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(54) Title: LENS EXCHANGE APPARATUS AND PORTABLE TERMINAL

(57) Abstract: The lens exchange apparatus 100 according to the present embodiment comprises a revolver 20 to hold a plurality of lenses 11 to 13 apart from each other around a rotation center, a holder 30 to rotatably support the revolver 20, and a motor 50 including a mover 51 attached to the revolver 20 and a stator 52 attached to the holder 30 so as to face the mover 51, wherein the motor 50 rotationally drives the revolver 20 with respect to the holder 30. By rotationally driving the revolver 20 with respect to the holder 30 with the motor 50, it is possible to exchange the plurality of lenses 11 to 13, select one of the lenses and position it on the optical axis L of the image sensor 99. A camera module of a lens exchange type in which one module is constructed from the lens and the image sensor 99 is provided.

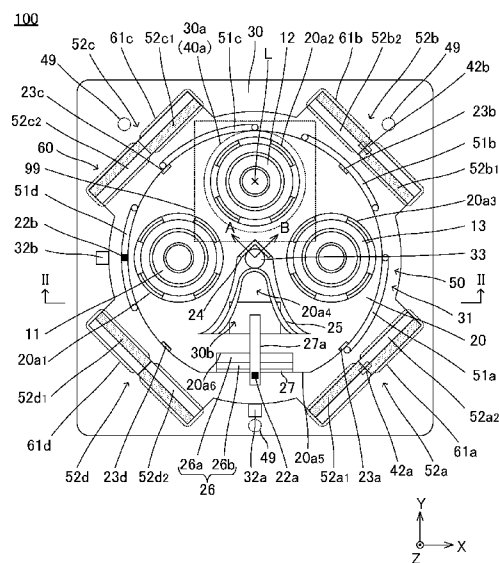


Fig. 1A

LENS EXCHANGE APPARATUS AND PORTABLE TERMINAL

BACKGROUND

1. TECHNICAL FIELD

[0001] The present invention relates a lens exchange apparatus and a portable terminal.

2. RELATED ART

[0002] In recent years, smartphones equipped with a multi-camera (also called a multi-eye camera) including a plurality of camera modules have been widely used. The multi-camera including for each camera module dedicated components such as a lens, an image sensor for imaging through the lens, a lens actuator for correcting positions of the lens, etc.. If a lens actuator included in each camera module is used to realize an auto focus (AF) function and an optical image stabilizer (OIS) function as disclosed in Patent Document 1 for each lens, the cost is remarkably increased.

Patent Document 1: **Japanese Patent Application Publication No 2017-49343**

[0003] Therefore, it is desired to employ a configuration in which a plurality of camera modules share dedicated components in order to realize the AF function and the OIS function and suppress the increase in cost.

SUMMARY

[0004] A first aspect of the present invention provides a lens exchange apparatus for exchanging a plurality of lenses to dispose any one on an optical axis of an image sensor, including a revolver to hold a plurality of lenses apart from each other around a rotation center, a holder to rotatably support the revolver, and a motor including a mover attached to the revolver and a stator attached to the holder so as to face the mover, wherein the motor rotationally drives the revolver with respect to the holder.

[0005] A second aspect of the present invention provides a portable terminal including a plurality of lenses, an image sensor, and the lens exchange apparatus according to the first aspect for exchanging the plurality of lenses to dispose any one on an optical axis of the image sensor.

[0006] The summary clause does not necessarily describe all necessary features of the embodiments of the present invention. The present invention may also be a sub-combination of the features described above.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Fig. 1A shows a configuration of a lens exchange apparatus according to the present embodiment in a top view.

Fig. 1B shows a configuration of the lens exchange apparatus on a cross section along the reference line II-II of Fig. 1A.

Fig. 1C shows a configuration of a revolver in a top view.

Fig. 1D shows a configuration of a holder in a top view.

Fig. 1E shows a configuration of a base in a top view.

Fig. 2 shows a configuration of a control system of the lens exchange apparatus according to the present embodiment.

Fig. 3A shows start of a lens exchange operation from the reference lens state to the right lens state.

Fig. 3B shows a state during the lens exchange operation (a state in which the revolver counterclockwise rotates by the unit rotation angle $\times 1$).

Fig. 3C shows a state during the lens exchange operation (a state in which the revolver counterclockwise rotates by the unit rotation angle $\times 2$).

Fig. 3D shows a state during the lens exchange operation (a state in which the revolver counterclockwise rotates by the unit rotation angle $\times 3$).

Fig. 3E shows the right lens state after the lens exchange operation (a state in which the revolver counterclockwise rotates by the unit rotation angle $\times 4$).

Fig. 3F shows start of a lens exchange operation from the right lens state to the reference lens state.

Fig. 4A shows start of a lens exchange operation from the reference lens state to the left lens state.

Fig. 4B shows a state during the lens exchange operation (a state in which the revolver clockwise rotates by the unit rotation angle $\times 1$).

Fig. 4C shows a state during the lens exchange operation (a state in which the revolver clockwise rotates by the unit rotation angle $\times 2$).

Fig. 4D shows a state during the lens exchange operation (a state in which the revolver clockwise rotates by the unit rotation angle $\times 3$).

Fig. 4E shows the left lens state after the lens exchange operation (a state in which the revolver clockwise rotates by the unit rotation angle $\times 4$).

Fig. 4F shows start of a lens exchange operation from the left lens state to the reference lens state.

Fig. 5A shows a configuration of a lens exchange apparatus according to the variation in a top view.

Fig. 5B shows a configuration of the lens exchange apparatus on a cross section along the reference line II-II of Fig. 5A.

Fig. 5C shows a configuration of the revolver in a top view.

Fig. 5D shows a configuration of a holder in a top view.

Fig. 5E shows a configuration of a base in a top view.

Fig. 6 shows a configuration of a control system of the lens exchange apparatus according to the variation.

Fig. 7 shows a configuration of a portable terminal.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0008] Hereinafter, (some) embodiment(s) of the present invention will be described. The embodiment(s) do(es) not limit the invention according to the claims. Also, every feature described with respect to a given embodiment should not be considered essential to aspects of the invention.

