **801** is a known actuator with a piezoelectric element which extends and contact in response to voltage to be applied. This piezoelectric actuator **801** has a piezoelectric driving element **801***a* and a drive circuit **801***b* which drives the driving element **801***a*. The drive circuit **801***b* is electrically connected to the control circuit **70** so that the drive circuit **801***b* applies voltage to the driving element **801***a* in reply to a command signal from the control circuit **70**. The command signal from the control circuit **70** gives the applied voltage an amount to be controlled of the motion of the element **801***a*.

The piezoelectric driving element **801***a* is rotatable independently of the deflection member **841** and gives the oscillating action to the deflection member **841** at the fixed position in the laser radar apparatus **800**. This element **801***a* is fixed on a support member **803** within the cylindrical shaft member **842**. The support member **803** is secured on the casing directly or via other members. And the cylindrical shaft member **842** is rotatable independently of the piezoelectric driving element **801***a*.

As shown in FIG. **20**, the driving element **801***a* contained in the cylindrical shaft member **842** extends or contacts in response to the voltage to be applied, thus pushing the deflection member **841** or stopping the push to the deflection member **841**. Thus, the command signal is able to oscillate the given part (i.e., the position pushed by the element **801***a*) of the deflection member **841**.

Thus, in the rotating deflection mechanism **840**, depending on the command signal in which the amount to be controlled is reflected, the protruding (extension/contraction) amount of the driving element **801***a* is adjusted. In response to this adjustment, the deflection member **841** is tilted around the rotation shaft (axis) **845***a* perpendicular to the central axis **842***b*. This tilting action causes the incident direction of the laser beam L**1** to the reflection surface **841***a* to change relatively to the laser beam L**1**, resulting in that the direction of the laser beam from the deflection member **841** is changed (i.e., scanned) in the cognitional (Y-axis) direction along the central axis **842***b*. This scanning is illustrated by solid lines L**2** and dashed lines L**2'**. The solid lines L**2** and dashed lined L**2'** show the travel of the laser beam and the reflected light, which is obtained when the deflection member **841** takes a tilted attitude shown by a solid line and a tilted attitude shown by a dashed line, respectively. The Y-axis directional width between the solid lines L**2** or dashed lines L**2'** shows a range through which the reflected light is taken in.

Depending on the protruded length (extension/contraction) of the piezoelectric driving element **801***a*, the degree of tilt of the deflection member **841** is decided. Thus, controlling the command signal leads in a precise control of the tilt of the deflection member **841**. The control circuit **70** is responsible for controlling the motor **850**, so that this circuit **70** knows information showing the rotated state of this motor **850**. Hence, the control circuit **70** is able to calculate the rotated position of the cylindrical shaft member **842**, thereby calculating the three-dimensional direction of the laser beam emitted form the deflection member **814** into a field to be observed. The distance from an object to the apparatus can be calculated as well in the same way explained.

In the present embodiment, the part of the deflection member **841** is given the push force by the piezoelectric driving element **801***a* which responds to the drive signal from the drive circuit **801***b* which is the under control of the control circuit **70**. That is, the extension and contraction of this element **801***a* cause the deflection to be tilted and not to be tilted in a controlled manner. This tilting action allows the laser beam L**1** from the apparatus **800** to be scanned in the longitudinal direction. Moreover, this longitudinal scanning can be performed at each angular position on the XY plane, thereby a three-dimensional high-precision scanning action in the field outside the apparatus **800**.

For scanning the longitudinal direction, it is enough that only part of the deflection member **841** is pushed or not pushed, which is relatively simple in its structure and accurate in controlling the push, that is, the oscillating action.

Further, the extension/contraction means is realized by using the piezoelectric element, thus preventing the means from being excessively large in size, but still maintaining the oscillation control at higher level.

(Modifications)

Referring to FIGS. **22**-**23**, modifications of the ninth embodiment will now be described.

(First Modification)

FIG. **22** shows a first modification, in which there is provided another type of rotating deflection mechanism **840**A.

As shown in FIG. **22**, this rotating deflection mechanism **840**A is different from the previous one **840** in that a size-changeable member **811***a* is adopted as the extension/contraction member, instead of the piezoelectric driving element **801***a* and an air-amount adjusting unit **811***b* is adopted as the extension/contraction-member drive means, instead of the drive circuit **801***b*. The remaining members are the same at those in the ninth embodiment. Controlling the drive of the air-amount adjusting unit **811***b* allows a given part of the deflection member **841** to be controlled in its oscillation. The given part is pushed by the size-changeable member **811***a*.

The rotating deflection mechanism **840**A is constructed in the same way as that in FIG. **20**.

The size-changeable member **811***a* is contained in the cylindrical bore **842***b* of the cylindrical shaft member **842** so as to intrude in the hole **844***a* of the plate member **844**. The outer size of this member **811***a* can be changed in accordance with the amount of air to be charged therein, so that this change appears as a change in the protrusion form the plate member **844**. This size-changeable member **811***a* has an accordion-shaped outer appearance and two ports consisting of a charge port **812** and a discharge port **813** located on both ends. The charge port **812** is for supplying this member **811***a* with air discharged by the air-amount adjusting unit **811***b*. The discharge port **813** is used when the air contained in the member **811***a* is discharged into the air-amount adjusting unit **811***b*.

The control circuit **70** is configured to command the air-amount adjusting unit **811***b* to adjust the amount of air to be charged or discharged using a command signal to the unit **811***b*.

The air-amount adjusting unit **811***b*, which functions as the gas-amount adjusting means, includes a first flow amount sensor detecting an amount of air supplied to the size-changeable member **811***a* via the port **812**, a second flow amount sensor detecting an amount of air discharged from the member **811***a* via the port **813**, an air supply device, such as an air pump and an air compressor, supplying the air, and electromagnetic valves or others selectively opening and closing air supply passages and air discharge passages.

In the configuration according to this modification, the deflection member **841** is rotatable independently of the size-changeable member **811***a*, which oscillates the deflection member **841** at the given location in the apparatus. This member **811***a* is fixed on the support member **803** within the cylindrical shaft member **842** in the same manner as that described in FIG. **20**. Thus, this member **842** is rotatable around the size-changeable member **811***a*.