[0009] Figs. 1A to 1E show a configuration of a lens exchange apparatus 100 according to the present embodiment, where Fig. 1A shows a configuration of the lens exchange apparatus 100 in a top view. Fig. 1B shows a configuration of the lens exchange apparatus 100 on a cross section along the reference line II-II of Fig. 1A. Fig. 1C shows a configuration of a revolver 20 in a top view. Fig. 1D shows a configuration of a holder

30 in a top view. Fig. 1E shows a configuration of a base 40 in a top view. In these figures, with respect to the optical axis L located at a light receiving center of an image sensor 99, the direction parallel to the optical axis L is defined as the Z-axis direction, the direction of the straight line connecting the optical axis L and the rotation center of the revolver 20 (the center of a shaft 33 on the holder 30) in a plane perpendicular to the Z-axis direction is defined as the Y-axis direction, and the direction orthogonal to the Z- and Y-axis directions is defined as the X-axis direction. Furthermore, the two axis directions crossing at the rotation center of the revolver 20 are A and B directions, where the direction crossing at an angle of +45 degrees the +Y direction and at an angle of -45 degrees the -X direction is the A direction and the direction crossing at an angle of +45 degrees the +X direction and at an angle of -45 degrees the +Y direction is the B direction.

[0010] The lens exchange apparatus 100 is to exchange a plurality of lenses 11 to 13 in a camera module mounted in a portable terminal such as a smartphone in order to dispose one of the lenses on the optical axis L of the image sensor 99. The lens exchange apparatus 100 comprises a revolver 20, a holder 30, a base 40, a motor 50, and a control unit 70.

[0011] The plurality of lenses 11 to 13 are optical systems each including a plurality of lens elements, etc. arranged along the optical axis thereof, and have optical properties different from each other. The lenses 11 to 13 may be lenses having different focal distances (i.e., different angles of view) such as a standard lens, a wide-angle lens, and a telephoto lens or lenses having different optical filters such as a neutral density filter, a polarizing filter, a color compensating filter, etc. In the present embodiment, the lenses 11 to 13 are referred to as a left lens, a standard lens, and a right lens,

respectively.

[0012] The revolver 20 is for holding the lenses 11 to 13. The revolver 20 has, as one example, a cylindrical shape with the width being larger than the height, where through holes 20a1 to 20a4 are formed around the central axis (i.e., the rotation center) separated from each other and penetrate the revolver 20 in the Z-axis direction, a flat surface 20a5 parallel to the Z-axis on the side surface adjacent to the through hole 20a4, and a groove 20a6 extending in the Z-axis direction is formed on the flat surface 20a5.

[0013] The through holes 20a1 to 20a3 have a circular cross section and are spaced apart at a constant angular pitch (in the present embodiment, a pitch of 90 degrees as one example). The lenses 11 to 13 are fitted respectively into the through holes 20a1 to 20a3 such that the optical axes are directed in the Z-axis direction. Thereby, the plurality of lenses 11 to 13 are held by the revolver 20 around the rotation center to be apart from each other at the constant angular pitch. In the present embodiment, the three lenses 11 to 13 are held by the revolver 20, but the number of the lens is not limited to three, and two, of four or more lenses may be held at a constant angular pitch.

[0014] The through hole 20a4 has such a shape that an approximate isosceles trapezoid having inwardly curved legs is combined with a triangle connected on the upper base of the trapezoid, as one example. The triangle and a part of the upper side portion of the trapezoid are arranged on the rotation center, and the bottom side portion of the trapezoid is arranged between and at an angle from the through holes 20a1 and 20a3 (in the direction 90 degrees from each of them). A slider 24 bent in an L-shape manner is fixed on an inner surface of the triangle portion of the through hole 20a4, and both ends of a U-shaped leaf spring 25 are fixed on the inner surface of the bottom-base

portion of the through hole 20a4 so that the revolver 20 is rotatably supported on the holder 30 by inserting and sandwiching a shaft 33 of the holder 30 between the slider 24 and the leaf spring 25.

[0015] The revolver 20 has a plurality of coils 51a to 51d, reference magnets 22a, 22b, a plurality of cores 23a to 23d, a vibrationproof member 26, and a flexible printed circuit board (FPC) 27.

[0016] The plurality of coils 51a to 51d are arranged on the side surface of the revolver 20 to configure a mover 51 of a motor 50. The configuration of the coils 51a to 51d is described below in detail in relation to the configuration of the motor 50.

[0017] The reference magnets 22a, 22b are permanent magnets that generate magnetic fields for detecting the rotational position and position in the Z-axis direction (i.e., focus positions) of the revolver 20, and arranged on the side surface of the revolver 20 at an angular pitch equal to the angular pitch of the lenses 11 to 13 (a pitch of 90 degrees in the present embodiment). In the present embodiment, the reference magnets 22a, 22b are provided on the FPC 27 and in the coil 51d, respectively.

[0018] The plurality of cores 23a to 23d are for positioning the revolver 20 in the rotation direction, and are formed of a high-permeability material such as Permalloy. The plurality of cores 23a to 23d are disposed on the side surface of the revolver 20, and respectively aligned with boundaries of first magnetic poles 52a1 to 52d1 and second magnetic poles 52a2 to 52d2 of a plurality of magnets 52a to 52d, described below, when the revolver 20 rotates such that one of the lenses 11 to 13 is located on the optical axis L. When the revolver 20 rotates and at least one of the cores 23a to 23d is aligned with the boundary of the magnetic poles of any of the magnets 52a to 52d, the attractive forces received by the cores 23a to 23d from respective magnetic poles are balanced and

the revolver 20 is thereby stabilized at the rotational position. Thereby, one of the lenses 11 to 13 can be positioned on the optical axis L of the image sensor 99 without application of a holding force.

[0019] In the present embodiment, since the lenses 11 to 13 and the magnets 52a to 52d are arranged at the same angular pitch of 90 degrees, the four cores 23a to 23d which are as many as the magnets 52a to 52d, are arranged at a pitch of 90 degrees. Thereby, when the revolver 20 rotates to dispose one of the lenses 11 to 13 on the optical axis L, each of the four cores 23a to 23d is aligned with the boundary of the first and second magnetic poles of one of the magnets 52a to 52d (respectively, the boundaries of the first and second magnetic poles of the magnets 52a to 52d in a state shown in Fig. 1A) so that each of the lenses 11 to 13 can be positioned on the optical axis L of the image sensor 99 without application of a holding force.

[0020] The vibrationproof member 26 is for suppressing vibrations of the revolver 20 which may be caused by AF-driving and OIS-driving, and includes a rubber 26a and a balancer 26b. The rubber 26a is formed of an elastic material such as chloroprene rubber (CR) and shaped into a plate-shape, and cushions vibrations of the revolver 20 to suppress transmission of the vibrations to the FPC 27. The balancer 26b is formed of a metal having a relatively large specific weight such as brass and shaped into a plate with an appropriate thickness, and aligns the center of mass of the revolver 20 with the rotation center. The rubber 26a and the balancer 26b are fitted into the groove 20a6 of the revolver 20.

[0021] The FPC 27 is a flexible substrate on which wirings for connecting the coils 51a to 51d to wirings on the base 40 are provided. The FPC 27 includes a main body and an extension 27a, and is connected to a FPC 40b of the base 40 via the through hole

20a4 of the revolver 20 and a opening 30b of the holder 30 overlapping the main body on the balancer 26b and fitting the main body into the groove 20a6 of the revolver 20, and allowing the extension 27a to extend from the -Z end of the main body.

[0022] The holder 30 is a casing for rotatably supporting the revolver 20. In the holder 30, a recess 31 having a circular shape in a top view and four grooves 31a to 31d having a rectangular shape are formed. The recess 31 is located at the center of the holder 30, and accommodates the revolver 20 therein. A circular opening 30a is formed in the +Y side portion of the bottom surface of the recess 31 and a rectangular opening 30b is formed in the -Y side portion. The four grooves 31a to 31d are located, respectively, in the +X, -Y side, +X, +Y side, -X, +Y side, -X, -Y side in the recess 31, and accommodate, respectively, the magnets 52a to 52d therein.

[0023] The holder 30 has a plurality of magnets 52a to 52d, magnetic sensors 32a, 32b, a shaft 33, an actuator 34, and a weight 35.

[0024] The plurality of magnets 52a to 52d are arranged around the revolver 20 to construct a stator 52 of a motor 50. The configuration of the magnets 52a to 52d is described below in detail in relation to the configuration of the motor 50.

[0025] The magnetic sensors 32a, 32b are for detecting magnetic fields generated by the reference magnet 22a, 22b to detect rotational positions of the revolver 20 and the position of the revolver 20 in the Z-axis direction (i.e., focus positions of the lens 11 to 13 on the optical axis L). For example, a Hall element may be employed as the magnetic sensors 32a, 32b. The magnetic sensors 32a, 32b are buried in the inner surfaces on the -Y side and the -X side in the recess 31, respectively, at an angular pitch of 90 degrees which is equal to the angular pitch of the lenses 11 to 13. By specifying active magnetic sensors of the two magnetic sensors 32a, 32b which are aligned with the two

reference magnets 22a, 22b and detect magnetic fields generated by them, it is possible to specify a lens positioned on the optical axis L of the image sensor 99 from among the lenses 11 to 13. Detection signals of the magnetic sensors 32a, 32b are transmitted to the AF-rotation control unit 71.

[0026] The shaft 33 is a columnar shaft body for rotatably supporting the revolver 20 on the holder 30, and is disposed at the center of the recess 31 such that its longitudinal direction extends in the Z-axis direction. As described above, by sandwiching the shaft 33 between the slider 24 and the leaf spring 25 of the revolver 20, the revolver 20 is held on the shaft 33 by the frictional forces therebetween. Here, since the center of mass of the revolver 20 aligns with its rotation center by the balancer 26b of the vibrationproof member 26, the revolver 20 can be supported at the center of mass by the shaft 33, thereby it is possible to preventing resonances from occurring when the position of the revolver 20 is corrected along the optical axis L (i.e., the lens held by the revolver 20 is AF-driven).

[0027] An actuator (also referred to as an AF-actuator) 34 is a device that expands and contracts to drive the shaft 33 in its longitudinal direction (i.e., the Z-axis direction). As the actuator 34, for example, a piezo element may be employed.

[0028] The weight 35 is for stably supporting on the holder 30 the shaft 33 holding the revolver 20. The weight 35 is fixed to the center of the recess 31, for example, with an adhesive. The shaft 33 is fixed on the weight 35 via the actuator 34.

[0029] A Smooth Impact Drive Mechanism (SIDM) is constructed from the shaft 33, the actuator 34, and the weight 35. The SIDM drives the revolver 20 along the shaft 33 in the Z-axis direction, i.e., AF-drives by using expansion and contraction of the actuator 34 fixed on the weight 35. 1) Slowly expanding the actuator 34 causes the

shaft 33 to move in the +Z direction. As a result, the revolver 20 supported by the shaft 33 is driven in the +Z direction. 2) Quickly contracting the actuator 34 causes the shaft 33 to move back in the -Z direction. In this case, inertia causes the revolver 20 slides on the shaft 33 due to inertia so that the revolver 20 remains at same position. 3) By repeating these operations, the revolver 20 is driven in the +Z direction with a long stroke. By performing reverse operations to the above, the revolver 20 can be driven in the -Z direction with a long stroke. By commonly driving all of the lenses 11 to 13 held by the revolver 20 in the Z-axis direction with the SIDM having such a configuration, it is possible to correct the position of the lens located on the optical axis L of the image sensor 99 along the optical axis L, i.e., perform auto focusing.

[0030] The base 40 is for swingably supporting the holder 30. The base 40 is a substantially square plate and has a circular opening 40a that centers on the optical axis L and an FPC 40b including wirings on the upper surface connected to a plurality of coils 61a to 61d.

[0031] The base 40 includes the plurality of coils 61a to 61d, magnetic sensors 42a, 42b, springs 48, and a bearing 49.

[0032] The plurality of coils 61a to 61d are to construct a stator 61 of an actuator 60, and are provided in the FPC 40b so as to be aligned in the Z-axis direction, respectively, with the plurality of magnets 52a to 52d provided in the holder 30. Each of the coils 61a to 61d includes a pair of sub-coils, where one sub-coil is aligned with a corresponding one of the first magnetic poles 52a1 to 52d1 included in the magnets 52a to 52d and a magnetic pole of an opposite polarity located on its back surface, and the other sub-coil is aligned with a corresponding one of the second magnetic poles 52a2 to 52d2 and a magnetic pole of an opposite polarity located on its back surface. The

actuator 60 (one example of a swing apparatus and also referred to as an OIS-actuator) is configured to swing the holder 30 in the A direction on the base 40 using the magnets 52a, 52c and the coils 61a, 61c aligned therewith, and swing the holder 30 in the B direction on the base 40 using the magnets 52b, 52d and the coils 61b, 61d aligned therewith.