In this modification, depending on the amount of air contained in the size-changeable member **811***a*, the tilt of the deflection member **841** is decided. Making the control circuit **70** control the amount of air supplied from the air-amount adjusting unit **811***b* makes it possible to accurately adjust the tilting angle of the deflection member **841**. By this tilting action, the laser beam emitted from the apparatus can scan in the longitudinal (Y-axial) direction an external field outside the a apparatus at each of the angular stepping angular positions along the XY plane, providing the three-dimensional scanning. This scanning results in an easier and more reliable measurement of the three-dimensional direction of each object and the distance therefrom in the same manner described.

Hence, the configuration of this modification provided the same or similar advantages as or to those in the ninth embodiment. In other words, the configuration can be simplified and larger amounts of extension/contraction can be secured easily.

(Second Modification)

FIG. **23** shows a second modification, in which there is provided another type of rotating deflection mechanism **840**B.

As shown in FIG. **23**, this rotating deflection mechanism **840**B is different from the previous one **840** in the oscillation means and the tilt control means. The remaining members are the same at those in the ninth embodiment.

The modification provided in FIG. **23** comprises a transmission member **821** transmitting a push force to the deflection member **841**, a reciprocating mechanism **822** reciprocating the transmission member **821**, and a motor **823** driving the reciprocating mechanism **822**. This motor **823** exemplifies the reciprocating-mechanism drive means. By the reciprocating motion of the transmission member **821**, the deflection member **841** can be tilted.

The transmission member **821** is fit into the cylindrical shaft member **842** and can be reciprocated therein in the up and down direction, that is, the Y-axis direction. This transmission member **821** is rotatably coupled with an arm **822***a*, which is rotatably coupled with another arm **822***a*. The second arm **822***b* is driven to rotate by the motor **823**. Thus the arms **822***a* and **822***b*, transmission member **821**, and cylindrical shaft member **842** constitute a crank and piston mechanism to covert the rotation motion to the linear motions. The transmission member **821** is forced to move up and down depending on the rotations of the motor **823**, changing amounts of protrusion of the transmission member **821** emerging from the plate member.

A combination of the rotating deflection mechanism **846**, transmission member **821**, reciprocating mechanism **822**, and motor **823** exemplifies the direction changing means and the tilt means. Further, the transmission member **821**, reciprocating mechanism **822**, and motor **823** exemplifies the oscillation means that oscillates the given part of the deflection member in the up and down direction.

The remaining components are the same as those in the first modification.

Accordingly, the second modification provided the same or similar advantages as or to those in the first modification. The use of the transmission member **821** is effective for pushing the part of the deflection member **841**, which is still confined to the simplified structure. The motor **823** is driven by the control circuit **70**, which allows the given plate part to oscillate. The tilt of deflection member **841** can thus be controlled with precision, with the result that it is possible to perform an accurate three-dimensional detection of objects.

Tenth Embodiment

Referring to FIGS. **24-27**, a laser radar apparatus according to a tenth embodiment of the present invention will now described.

FIG. **24** outlines the configuration of a laser radar apparatus **900** according to the present embodiment. This configuration is different from that shown in the seventh-ninth embodiments in the rotating deflection means and oscillation means. The remaining parts are the same or similar as or to those in the seventh-ninth embodiments, which are omitted from explaining in detail.

As shown in FIG. **24**, the laser radar apparatus **900** is provided with, as some of new components, a rotating deflection mechanism **940**, a motor **950** having a shaft member **942**, and first and second edge oscillating units **961** and **965**. The shaft member **942** is different from that in the first embodiment, but the motor **950** itself is the same as that in the first embodiment.

The rotating deflection mechanism **940** has a central axis **942***a* on which this mechanism **940** is rotatable. The direction along the central axis **942***a* is set to the Y-axis and the remaining X- and Z-axis are set to the same as those described already.

To be specific, the rotating deflection mechanism **940** includes a deflection member **941** (serving as the deflection means) which is a mirror and rotatable on the central axis **942***a*, a shaft member **942**, a flat plate-like flange **943** serving as a base plate, and a coupling mechanism **944**. The shaft member **942** is driven to rotate by the motor **950**. The flange **943** is unified with the deflection member **941** as one unit. The coupling mechanism **944** couples the shaft member **942** and the flange **943**.

The deflection member **941** has a flat reflection surface **941***a* which is oblique to the central axis **942***a* and located to receive the incident laser beam L**1**. The reflection surface **941***a* functions in the same way as that in the first embodiment. The deflection member **941** responds to the oscillation of the oscillation means late described such that the tilting angle of the surface **941***a* to the central axis **942***a* is controllably changed. In response to the drive of the moor **950**, the deflection member **941** is also rotatable on the central axis **942***a* which is along the Y-axis.

The flange **943** exemplifies the unified swing member. As shown in FIGS. **25** and **27**, the flange **943** is formed to have an almost circular shape having an outer edge which extends more than the outer edge of the deflection member **941**. The flange **943** is rigidly coupled with the lower surface portion of the deflection member **941** so that the flange **943** can be rotated and oscillated together with the deflection member **941**. Additionally, the flange **943** is linked with the shaft member **942** via the coupling mechanism **944**.

The shaft member **942** is produced as the rotation shaft of the motor **950**. On the top of the shaft member **942**, the coupling mechanism **944** is arranged. As illustrated in FIGS. **25**A, **25**B and **26**A, **26**B, the coupling mechanism **944** is a ball joint, which is constructed like shown in FIG. **7**. That is, the coupling mechanism **944** includes a spherical portion **944***a* and a spherical shell portion **944***b* which are assembled into a spherical bearing stud and socket, which is described in FIG. **7**. The flange **943** and the coupling mechanism **944** compose the tilt mechanism which tiltably supports the deflection member **941**.

As shown in FIG. **26**, the shaft member **942** is provided with a protrusion **945** to transmit the rotation force of the shaft member **942** to the spherical shell portion **944***b* of the coupling mechanism **944** (practically, to a protrusion **946** on the spherical shell portion **944***b*). The protrusion **945** from the shaft member **942** forcibly rotates around the spherical shell portion **944***b* by the rotation of the shaft member **942**. The configuration shown in FIGS. **26**A and **26**B is just one example, so any other configurations can be adopted provided that the flange **943** is swingably held during which time the rotation of the shaft member **942** can be transmitted to the flange **943**. By way of example, a universal joint may be employed to couple the flange **943** and the shaft member **942**.