[0033] According to the actuator 60 having such a configuration, it is possible to correct the position of the lens located on the optical axis L of the image sensor 99 in the X- and Y-directions, i.e., to perform image stabilization by commonly swinging all of the lenses 11 to 13 held by the revolver 20 supported by the holder 30 in a plane direction orthogonal to the optical axis L (i.e., the A and B directions). The motor 50 for rotationally driving the revolver 20 on the holder 30 and the actuator 60 for swinging the holder 30 on the base 40 share the plurality of magnets 52a to 52d so that the motor 50 and the actuator 60 have a compact configuration.

[0034] The magnetic sensors 42a, 42b are for detecting, respectively, magnetic fields generated by the magnets 52a, 52b to detect the position of the holder 30 in the A and B directions with respect to the base 40. For example, a Hall element may be employed as the magnetic sensors 42a, 42b. The magnetic sensors 42a, 42b are provided on the FPC 40b so as to overlap the coils 61a, 61b, respectively. Detection signals of the magnetic sensors 42a, 42b are transmitted to an OIS control unit 72.

[0035] The springs 48 are for urging the holder 30 toward the base 40. The springs 48 are attached between the four corners of the back surface of the holder 30 and the four corners of the upper surface of the base 40.

[0036] The bearings 49 are ball-shaped members that support the holder 30 on the base 40. The number of the bearings 49 is three in the present embodiment, but may

be any number of 3 or more. The three bearings 49 are disposed on the base 40 at the +X, +Y corner, the -X, +Y corner, and the +Y center, respectively. The holder 30 is urged toward the base 40 by the springs 48 and the pressure is thereby applied to the bearings 49 so that the holder 30 is swingably supported on the base 40.

[0037] The motor 50 is for rotationally driving the revolver 20 with respect to the holder 30, and includes a stator 52 provided in the holder 30 and a mover 51 provided in the revolver 20 so as to face the stator 52.

[0038] The stator 52 has a plurality of magnets 52a to 52d arranged on the holder 30 around the revolver 20 so as to interact with a plurality of coils 51a to 51d of the stator 52. Each of the magnets 52a to 52d is constructed from two permanent magnets, for example, a permanent magnet having a first magnetic pole (e.g., N-pole) 52a1 to 52d1 and a magnetic pole (S-pole) of an opposite polarity located on its back surface and a permanent magnet having a second magnetic pole (S-pole) 52a2 to 52d2 and a magnetic pole (N-pole) of an opposite polarity located on its back surface, such that the first magnetic pole 52a1 to 52d1 and the second magnetic pole 52a2 to 52d2 are arranged on one surface.

[0039] The plurality of magnets 52a to 52d are accommodated, respectively, in the grooves 31a to 31d on the holder 30. The magnets 52a, 52c are located on opposite sides in the A direction and the magnets 52b, 52d are located on opposite sides in the B direction with respect to the rotation center of the revolver 20 (i.e., the center of the shaft 33). Thereby, the magnets 52a to 52d are spaced apart from each other in the circumferential direction, and the first magnetic poles 52a1 to 52d1 and the second magnetic poles 52a2 to 52d2 facing the center of the shaft 33 are arranged alternately around the revolver 20.

[0040] With respect to the center of the shaft 33, an angular interval corresponding to the center-to-center distance between the first magnetic pole 52a1 to 52d1 and the second magnetic pole 52a2 to 52d2 of the magnets 52a to 52d gives a unit rotation angle of the revolver 20 achieved by the motor 50. In the present embodiment, the unit rotation angle is 22.5 degrees as one example. The first magnetic poles 52a1 to 52d1 and the second magnetic poles 52a2 to 52d2 of the magnets 52a to 52d have a width larger than that corresponding to the unit rotation angle. The magnets 52a to 52d are arranged at an angular pitch which is 4 times as large as the unit rotation angle (equal to 2 times as large as the separation distance between the two sides of the coils, 90 degrees in the present embodiment).

[0041] The mover 51 has a plurality of coils 51a to 51d arranged on the side surface of the revolver 20. The coils 51a to 51d may be constructed by FPC coils, for example.

[0042] The plurality of coils 51a to 51d have, for example, in a rectangular shape and include first sides 51a1 to 51d1 and second sides 51a2 to 51d2 separated from each other along the circumference of the revolver 20. The size and arrangement of the plurality of coils 51a to 51d relative to the plurality of magnets 52a to 52d is such that, for a rotational position of the revolver 20, the first sides 51a1 to 51d1 and the second sides 51a2 to 51d2 of the coils 51a to 51d are aligned, respectively, with the first magnetic poles 52a1 to 52d1 and the second magnetic poles 52a2 to 52d2 of the magnets 52a to 52d and also aligned, respectively, with the first magnetic poles 52a1 to 52d1 of one of two adjacent magnets of the plurality of magnets 52a to 52d and the second magnetic poles 52a2 to 52d2 of the other of the two adjacent magnets. The separation distance between the first sides 51a1 to 51d1 and the second sides 51a2 to 51d2 of the coils 51a to 51d is equal to 2 times as large as the unit rotation angle (45

degrees in the present embodiment).

[0043] The coils 51a to 51d are arranged on the side surface of the revolver 20 at an angular pitch which is 3 times as large as the unit rotation angle (equal to $3/2$ times as large as the separation distance between the first side and the second side, 67.5 degrees in the present embodiment). Thereby, in a state shown in Fig. 1A (the standard lens state in which the lens 12 is located on the optical axis L), the first side 51a1 and the second side 51a2 of the coil 51a are respectively at angular positions of -45 degrees (-2 in units of the unit rotation angle) and 0 degrees (0), the first side 51b1 and the second side 51b2 of the coil 51b are respectively at angular positions of 22.5 degrees (1) and 67.5 degrees (3), the first side 51c1 and the second side 51c2 of the coil 51c are respectively at angular positions of 90 degrees (4) and 135 degrees (6), and the first side 51d1 and the second side 51d2 of the coil 51d are respectively at angular positions of 157.5 degrees (7) and 202.5 degrees (9).

[0044] According to the arrangement of the magnets 52a to 52d and the coils 51a to 51d described above, in the standard lens state shown in Fig. 1A, the first and second sides 51b1, 51b2 of the coil 51b are aligned with the first and second magnetic poles 52b1, 52b2 of the magnet 52b, respectively, and the first and second sides 51d1, 51d2 of the coil 51d are aligned with the second magnetic pole 52c2 of the magnet 52c and the first magnetic pole 52d1 of the magnet 52d, respectively. Furthermore, the first and second sides 51c1, 51c2 of the coil 51c are aligned with the space between the magnets 52b, 52c and with the boundary of the first and second magnetic poles 52c1, 52c2 of the magnet 52c, respectively, and the first and second sides 51a1, 51a2 of the coil 51a are aligned with the boundary of the first and second magnetic pole 52a1, 52a2 of the magnet 52a and with the space between the magnets 52a, 52b, respectively. A pair of

the coils 51a, 51c and a pair of the coils 51b, 51d are disposed with a shift of the relative phase of 90 degrees. As a result, whenever the revolver 20 is rotated by an integer multiple of the unit rotation angle, the two sides of each of the coils 51a, 51c or the two sides of each of the coils 51b, 51d are always aligned with the first magnetic poles 51a1 to 51d1 and the second magnetic poles 51a2 to 51d2 of the magnets 52a to 52d.

[0045] Fig. 2 shows a configuration of a control system of the lens exchange apparatus 100 according to the present embodiment. The control system is constructed by a control unit 70 to rotationally control the revolver 20, and AF-control (i.e., auto focus) and OIS-control (i.e., image stabilize) a lens positioned on the optical axis L. A computer apparatus executes a control program to realize the control unit 70 having functions of an AF-rotation control unit 71 and an OIS control unit 72.

[0046] The AF-rotation control unit 71 is for rotationally controlling the revolver 20 and AF-controlling a lens on the optical axis L based on output signals of the magnetic sensors 32a, 32b on the holder 30.

[0047] The rotational position of the revolver 20 is detected by specifying active sensors of the magnetic sensors 32a, 32b, when the revolver 20 rotates and the magnetic sensors 32a, 32b are aligned with the reference magnets 22a, 22b to detect magnetic fields generated by them. As shown in Figs. 3A and 4A, in the standard lens state in which the revolver 20 is located at the reference position and the lens 12 is positioned on the optical axis L, the magnetic sensors 32a, 32b detect the reference magnets 22a, 22b, respectively, to output valid detection signals (i.e., the magnetic sensors 32a, 32b are activated). As shown in Fig. 3E, in the right lens state in which the revolver 20 is counterclockwise rotated by 90 degrees from the standard lens state and the lens 13 is located on the optical axis L, only the magnetic sensor 32a detects the reference magnet

22b and activated. As shown in FIG. 4E, in the left lens state in which the revolver 20 is clockwise rotated by 90 degrees from the standard lens state and the lens 11 is located on the optical axis L, only the magnetic sensor 32b detects the reference magnet 22a and activated. The AF-rotation control unit 71 specifies active magnetic sensors by determining whether the detection signals received from the magnetic sensors 32a, 32b are valid.

[0048] When both of the magnetic sensors 32a, 32b are active, the AF-rotation control unit 71 detects that the revolver 20 is at the reference position and specifies the lens state as the standard lens state. When only the magnetic sensor 32a is active, the AF-rotation control unit 71 detects that the revolver 20 is at a rotational position of 90 degrees from the reference position and specifies the lens state as the right lens state. When only the magnetic sensor 32b is active, the AF-rotation control unit 71 detects that the revolver 20 is at a rotational position of -90 degrees from the reference position and specifies the lens state as the left lens state.

[0049] The AF-rotation control unit 71 detects the rotational position of the revolver 20 and specifies the lens positioned on the optical axis L (i.e., any one of the standard lens state, the right lens state, and the left lens state) as described above to exchange the lenses 11 to 13 by controlling the motor 50 to rotationally drive the revolver 20.

[0050] The position of the revolver 20 in the Z-axis direction (also referred to as the AF position) is detected by one or more active sensors among the magnetic sensors 32a, 32b that detect the reference magnets 22a, 22b on the revolver 20 and output valid detection signals. Both of the magnetic sensors 32a, 32b are active in the standard lens state, the magnetic sensor 32a is active in the right lens state, and the magnetic sensor 32b is active in the left lens state. Here, the AF-rotation control unit 71 detects the position

of the revolver 20 in the Z-axis direction based on the detection signals of the active magnetic sensors. When both of the magnetic sensors 32a, 32b are active, any one or both of them may be used.

[0051] The AF-rotation control unit 71 corrects the position of the lens located on the optical axis L along the optical axis L, i.e., AF-controls the lens by detecting the position of the revolver 20 in the Z-axis direction and controlling the actuator 34 based on the results to drive the revolver 20 (i.e., the lenses 11 to 13 held by the revolver 20 jointly) in the Z-axis direction as described above. For the control unit 70 having such a configuration, the magnetic sensors 32a, 32b are shared in the rotational position detection and the AF position detection of the revolver 20.

[0052] The OIS control unit 72 is for OIS-controlling a lens on the optical axis L based on detection signals of the magnetic sensors 42a, 42b on the base 40. The OIS control unit 72 swings the holder 30 in the A and B directions on the base 40 by calculating the position of the holder 30 in the A and B directions with respect to the base 40 based on the detection signals of the magnetic sensors 42a, 42b and exciting the plurality of coils 61a to 61d constructing the actuator 60 based on the calculated results. As a result, it is possible to correct the position of the lens located on the optical axis L of the image sensor 99 in the X- and Y-directions, i.e., to perform image stabilization by jointly swinging all of the lenses 11-13 held by the revolver 20 in a plane direction orthogonal to the optical axis L (i.e., the A and B directions).

[0053] The control unit 70 having such a configuration rotationally drives the revolver 20 that holds the plurality of lenses 11 to 13 using the motor 50 to exchange the lenses 11 to 13 and position one of the lenses on the optical axis L, and AF-controls and OIS-controls the lens on the optical axis L by driving the revolver 20 in the Z-axis

direction using the actuator 34 and swinging the revolver 20 in the plane direction orthogonal to the optical axis L (i.e., in the A and B directions) using the actuator 60. Thereby, it is possible to precisely control the position of each of the plurality of lenses 11 to 13 by means of the common control system.

[0054] The principles of the lens exchange operation by the AF-rotation control unit 71 and the rotational driving of the revolver 20 by the motor 50 (timing of excitation switching) are described.