Further, as shown in FIGS. **24**, **25**A, **25**B and **27**, the first and second edge oscillating units **961** and **965** are provided as the edge oscillating means to oscillate (i.e., lift up and down) the edge of the flange **943**. The first edge oscillating unit **961** includes a transmission member **962** transmitting a force to the deflection member **941** via the flange **943**, a reciprocating mechanism **963** reciprocating the transmission member **943**, and a motor **964** driving the reciprocating mechanism **963**. This first edge oscillating unit **961** is in charge of oscillating (i.e., lifting up and down) a first edge position of the flange **943**, so that the deflection member **941** can be oscillated up and down in an oblique direction to the central axis **942***a.*

The transmission member **962** is typically shown in FIGS. **25**A, **25**B, **27**A and **27**B, in which this member **962** is fit in grooves of both-side guide member **963***c* arranged at a fixed position in the apparatus **900** (refer to FIGS. **27**A and **27**B). The guide members **963***c* are in parallel with the central axis **942***a*, so that the transmission member **962** can be guided by the guide member **963***c* so as to be slid in the up and down direction. An arm **963***a* is rotatably linked with this transmission member **962**, and another arm **963***b* is rotatably linked with this arm **963***a* (refer to FIGS. **25**A and **25**B). The arms **963***a* and **963***b* and the guide member **963***c* compose the reciprocating mechanism **963**.

The arm **963***b* is driven by a motor **964**, so that the reciprocating mechanism **963** converts the rotating motion of the motor **964** to the liner motion of the transmission member **962**. The transmission member **962** has a groove **962***a* into which the edge of the flange **943** is located with a predetermined-height clearance left therein. Thus the flange **943** is allowed to rotate in response to the drive of the motor **950** under the condition that its edge is still located in the groove **962***a*. Hence rotating the motor **964** to a given first rotation position makes the reflection surface **941***a* of the deflection member **941** keep a first oblique attitude shown in FIG. **25**A. Rotating the motor **964** to a given second rotation position allow the reflection surface **941***a* to keep a second oblique attitude as shown in FIG. **25**B. A spring may be placed to push the flange **943** at the opposite position to the transmission member **962** shown by an arrow F**2**, which gives a stable positioning action to the deflection member **941**.

The second edge oscillating unit **965** is shown in FIG. **27**A, though part of which is omitted from the drawing. This unit **965** is identical to that of the first edge oscillating unit **961** and includes a transmission member **966** to give a up-and-down push force to the flange **943** as well as a reciprocating mechanism (not shown) and a motor (not shown). The first and second edge oscillating units **961** and **965** are located separately from each other as shown in FIGS. **27**A and **27**B. The first edge oscillating unit **961** is located at a first edge position shown by M**1**, while the second one **965** is located at a second edge position shown by M**2** which is 90 degrees apart from M**1** about the central axis **942***a* (refer to FIG. **27**A). The references M**1** and M**2** show imaginary planes each including the central axis **942***a* and passing the transmission member **962** (**966**).

The control circuit **70** includes a microcomputer with a CPU and memories, as described in the first embodiment, and is configured to perform given software programs for detecting objects and controlling the drive of the various motors or others. Such programs are installed beforehand in a memory of the microcomputer.

In the present laser radar apparatus **900**, when the deflection member **941** is located at given rotation positions, the second edge oscillating unit **965** woks to oscillate the flange **943**. However, the deflection member **941** is located at rotation positions other than the given rotation positions, the first edge oscillating unit **961** works. This separate operation is achieved by the control circuit **70** which controls the drive of the various motors.

Specifically, the given rotation positions are decided as rotation positions which permits an angle between another imaginary plane M**3** and the foregoing imaginary plane M**1** to be equal or large to or than a given threshold (for example, 45 degrees), where the third imaginary plane M**3** is a plane including the central axis **942***a* and being perpendicular to the reflection surface **941***a*. In this case, as shown in FIG. **27**B, the second edge oscillating unit **965** oscillates the edge of the flange **943**. As shown FIG. **27**A, in the cases other than the above, that is, when the angle between the planes M**3** and M**1** is smaller than the given threshold, the first edge oscillating unit **961** oscillates the edge of the flange **943**.

FIG. **24** shows the case in which the angle between the imaginary planes M**1** and M**3** is smaller than the threshold and the first edge oscillating unit **961** is in operation. That is, when this unit **961** is driven to the state shown in FIG. **24**, the deflection member **941** is located as shown by a solid line, so that the laser beam is emitted from the apparatus **900** as a solid line and the reflected light returns as shown by solid lines L**2**. In this situation, when the unit **961** is driven to a new state to allow the deflection member **941** to be oblique as shown by dashed line in FIG. **24**, the path of the laser beam is changed to L**1'** and the path of the reflected light is changed to L**2'**.

This means that the laser beam L**1** is transmitted in a specified direction in the XZ plane and scanned in the longitudinal (Y-axis) direction in the field outside the apparatus **900**. This scanning is carried out repeatedly at the next angular position in the XZ plane using the first or second edge oscillating units **961** or **965**, resulting in the three-dimensional scanning of the field.

Thus, the present embodiment provides the same or identical operations and advantages to those in the first embodiment. Additionally, the oscillation means is divided into the first and second edge oscillating units **961** and **965** which selectively work at the different edge positions and at the different angle zone. Hence the rotationally driving mechanism for the deflection mechanism **940** can be made compact in size and less in weight, thus improving accuracy in rotation control and speeding up the rotation. The motor **950** can also be made compact in size. In addition, since the first and second edge oscillating units **916** and **965** oscillates the flange **943** at the different fixed positions in the apparatus **900**, so that power supply and control signal transmission can be made easier, compared to the structure in which the oscillation means and deflection means are unified together.

The shaft **942** and the flange **943** can be rotated together, while the oscillation means is divided into the units **961** and **965** so as to oscillate at the different edge portions. Thus the oscillating means and the deflection means can be worked separately, so the oscillation means can be located at given, but desired positions in the apparatus, while still providing the oscillating and deflecting functions. The flange **943** is swung at its edge portions, resulting in that the force for the oscillation becomes smaller, compared to the case where the oscillating force is applied to the central part of the flange. This is effective for producing a compact, lower parts-cost apparatus.

As described, the first and second edge oscillating unit **961** and **965** are separated from each other to oscillate (i.e., apply a force) the first and second edge positions and are selectively used depending on the rotation position of the deflection member **941**. As a result, the flange **943** can be swung (tilted up and down) along multiple imaginary planes, not limited to being along a particular pane, increasing the degree of swinging. The deflection member **941**, rotated together with the flange **943**, can also be swung depending on each rotation position in the XZ (horizontal) plane, leading to a preferred scanning in the Y-axis (longitudinal) direction.