[0055] Table 1 shows a timing chart of excitation switching of the plurality of coils 51a to 51d. This chart shows, for each rotational position of the revolver 20, which of the first magnetic poles (N-poles) 52a1 to 52d1 and the second magnetic poles (S-pole) 52a2 to 52d2 of the magnets 52a to 52d, the boundaries (D) of the first and second magnetic poles, and the spaces (-) between the magnets 52a to 52d are aligned with the first sides 51a1 to 51d1 and the second sides 51a2 to 51d2 of the coils 51a to 51d. The chart also shows which coil is to be excited and which direction the coil is to be excited to rotate the revolver 20 counterclockwise (CCW) and clockwise (CW) from each rotational position. The rotational position of the revolver 20 is given in increments of the unit rotation angle (22.5 degrees) within a range of -90 degrees to 90 degrees with reference to the reference lens state (0 degree). Furthermore, the direction of the excitation of the coils 51a to 51d is defined as energizing direction, which is indicated by one of u (the +Z direction) and d (the -Z direction), and no marks (no energizing) of the first side 51a1 to 51d1 and the second side 51a2 to 51d2. In the parenthesis, the left and right letters respectively indicate counterclockwise and clockwise rotations.

Magnet /pole		Coil (side) and excitation directions (CCW/CW)								
		90	67.5	45	22.5	0	-22.5	-45	-67.5	-90
52a	52a ₁ (N)	51d ₂ (-/u)					51a ₁ (d/u)		51a ₂ (d/u)	51b ₁ (d/-)
	D					51a ₁		51a ₂	51b ₁	
	52a ₂ (S)				51a ₁ (u/d)		51a ₂ (u/d)	51b ₁ (u/d)		51b ₂ (u/-)
	---			51a ₁		51a ₂	51b ₁		51b ₂	51c ₁
52b	52b ₁ (N)		51a ₁ (d/u)		51a ₂ (d/u)	51b ₁ (d/u)		51b ₂ (d/u)	51c ₁ (d/u)	
	D	51a ₁		51a ₂	51b ₁		51b ₂	51c ₁		51c ₂
	52b ₂ (S)		51a ₂ (u/d)	51b ₁ (u/d)		51b ₂ (u/d)	51c ₁ (u/d)		51c ₂ (u/d)	51d ₁ (u/-)
	---	51a ₂	51b ₁		51b ₂	51c ₁		51c ₂	51d ₁	
52c	52c ₁ (N)	51b ₁ (-/u)		51b ₂ (d/u)	51c ₁ (d/u)		51c ₂ (d/u)	51d ₁ (d/u)		51d ₂ (d/-)
	D		51b ₂	51c ₁		51c ₂	51d ₁		51d ₂	
	52c ₂ (S)	51b ₂ (-/d)	51c ₁ (u/d)		51c ₂ (u/d)	51d ₁ (u/d)		51d ₂ (u/d)		
	---	51c ₁		51c ₂	51d ₁		51d ₂			
52d	52d ₁ (N)		51c ₂ (d/u)	51d ₁ (d/u)		51d ₂ (d/u)				
	D	51c ₂	51d ₁		51d ₂					51a ₁
	52d ₂ (S)	51d ₁ (-/d)		51d ₂ (u/d)					51a ₁ (u/d)	
	---		51d ₂					51a ₁		51a ₂

[0056] Excitation switching of the coils 51a to 51d in a lens exchange operation from the reference lens state, where the lens 12 is positioned on the optical axis L, to the right lens state, where the lens 13 is positioned on the optical axis L, is described.

[0057] In the reference lens state shown in Fig. 3A, the cores 23a to 23d on the revolver 20 are aligned with the boundaries of the magnetic poles of the magnets 52a to 52d, respectively, so that the revolver 20 is positioned at the reference position without application of a holding force and the lens 12 is accordingly positioned on the optical

axis L. The AF-rotation control unit 71 specifies the lens state as the standard lens state by sensing that both of the magnetic sensors 32a, 32b detect the reference magnets 22a, 22b (receive valid detection signals from them) and are thus activated.

[0058] In the reference lens state shown in Fig. 3A, i.e. when the revolver 20 is at the reference position (0 degrees), the first side 51b1 and the second side 51b2 of the coil 51b are respectively aligned with the first magnetic pole 52b1 and the second magnetic pole 52b2 of the magnet 52b, and the first side 51d1 and the second side 51d2 of the coil 51d are respectively aligned with the second magnetic pole 52c2 of the magnet 52c and the first magnetic pole 52d1 of the magnet 52d. At the same time, the first sides 51a1, 51c1 and the second sides 51a2, 51c2 of the coils 51a, 51c are aligned with the boundaries of the magnetic poles of the magnets 52a to 52d or with the space between two adjacent magnets, and thus not aligned with the magnetic poles of any of the magnets 52a to 52d. The AF-rotation control unit 71 then excites the coils 51b, 51d so that the current flows through the first side 51b1 and the second side 51b2 of the coil 51b in the -Z direction and the +Z direction, respectively, and the current flows through the first side 51d1 and the second side 51d2 of the coil 51d in the +Z direction and the -Z direction, respectively. As a result, a counterclockwise driving force is applied to the revolver 20 with respect to the holder 30, the cores 23a to 23d escape from the attractive forces of the magnets 52a to 52d, and the revolver 20 starts to rotate in the direction shown by the arrow in the figure.

[0059] As shown in Fig. 3B, when the revolver 20 rotates counterclockwise by the unit rotation angle (22.5 degrees), the first side 51c1 and the second side 51c2 of the coil 51c are respectively aligned with the first magnetic pole 52c1 and the second magnetic pole 52c2 of the magnet 52c, and the first side 51a1 and the second side 51a2 of the coil 51a

are respectively aligned with the second magnetic pole 52a2 of the magnet 52a and the first magnetic pole 52b1 of the magnet 52b. At the same time, the first sides 51b1, 51d1 and the second sides 51b2, 51d2 of the coils 51b, 51d are aligned with the boundaries of the magnetic poles of the magnets 52a to 52d or with the space between two adjacent magnets, and thus not aligned with the magnetic poles of any of the magnets 52a to 52d. The AF-rotation control unit 71 then excites the coils 51c, 51a so that the current flows through the first side 51c1 and the second side 51c2 of the coil 51c in the -Z direction and the +Z direction, respectively, and the current flows through the first side 51a1 and the second side 51a2 of the coil 51a in the +Z direction and the -Z direction, respectively. As a result, a counterclockwise driving force is applied to the revolver 20 with respect to the holder 30, and the revolver 20 further rotates in the direction shown by the arrow in the figure.