Eleventh Embodiment

Referring to FIGS. **28-30**, a laser radar apparatus according to an eleventh embodiment of the present invention will now described.

FIG. **28** outlines the configuration of a laser radar apparatus **1000** according to the present embodiment. This configuration is different from that shown in the seventh-tenth embodiments in the rotating deflection means. The remaining parts are the same or similar as or to those in the seventh-tenth embodiments, which are omitted from explaining in detail.

As shown in FIG. **28**, the laser radar apparatus **1000** is provided with a mirror **1030** and a rotating deflection mechanism **1040** having a deflection member **1041** and a central axis **1042***a*, to which the Y-axis is assigned like the foregoing apparatuses. The mirror **1030** is arranged to receive the laser beam L**1** emitted from the laser diode **10** in the X-axis direction and reflect it almost perpendicularly toward the rotating deflection mechanism **1040**. The incident laser beam L**1** onto this mechanism **1040** enters a central part of the deflection member **1041**.

The rotating deflection mechanism **1040** includes the deflection member **1041** described above, a shaft member **1042**, a protruding member **1043** protruding from the deflection member **1041**, a coupling mechanism **1044**, and a motor **1050** driving the shaft member **1042**. The deflection member **1041** is a mirror.

The deflection member **1041** is rotatable on the central axis **1042***a* by the drive of the motor **1050**, and its deflection actions are the same as that described before.

The coupling unit **1044** includes protrusions **1042***a* protruding from both sides of the shaft member **1042** and a bearing **1043***a* rotatably supporting the protrusions **1042***b*, giving a rotatable support between the shaft member **1042** and the protruding member **1043**. The coupling unit **1044** serves as a support mechanism for tiltably supporting the deflection member **1041**.

The deflection member **1041**, which is tiltably supported by the coupling unit **1044**, includes a reflection surface **1041***a* oblique to the central axis **1042***a*, so that the angle between the reflection surface **1041***a* and the central axis **1042***a* changes as the deflection member **1041** is made to tilt. The protrusions **1042***b* provide a rotation axis on which the protruding member **1043** rotates. This rotation axis is perpendicular to the central axis **1042***a*, i.e., the Y-axis. Hence, the motor **1050** is driven to rotate, the shaft member **1042** is rotated, and the coupling unit **1044** is rotated, which enables the imaginary rotation axis passing the protrusions **1042***b* to rotate around the central axis **1042***a* in the XZ plane.

The laser radar apparatus **1000** is further provided with a pair of rotation units **1045** and **1046**, which are arranged below the deflection member **1041** and configured to rotate together with the deflection member **1041**. Each of the rotation units **1045** and **1046** extends radially from the rear face of the bottom of the deflection member **1041** so as to step away from the central axis **1042***a* in the XZ plane lower in level than the deflection member **1041**. For this arrangement, each of the rotation units **1045** and **1046** includes a fixed member **1045***a* (**1046***a*) fixed to the rear race of the bottom of the deflection member **1041** and a rotation member **1045***b* (**1046***b*) rotatably attached to a distal end of each fixed member **1045***a* (**1046***a*).

As shown in FIGS. **28** and **29**, the present laser radar apparatus **1000** is further provided with an annular guide passage **1047** fixedly arranged to pass the positions of the rotation units **1045** and **1046** by surrounding the rotating deflection mechanism **1040**. This guide passage **1047** provides a rail portion guiding the distal end of each rotation unit **1045** (**1046**). While the rotation of the motor **1050**, the rotation units **1045** and **1046** is rotated as well, during which time the guide passage **1047** enables the distal end of each rotation unit positionally to change in the direction of the central axis **1042***b*, that is, in the Y-axis direction. For realizing this, the guide passage **1047** has a unique guide path, which will now be described.

The guide passage **1047** has an annular trough portion as the guide path, and the trough portion has a box shape with one-end open when being viewed in section. The rotation members **1045***b* and **1046***b* of the rotation units **1045** and **1046** are inserted in the trough portion and guided along the guide plane as the deflection member **1041** is rotated. The rotation members **1045***b* and **1046***b* are rollers so that the rotation members can be held and rolled in the trough portion of the guide passage **1047**.

As shown in FIG. **30**, the trough portion of the guide passage **1047** is formed to continuously change in level in the direction of the central axis **1042***a*, that is, the Y-axis direction. Practically, the trough portion consists of first upward curved portions **1047***b* and second downward curved portions **1047***c*, which are arranged alternately to form, for example, a sine-curve path. Thus, this path consists of a gradually-rising path and a gradually-falling path, which come alternately. The displacements (levels) of rising and falling in the Y-axis direction are set to the same.

The rotation units **1045** and **1046** are opposed to each other with the central axis **1042***a* located therebetween, and inserted into the guide passage **1047**. Hence, in consideration of this arrangement, the trough portion of the guide passage **1047** is produced such that each of the first upward curved portions **1047***b* is opposed to each of the second downward curved portions **1047***c* with the central axis **1042***b* located therebetween. Thus, whenever, of two rotation units **1045** and **1046**, one rises, the other always falls.

The rotation units **1045** and **1046** and the guide passage **1047** serve as the direction changing means, so that during the rotation of the deflection member **1041** along the XZ plane in response to the rotation of the motor **1050**, the distal ends of the rotation units **1045** and **1046** undulate at given cycles in the Y-axis direction along the central axis **1042***a*. This undulation of the rotation units **1045** and **1046** is converted to swinging (tilting up and down) motions of the deflection member **1041** in the Y-axis direction, giving relative positional changes to the incident laser beam L**1**, that is, relative changes in its incident direction. In the present embodiment, the undulation is set to cause the deflection member **1041** to tilt between two attitudes shown by a solid line and a dashed line in FIG. **28**. As a result, the direction of the laser beam L**1** emitting from the deflection member **1041** is changed, i.e., scanned in the Y-axis direction.

The motor **1050** is similar to that in the first embodiment except for the structure of the shaft member **1042**. The control circuit **70** is also configured in the same way as that in first embodiment except for the components to be controlled and how to control them. The contents of the control have been explained above. The combination of the motor **1050** and the control circuit **70** functions as the drive means, and the control circuit **70** also functions as the control means.