[0060] As shown in Fig. 3C, when the revolver 20 rotates counterclockwise by the unit rotation angle $\times 2$ (45 degrees), the first side 51d1 and the second side 51d2 of the coil 51d are respectively aligned with the first magnetic pole 52d1 and the second magnetic pole 52d2 of the magnet 52d, and the first side 51b1 and the second side 51b2 of the coil 51b are respectively aligned with the second magnetic pole 52b2 of the magnet 52b and the first magnetic pole 52c1 of the magnet 52c. At the same time, the first sides 51a1, 51c1 and the second sides 51a2, 51c2 of the coils 51a, 51c are aligned with the boundaries of the magnetic poles of the magnets 52a to 52d or with the space between two adjacent magnets, and thus not aligned with the magnetic poles of any of the magnets 52a to 52d. The AF-rotation control unit 71 then excites the coils 51d, 51b so that the current flows through the first side 51d1 and the second side 51d2 of the coil 51d in the -Z direction and the +Z direction, respectively, and the current flows through

the first side 51b1 and the second side 51b2 of the coil 51b in the +Z direction and the -Z direction, respectively. As a result, a counterclockwise driving force is applied to the revolver 20 with respect to the holder 30, and the revolver 20 further rotates in the direction shown by the arrow in the figure.

[0061] As shown in Fig. 3D, when the revolver 20 rotates counterclockwise by the unit rotation angle $\times 3$ (67.5 degrees), the first side 51a1 and the second side 51a2 of the coil 51a are respectively aligned with the first magnetic pole 52b1 and the second magnetic pole 52b2 of the magnet 52b, and the first side 51c1 and the second side 51c2 of the coil 51c are respectively aligned with the second magnetic pole 52c2 of the magnet 52c and the first magnetic pole 52d1 of the magnet 52d. At the same time, the first sides 51b1, 51d1 and the second sides 51b2, 51d2 of the coils 51b, 51d are aligned with the boundaries of the magnetic poles of the magnets 52a to 52d or with the space between two adjacent magnets, and thus not aligned with the magnetic poles of any of the magnets 52a to 52d. The AF-rotation control unit 71 then excites the coils 51a, 51c so that the current flows through the first side 51a1 and the second side 51a2 of the coil 51a in the -Z direction and the +Z direction, respectively, and the current flows through the first side 51c1 and the second side 51c2 of the coil 51c in the +Z direction and the -Z direction, respectively. As a result, a counterclockwise driving force is applied to the revolver 20 with respect to the holder 30, and the revolver 20 further rotates in the direction shown by the arrow in the figure.

[0062] As shown in Fig. 3E, when the revolver 20 rotates counterclockwise by the unit rotation angle $\times 4$ (90 degrees), the cores 23a to 23d on the revolver 20 are aligned with the boundaries of the magnetic poles of the magnets 52b to 52d and 52a, respectively, so that the revolver 20 is positioned at that position without application of a holding force

and the lens 13 is accordingly positioned on the optical axis L. The AF-rotation control unit 71 specifies the lens state as the right lens state by sensing that only the magnetic sensor 32a detects the reference magnet 22b to be activated and finishes the lens exchange operation.

[0063] The excitation switching of the coils 51a to 51d in the lens exchange operation from the right lens state to the reference lens state is described.

[0064] In the right lens state shown in Fig. 3F, i.e. when the revolver 20 is at a position of 90 degrees, the first side 51b1 and the second side 51b2 of the coil 51b are aligned with the first magnetic pole 52c1 and the second magnetic pole 52c2 of the magnet 52c, respectively, and the first side 51d1 and the second side 51d2 of the coil 51d are aligned with the second magnetic pole 52d2 of the magnet 52d and the first magnetic pole 52a1 of the magnet 52a, respectively. At the same time, the first sides 51a1, 51c1 and the second sides 51a2, 51c2 of the coils 51a, 51c are aligned with the boundaries of the magnetic poles of the magnets 52a to 52d or with the space between two adjacent magnets, and thus not aligned with the magnetic poles of any of the magnets 52a to 52d. The AF-rotation control unit 71 then excites the coils 51b, 51d so that the current flows through the first side 51b1 and the second side 51b2 of the coil 51b in the +Z direction and the -Z direction, respectively, and the current flows through the first side 51d1 and the second side 51d2 of the coil 51d in the -Z direction and the +Z direction, respectively. As a result, a clockwise driving force is applied to the revolver 20 with respect to the holder 30, the cores 23a to 23d escape from the attractive forces of the magnets 52a to 52d, and the revolver 20 starts to rotate in the direction shown by the arrow in the figure.

[0065] Next, the AF-rotation control unit 71 performs the excitation switching

described above at each position of the revolver 20 shown in Figs. 3B to 3D with energizing of the coils 51a to 51d in the reverse direction. Thereby, the revolver 20 further rotates clockwise.

[0066] As shown in Fig. 3A, when the revolver 20 returns to the reference position (0 degrees), the cores 23a to 23d on the revolver 20 are aligned with the boundaries of the magnetic poles of the magnets 52a to 52d, respectively, so that the revolver 20 is positioned at the reference position without application of a holding force and the lens 12 is accordingly positioned on the optical axis L. The AF-rotation control unit 71 specifies the lens state as the standard lens state by sensing that both of the magnetic sensors 32a and 32b detect the reference magnets 22a and 22b and are thus activated.

[0067] Excitation switching of the coils 51a to 51d in a lens exchange operation from the reference lens state, where the lens 12 is positioned on the optical axis L, to the left lens state, where the lens 11 is positioned on the optical axis L, is described.

[0068] In the reference lens state shown in Fig. 4A, i.e. when the revolver 20 is at the reference position (0 degrees), as described above, the first sides 51b1, 51d1 and the second sides 51b2, 51d2 of the coils 51b, 51d are aligned with the magnetic poles of the magnets 52a to 52d, and the first sides 51a1, 51c1 and the second sides 51a2, 51c2 of the coils 51a, 51c are thus not aligned with the magnetic poles of any of the magnets 52a to 52d. The AF-rotation control unit 71 then excites the coils 51b, 51d so that the current flows through the first side 51b1 and the second side 51b2 of the coil 51b in the +Z direction and the -Z direction, respectively, and the current flows through the first side 51d1 and the second side 51d2 of the coil 51d in the -Z direction and the +Z direction, respectively. As a result, a clockwise driving force is applied to the revolver 20 with respect to the holder 30, the cores 23a to 23d escape from the attractive forces of the

magnets 52a to 52d, and the revolver 20 starts to rotate in the direction shown by the arrow in the figure.