In the present radar apparatus **1000**, when the Y-axis directional positions of the rotation members **1045***b* and **1046***b* are the same, the deflection member **1041** takes an attitude shown by the solid line in FIG. **28**. In this case, the laser beam L**1** travels along the path shown by a solid line, while reflected light L**2** returns along solid lines and enters the deflection member **1041**. Meanwhile, the deflection member **1041** takes an attitude shown by the dashed line, when this member **1041** is rotated to another angular position in the XZ plane. This is caused due to the undulation path of the guide passage **1047** as described. Thus the laser beam L**1** travels along a line L**1**' into the field outside the apparatus and reflected light L**2**' returns to the deflection member **1041** along dashed lines.

It is therefore possible that the present embodiment provide the identical or similar advantages to those explained already, which is a preferable three-dimensional detection of objects. In addition, because the rotation units **1045** and **1046** and the guide passage **1047** are combined as above, the relative position of the deflection member **1041** to the laser beam L**1** can be changed. It is not necessary to adopt any particular actuator to swing or tilt the deflection member **1041**. Thus the power of the motor **1050** can be used for both the rotation and the swing or tilt of the deflection member **1041**. This helps to reduce production costs and to lower the apparatus weight.

The annular guide passage **1047** is adopted, in which the undulation path is formed, at least, over a part thereof. This undulation path makes the deflection member **1041** swing or tilt reliably. It is possible to arrange this annular guide passage **1047** so as not to interfere with the rotation of the deflection member **1041** in the apparatus. This arrangement can be made compact. The annular guide passage **1047** provides a stable support and a smooth guide of the rotation units.

(Modifications)

The form of the guide passage **1047** is not limited to that described in FIG. **30**. FIG. **31** show another example, in which there is formed straight segments **1047***d* each connecting adjacent curved portions **1047***b* and **1047***d*. This also provides an undulation path that changes in the Y-axis direction.

The configuration shown in FIG. **28** may be replaced by that shown in FIG. **32**. The laser radar apparatus **1100** shown in FIG. **32** differs from that in FIG. **28** in that there is provided a rotating deflection mechanism **1140**. Practically, the foregoing rotation units **1045** and **1046** are replaced by other rotation units **1048***a* and **1048***b* and the trough width of the guide path is made to agree with the sizes of ends of the rotation units **1048***a* and **1048***b*. The remaining configurations are the same as those in FIG. **28**.

In this configuration, no rotation member is employed by the rotation units **1048***a* and **1048***b*. That is, the rotation units **1048***a* and **1048***b* are just formed into an arm with no rotation member, unlike the ones shown in FIG. **28**. The arm-like distal end is directly fit into the trough of a guide passage **1049**. This guide passage **1049** is identical in the shape and sine-curve guide path to the foregoing guide passage **1047**, like shown in FIG. **30**A, except for the trough width.

Thus when the motor **1050** is driven to rotate, the deflection member **1041** and the rotation units **1048***a* and **1048***b* rotates together, whereby the distal ends of both units **1048***a* and **1048***b* slide along the inner walls (guide path) of the guide passage **1049**. It is therefore possible to provide the same operations and advantage as those gained in the previous embodiment. The guide passage **1047** provides a smooth and stable, but undulated slide motion to the rotation units **1048***a* and **1048***b*, which gives the deflection member **1041** smooth and reliable swing (tilt) operations.

Twelfth Embodiment

Referring to FIGS. **33**-**35**, a laser radar apparatus according to a twelfth embodiment of the present invention will now described.

FIG. **33** outlines the configuration of a laser radar apparatus **1200** according to the present embodiment. This configuration is different from that shown in the first embodiment in the rotating deflection means. The remaining parts are the same or similar as or to those in the first embodiment, which are omitted from explaining in detail.

The laser radar apparatus **1200** is provided with a rotating deflection mechanism **1240** to which the central axis **42***a* is given. The direction of this central axis **42***a* corresponds to the Y-axis, as in the first embodiment. This mechanism **1240** comprises a deflection member **1241** which is rotatable on the central axis **42***a*.

In addition to the laser diode **10** and the photodiode **20**, the laser radar apparatus **1200** is further provided with a mirror **1230** to reflect the laser beam L**1** from the laser diode **10** almost at the right angle. The reflected laser beam L**1** enters a central part of the deflection member **1241**. The rotating deflection mechanism **1240** includes the deflection member **1241** driven to rotate by the motor **50** so that the member **1241**, that is, the mechanism **1240** is rotatable on the central axis **42***a*.

As shown in FIGS. **34** and **35**, the deflection member **1241** is provided with a plurality of reflection layers **1241***a*-**1241***e* laminated at the beam-incident position of the laser beam L**1** from the mirror **1230**. The lowest reflection layer **1241***a* is composed of a mirror and the remaining reflection layers **1241***b*-**1241***e* are composed of a half-silvered mirror. Thus, the laser beam L**1** reflected by the mirror **1230** is reflected by and transmitted through the remaining reflection layers **1241***b*-**1241***e* other than the lowest reflection layer **1241***a*, and reflected by the lowest reflection layer **1241***a*. Additionally, as shown in FIG. **35**, the respective reflection layers **1241***a*-**1241***e* are set to have different reflecting directions for the laser beam L**1**. These different reflecting directions are realized by, for example, changing the thickness of each reflection layer so as to become thicker as advancing to its end.

The laser radar apparatus **1200** is further provided with a laser beam selector **1202** to select any from a plurality of reflected laser beams La-Le of different reflection angels produced by the plural reflection layers **1241***a*-**1241***e*. This laser beam selector **1202** includes a light-shielding unit **1210** and a liner actuator **1218** linearly driving the light-shielding unit **1210**. Driving the light-shielding unit **1210** by the linear actuator **1218** permits not only any of the reflected laser beams La-Le to be emitted toward the side of a filed to be observed for objects but also the remaining ones to be shut off. That is, the selector **1202** is able to selectively perform a switchover among the reflected laser beams La-Le so as to select a laser beam for use in the detection in the field. The laser beam selector **1202** exemplifies the laser beam selecting means.

The light-shielding unit **1210** is provided with a pair of annular light-shielding member **1211** and **1212** and connectors **1214**. These shielding members **1211** and **1212** are located a given distance apart in the Y-axis direction along the central axis **42***a* and connected to each other by the connectors **1214**. A slit **1213**, which permits any of the reflected laser beams La-Le to pass therethrough, is thus formed between the shielding members **1211** and **1212** so as to surround the whole deflection member **1241**.

The linear actuator **1218** exemplifies the displacement means and responds to a command from the control circuit **70** to displace the pair of annular light-shielding unit **1211** and **1211** as one unit. The laser beam selector **1202** responds to the drive of the linear actuator **1218** to displace the light-shielding unit **1210** by positionally changing the slit **1213**.

Thus when the position of the slit **1213** is changed, the reflected laser beams La-Le can be selected to one for detecting objects, whereby the direction of the laser beam emitted from the deflection member for the detection can be changed (scanned) in the Y-axis direction. The example shown in FIG. **33** illustrates that a reflected laser beam La from the lowest reflection layer **1241***a* is selected. Meanwhile, the reflected light L**2** from an object enters the deflection member **1241**.

When the light-shielding unit **1210** is displaced to select the reflected laser beam Le from the reflection layer **1241***e*, the travel path of the laser beam L**1** is formed as shown by L**1'**. In this case, the return path of the reflected light L**2** to the deflection member **1241** is shown by L**2'**.

The control circuit **70** is the same in its physical configuration as that explained in the first embodiment, but software programs for the above control can be installed in its memory in advance.

In the present embodiment, like the foregoing various embodiments, the laser beam can be emitted toward a field to be observed and scanned three-dimensionally for detection of objects in a simple, but effective and reliable manner. In particular, as the deflection means, a plurality of reflection layers are used to produce a plurality of laser beams of different reflection angles on the reflection on each layer. Any of the laser beams of different reflection angles is selected to solely be emitted toward the field in a controlled manner. Since the selection is made such that the selected laser beam is for scanning in the Y-axis direction in the field, with the result that the laser beam is scanned in the longitudinal (the Y-axis) direction. In addition, the deflection member **1241** is rotated along the XZ plane like the first embodiment. Accordingly, the three-dimensional detection for objects can be performed reliably.

Further, the laminated reflection layers except for the lowest one is composed of a half-silvered mirror, which provides a simple and reliable light-reflection/transmission optical system.

The pair of pair of annular light-shielding member **1211** and **121** are arranged to form the slit **1213**. The paired members **1211** and **1212** are displaced as a unified unit in a controlled manner. Accordingly, the switchover among the reflected laser lights at the deflection member **1241** can be performed quickly and smoothly. Particularly, whatever the deflection member **1241** is at any rotation position along the XZ plane, the reflected laser lights can be selected smoothly from the deflection member **1241**, providing a stable detection of objects around the apparatus.

Other Embodiments

In the forth embodiment in FIG. **5**, the laser diode **10** and the photodiode **20** are arranged to be opposed to each other with the first deflection member **343** located therebetween along the central axis **342***a*. However, this is not a decisive list. For example, the laser diode **10** may be disposed to emit the laser beam to the first deflection member **343** from the same side as the side in which the photodiode **20** is disposed.

In the foregoing embodiments, on the optical path of the reflected light from the rotating deflection means to the optical detection means, the light-collecting means (lens) to collect the reflected light is disposed. Alternatively, this light-collecting means may be omitted from the path, while a relatively large aperture optical detector may be disposed instead.

The foregoing embodiments have adopted the optical selecting means (optical filter) disposed on the optical path of the reflected light from the rotating deflection means to the optical detection means. However, this optical selecting means may be removed from the path, if necessary.

In FIG. **4**, the explanation of the structure for tiltably supporting the deflection member **241** has been simplified. By way of example the tilting mechanism shown in FIG. **14**A can be applied as the tiltably supporting mechanism for the deflection member **241**.

In the fifth embodiment shown in FIG. **6**, a plurality of piezoelectric actuators other than four may be used as actuators for the deflection means. In addition, only one piezoelectric actuator may be used.

Furthermore, a modification for the eighth embodiment in FIG. **8** can be provided in the following.

This modification concerns the connection of the oscillation means (the cam mechanism **680** and motor **682**) with the external power supply. In the eighth embodiment, the external power supply is designed not to rotate together with the deflection means. This is just an example, and may be modified into the following. That is, as shown in FIG. **36**A, a battery powering the oscillation means is provided, which is rotatable as one unit with the deflection means. The configuration shown in FIG. **36**A differs from the eight embodiment in only the powering structure for the oscillation means (the cam mechanism **680** and motor **682**).

Practically, the power line **686**, the frame **685**, a battery **688** are arranged differently from those in the eighth embodiment. The battery **688** as well as the oscillation means (the cam mechanism **680** and motor **682**) are designed to be rotatable together with the deflection member **641**. The motor **682** and the battery **688** are mounted on the frame **685** attached to the shaft member **642**. Further, the power line **686** are wired on and along the frame **685** from the battery **688** to the motor **682**. The battery **688** is made up of either a primary battery such as a manganese dioxide battery or alkaline battery or a secondary battery such as a lithium-ion battery or a nickel battery.

Hence, employing this powering configuration eliminates the need or wiring the power line bridging the rotated and fixed component parts, thus simplifying the wiring structure and making it possible not use complex control for the powering, thus improving the powering configuration.

Incidentally, the foregoing modification can be modified further into the powering configuration shown in FIG. **36**B.

As shown in FIG. **36**B, the configuration shown in FIG. **19**A is modified to have a light source **690** that emits light onto a solar cell **689** serving as the battery. Like the foregoing, the solar cell **689** is mounted on the frame **685**. In addition, at a fixed position in the casing **3**, the light source **690** is located fixedly to emit the light to the solar cell **689**. The light source **690** is powered by an external power supply (e.g., commercial power supply) fixedly placed outside the apparatus. The light source **690** is for example an LED (light-emitting diode) or other lighting means.

Hence, it is possible to have the same advantages stated above with the modification in FIG. **36**A. Additionally, to use the solar cell makes it possible to stably power the motors or others within the rotating structure for a long time.

The configurations stated in FIGS. **36**A and **36**B may be applied to the eighth embodiment shown in FIG. **17**.

The laser radar apparatuses shown in the foregoing various embodiments and modifications provide a high availability when they are used as an area sensor or a safety sensor detecting obstacles in the surrounding.

The present invention may be embodied in several other forms without departing from the spirit thereof. The embodiments and modifications described so far are therefore intended to be only illustrative and not restrictive, since the scope of the invention is defined by the appended claims rather than by the description preceding them. All changes that fall within the metes and bounds of the claims, or equivalents of such metes and bounds, are therefore intended to be embraced by the claims.

What is claimed is:

1. A laser radar apparatus comprising:

a laser beam generator that generates a laser beam;

an optical detector that detects reflected light that has been reflected from a field to be observed;

a deflection member that has a surface deflecting the laser beam toward the field and deflection the reflected light toward the optical detector;

a support member that has a central axis, supports the deflection member, and is rotatable on the central axis;

a drive means that drives the support member so that the support member is rotated on the central axis;

changing means that changes an incidence direction of the laser beam onto the deflection member relatively to the surface of the deflection member so that the laser beam deflected from the deflection member is scanned in a direction along the central axis; and

control means that controls the changing means so as to allow the laser beam deflected from the deflection member to scan the field in the direction at all rotated positions of the support member.

2. The laser radar apparatus of claim **1**, wherein

the changing means includes a light deflection means that deflects the laser beam from the laser beam generator toward the deflection member and that has an axis on which the light deflection means is swingable, and

the control means is a swing control means that controls a swing action of the light deflection means.

3. The laser radar apparatus of claim **2**, wherein

the light deflection means comprises

a light deflector that deflects the laser beam,

a swing mechanism that swingably supports the light deflector, and

an actuator that drives the light deflector supported by the swing mechanism, and

the swing control means is adapted to control a state of the light deflector driven by the actuator.

4. The laser radar apparatus of claim **3**, wherein

the actuator consists of one or more piezoelectric actuators that change a position of a specific portion of the deflection member, and

the swing control means is adapted to control movement of the piezoelectric actuator to control a spatial attitude of the deflector to the laser beam.

5. The laser radar apparatus of claim **3**, wherein

the swing mechanism includes a holding member that holds the light deflector and a ball joint that links the light deflector and the holding member by using a spherical bearing stud and socket.

6. The laser radar apparatus of claim **2**, wherein

the swing control means is adapted to change a swing control given to the light deflection means based on the rotated positions of the support member.

7. The laser radar apparatus of claim **2**, wherein the deflection member is given a first deflection range in which the deflection member deflects the reflected light and the light deflection means is given a second deflection range in which the light deflection means deflects the laser beam, the first deflection range being greater than the second deflection range.

8. The laser radar apparatus of claim **1**, wherein

the changing means comprises

a mirror unit equipped with a plurality of mirrors, and

a displacement mechanism that displaces the mirror unit so that the plurality of mirrors are arranged in turn at a laser-beam incidence position where the laser beam arrives from the laser beam generator, wherein

the mirrors of the mirror unit have reflection surfaces whose oblique angles are different from each other,

the mirror unit is arranged at the laser-beam incidence position by the displacement mechanism, and the control means is adapted to control the displacement mechanism so as to switch the mirrors to be located at the laser-beam incidence position, whereby a relative incidence direction of the laser beam to the deflection member is changed.

9. The laser radar apparatus of claim **8**, wherein

the mirror unit which is rotatable on a given rotation axis thereof and which is formed such that the plurality of mirrors are located circularly around the given rotation axis and the oblique angles of the reflection surfaces of the respective mirrors are different from each other to the given rotation axis,

the displacement mechanism is a rotation mechanism that rotates the mirror unit on the given rotation axis, and

the control means is adapted to control rotation of the rotation mechanism so as to switch the mirrors to be located in turn at the laser-beam incidence position.

10. The laser radar apparatus of claim **9**, wherein

the drive means is configured to rotate the deflection member every given angle, and

the control means is adapted to control the rotation of the rotation mechanism such that all the plurality of mirrors are located in turn at the laser-beam incidence position every time the deflection member is rotated every given angle, whereby the direction of the central axis is scanned at each rotated angle position of the deflection means.

11. The laser radar apparatus of claim **1**, wherein the changing means is formed as output direction changing means that displaces the laser beam generator so as to change an output direction of the laser beam generated from the laser beam generator, and

the control means is formed as displacement control means that controls an amount of displacement of the laser beam generator.

12. The laser radar apparatus of claim **1**, wherein

the changing means is formed as tilt means that tilts at least a portion of the deflection member onto which the laser beam comes, and

the control means is formed as tilt control means that tilts a tilt action of the tilt means.

13. The laser radar apparatus of claim **12**, wherein

the deflection means includes a first deflection means that deflects the laser beam from the laser beam generator and second deflection means that deflects the reflected light from the field, and

the tilt means is adapted to tilt the first deflection member independently of the second deflection means.

14. The laser radar apparatus of claim **13**, wherein

the second deflection member is given a deflection range in which the second deflection member deflects the reflected light and the first deflection member is given a deflection range in which the first deflection means deflects the laser beam, the deflection range given to the second deflection member being greater than the deflection range given to the first deflection member.

15. The laser radar apparatus of claim **12**, wherein

the laser beam generator and the optical detector are arranged to allow the deflection member to be located therebetween in the central axis.

16. The laser radar apparatus of claim **12**, wherein

the tilt means comprises

a tilt mechanism that tiltably supports the deflection means and

an oscillation means that oscillates a given part of the deflection member at which the deflection member is supported by the tilt mechanism, and

the tilt control means is adapted to control an oscillation of the given part of the deflection means which is oscillated by the oscillation means.

17. The laser radar apparatus of claim **16**, further comprising

a limiting means that limits the given part of the deflection member from oscillating in excess of a given oscillation range.

18. The laser radar apparatus of claim **16**, wherein

the oscillation means comprises

a cam mechanism that has a cam rotatable with touching the given part of the deflection means and making the cam rotate to provide the given part of the deflection member with a liner movement and

a cam-mechanism drive means that drives the cam mechanism, and

the tilt control means is adapted to control the cam-mechanism drive means to control the oscillation at the given part of the deflection means.

19. The laser radar apparatus of claim **16**, wherein

the oscillation means comprises

a transmission member that transmits a force to the deflection means,

a reciprocating mechanism that reciprocates the transmission member, and

a reciprocating-member drive means that drives the reciprocating mechanism, and

the tilt control means is adapted to control the reciprocating-member drive means to control the oscillation at the given part of the deflection member.

20. The laser radar apparatus of claim **16**, wherein

the oscillation means comprises

an extension member that composes a part to transmit a force to the deflection member and that is extendable and

an extension member drive means that extends and contracts the extension member, and

the tilt control means is adapted to control the extension member drive means to control the oscillation at the given part of the deflection member.

21. The laser radar apparatus of claim **20**, wherein

the extension member is a piezoelectric actuator.

22. The laser radar apparatus of claim **20**, wherein

the extension member is formed as a size-changeable member having an inner space in which a gas is charged and of which outer size is changeable depending on an amount of the gas to be charged, and

the extension member drive means is formed as a gas-amount adjustment means that adjusts the amount of the gas charged in the size-changeable member.

23. The laser radar apparatus of claim **16**, wherein

the oscillation means is configured to be rotatable together with the deflection member as one unit and to be powered by an external power supply that is not rotated together with the deflection means,

the deflection member and the external power supply are mutually electrically connected by a power supply line, and

the drive means is adapted to drive the rotation of the deflection performing means so as to allow the deflection means to reciprocate within a predetermined rotation range.

24. The laser radar apparatus of claim **16**, wherein

the oscillation means are configured to be rotatable together with the deflection member as a one unit and to be powered by a battery that is rotated together with the deflection means.

25. The laser radar apparatus of claim **24**, wherein
the battery is a solar battery and
the laser radar apparatus comprises a light source that emits light to the solar battery in reply to the power supply from the external power supply that is not rotated together with the deflection member, the light source being located at a position which is not rotated together with the deflection member.

26. The laser radar apparatus of claim **16**, wherein
the deflection member is configured to be rotatable independently of the oscillation means and
the oscillation means is configured to make the deflection member oscillate at a given position in the apparatus.

27. The laser radar apparatus of claim **26**, wherein
the deflection performing member comprises
a cylindrical shaft member which is cylindrical to have a cylindrical bore and driven by the drive means and
a support base which is arranged on one end side of the cylindrical shaft member so as to be rotatable together with the cylindrical shaft member and which supports the deflection member so as to rotate on a position shifted from the central axis, and
the oscillation means is arranged in a cylindrical bore of the cylindrical shaft member and configured to press the deflection means.

28. The laser radar apparatus of claim **26**, wherein
the deflection performing means comprises
a shaft member driven by the drive means and
a swing member having a substantially circular outer edge portion, being formed to rotate together with the deflection member, and being swingable relatively to the shaft member, and
the oscillation means is formed as an edge oscillation means for oscillating the edge of the swing member at the given position in the apparatus.

29. The laser radar apparatus of claim **28**, wherein
the edge oscillation means comprises
a first oscillation means that oscillates the edge of the swing member at a first position in the apparatus and
a second oscillation means that oscillates the edge of the swing member at a second position in the apparatus, the second position being different from the first position, and the first and second positions serving as the given position in the apparatus.

30. The laser radar apparatus of claim **29**, wherein
the tilt control means is adapted to enable at least the second oscillation means to oscillate when the deflection member are at a given rotation position and to enable at least the first oscillation means to oscillate when the deflection means is at the rotation positions other than the given rotation position.

31. The laser radar apparatus of claim **1**, wherein
the support means is configured to tiltably support the deflection member, and
the changing means comprises
a rotating portion that is rotatable together with the deflection member, and
a guide means that guides the rotating portion so that part of the rotating portion positionally changes toward the central axis during a rotation of the rotating portion, by deciding part of a guide plane along which the rotating portion rotates, whereby the positional change of the part of the rotating portion allows both the rotating portion and the deflection member to be swung to change a relative position of the deflection member to the laser beam when the deflection member is driven to rotate by the drive means.

32. The laser radar apparatus of claim **31**, wherein
the rotating portion has a base end oriented to the deflection member and is elongated from the base end,
the guide means includes an annular guide passage arranged to encircle the rotating portion and formed to guide a distal end of the rotating portion, and
the guide passage is formed such that a position of at least part of the guide passage in a direction of the central axis is changed.

33. The laser radar apparatus of claim **32**, wherein
the rotating portion comprises
a fixed member fixed to the deflection means and
a rotation member rotatably attached to the fixed member, and
the guide passage is formed to guide the rotation member, wherein
the rotation member is formed to be supported on a wall surface of the guide passage and is formed to roll along the wall surface when the rotation member is guided by the guide passage.

34. The laser radar apparatus of claim **33**, wherein
the guide passage comprises a first curved portion convexed toward a first direction along the central axis and a second curved portion convexed toward a second direction along the central axis, the second direction being opposite to the first direction, the first and second curved portions being arranged alternately along the guide passage.

35. The laser radar apparatus of claim **1**, wherein
the direction changing means includes means for changing an incidence direction of the laser beam to the deflection means.

36. The laser radar apparatus of claim **1**, wherein
the changing means includes means for changing a deflection angle of the deflection member, the laser beam being deflected from the deflection member by the deflection angle.

37. The laser radar apparatus of claim **1**, wherein
a light collecting means that collects the reflected light on an optical path of the reflected light between the deflection member and the optical detector.

38. The laser radar apparatus of claim **1**, wherein
a light selecting means that selected the reflected light by enabling the reflected light to be transmitted therethrough and shutting off light other than the reflected light, the light selecting means being disposed on an optical path of the reflected light between the deflection member and the optical detector.

39. A laser radar apparatus comprising:
a laser beam generator that generates a laser beam;
an optical detector that detects reflected light that has been reflected by an object in a field to be observed;
a deflection member that has a surface deflecting the laser beam toward the field and deflecting the reflected light toward the optical detector; a support member that has a central axis, supports the deflection member, and is rotatable on the central axis; and
a drive means that drives the support member to rotate so that the support member is rotated on the given central axis, wherein
the deflection means comprise
a plurality of reflection layers laminated on one another at an incident position of the laser beam and produced to reflect the laser beam at different directions, wherein, of the reflection layers, only reflection layers other than a lowest reflection layer performs the reflection and transmission of the laser beam,

a laser beam selecting means that selects only a one laser beam from laser beams reflected by the plurality of reflection layers, the selected one laser beam being emitted into the field for detection of an object, and

a control means that controls a selection carried out by the laser beam selecting means so that the selected laser beam is scanned in a direction of the central axis such that the laser beam is deflected from the deflection member to scan the field in the direction at all rotated positions of the support member.

40. The laser radar apparatus of claim **39**, wherein

the reflection layers other than the lowest reflection layer are formed as half-silvered mirrors.

41. The laser radar apparatus of claim **39**, wherein

the laser beam selecting means comprises

a pair of annular light-shielding members arranged around the deflection member to be located along the direction of the central axis with a given space apart from each other so as to produce a slit therebetween, and

a displacement means that displaces the pair of annular light-shielding members together, wherein

the control means includes means for controlling a displacement carried out by the displacement means.

42. The laser radar apparatus of claim **39**, wherein

a light collecting means that collects the reflected light on an optical path of the reflected light between the deflection performing member and the optical detector.

43. The laser radar apparatus of claim **39**, comprising

a light selecting means that selected the reflected light by enabling the reflected light to be transmitted therethrough and shutting off light other than the reflected light, the light selecting means being disposed on an optical path of the reflected light between the deflection member and the optical detector.

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