[0069] As shown in Fig. 4B, when the revolver 20 rotates clockwise by the unit rotation angle (-22.5 degrees), the first side 51a1 and the second side 51a2 of the coil 51a are respectively aligned with the first magnetic pole 52a1 and the second magnetic pole 52a2 of the magnet 52a, and the first side 51c1 and the second side 51c2 of the coil 51c are respectively aligned with the second magnetic pole 52b2 of the magnet 52b and the first magnetic pole 52c1 of the magnet 52c. At the same time, the first sides 51b1, 51d1 and the second sides 51b2, 51d2 of the coils 51b, 51d are aligned with the boundaries of the magnetic poles of the magnets 52a to 52d or with the space between two adjacent magnets, and thus not aligned with the magnetic poles of any of the magnets 52a to 52d. The AF-rotation control unit 71 then excites the coils 51a, 51c so that the current flows through the first side 51a1 and the second side 51a2 of the coil 51a in the +Z direction and the -Z direction, respectively, and the current flows through the first side 51c1 and the second side 51c2 of the coil 51c in the -Z direction and the +Z direction, respectively. As a result, a clockwise driving force is applied to the revolver 20 with respect to the holder 30, and the revolver 20 further rotates in the direction shown by the arrow in the figure.

[0070] As shown in Fig. 4C, when the revolver 20 rotates clockwise by the unit rotation angle $\times 2$ (-45 degrees), the first side 51d1 and the second side 51d2 of the coil 51d are respectively aligned with the first magnetic pole 52c1 and the second magnetic pole 52c2 of the magnet 52c, and the first side 51b1 and the second side 51b2 of the coil 51b are respectively aligned with the second magnetic pole 52a2 of the magnet 52a and the first magnetic pole 52b1 of the magnet 52b. At the same time, the first sides 51a1,

51c1 and the second sides 51a2, 51c2 of the coils 51a, 51c are aligned with the boundaries of the magnetic poles of the magnets 52a to 52d or with the space between two adjacent magnets, and thus not aligned with the magnetic poles of any of the magnets 52a to 52d. The AF-rotation control unit 71 then excites the coils 51d, 51b so that the current flows through the first side 51d1 and the second side 51d2 of the coil 51d in the +Z direction and the -Z direction, respectively, and the current flows through the first side 51b1 and the second side 51b2 of the coil 51b in the -Z direction and the +Z direction, respectively. As a result, a clockwise driving force is applied to the revolver 20 with respect to the holder 30, and the revolver 20 further rotates in the direction shown by the arrow in the figure.

[0071] As shown in Fig. 4D, when the revolver 20 rotates clockwise by the unit rotation angle $\times 3$ (-67.5 degrees), the first side 51c1 and the second side 51c2 of the coil 51c are respectively aligned with the first magnetic pole 52b1 and the second magnetic pole 52b2 of the magnet 52b, and the first side 51a1 and the second side 51a2 of the coil 51a are respectively aligned with the second magnetic pole 52d2 of the magnet 52d and the first magnetic pole 52a1 of the magnet 52a. At the same time, the first sides 51b1, 51d1 and the second sides 51b2, 51d2 of the coils 51b, 51d are aligned with the boundaries of the magnetic poles of the magnets 52a to 52d or with the space between two adjacent magnets, and thus not aligned with the magnetic poles of any of the magnets 52a to 52d. The AF-rotation control unit 71 then excites the coils 51c, 51a so that the current flows through the first side 51c1 and the second side 51c2 of the coil 51c in the +Z direction and the -Z direction, respectively, and the current flows through the first side 51a1 and the second side 51a2 of the coil 51a in the -Z direction and the +Z direction, respectively. As a result, a clockwise driving force is applied to the revolver

20 with respect to the holder 30, and the revolver 20 further rotates in the direction shown by the arrow in the figure.

[0072] As shown in Fig. 4E, when the revolver 20 rotates clockwise by the unit rotation angle $\times 4$ (-90 degrees), the cores 23a to 23d on the revolver 20 are aligned with the boundaries of the magnetic poles of the magnets 52d, 52a to 52c, respectively, so that the revolver 20 is positioned at that position without application of a holding force and the lens 11 is accordingly positioned on the optical axis L. The AF-rotation control unit 71 specifies the lens state as the left lens state by sensing that only the magnetic sensors 32b detects the reference magnets 22a to be activated and finishes the lens exchange operation.

[0073] The excitation switching of the coils 51a to 51d in the lens exchange operation from the left lens state to the reference lens state is described.

[0074] In the left lens state shown in Fig. 4F, i.e. when the revolver 20 is at a position of -90 degrees, the first side 51b1 and the second side 51b2 of the coil 51b are aligned with the first magnetic pole 52a1 and the second magnetic pole 52a2 of the magnet 52a, respectively, and the first side 51d1 and the second side 51d2 of the coil 51d are aligned with the second magnetic pole 52b2 of the magnet 52b and the first magnetic pole 52c1 of the magnet 52c, respectively. At the same time, the first sides 51a1, 51c1 and the second sides 51a2, 51c2 of the coils 51a, 51c are aligned with the boundaries of the magnetic poles of the magnets 52a to 52d or with the space between two adjacent magnets, and thus not aligned with the magnetic poles of any of the magnets 52a to 52d. The AF-rotation control unit 71 then excites the coils 51b, 51d so that the current flows through the first side 51b1 and the second side 51b2 of the coil 51b in the -Z direction and the +Z direction, respectively, and the current flows through the first side 51d1 and

the second side 51d2 of the coil 51d in the +Z direction and the -Z direction, respectively. As a result, a counterclockwise driving force is applied to the revolver 20 with respect to the holder 30, the cores 23a to 23d escape from the attractive forces of the magnets 52a to 52d, and the revolver 20 starts to rotate in the direction shown by the arrow in the figure.

[0075] Next, the AF-rotation control unit 71 performs the excitation switching described above at each position of the revolver 20 shown in Figs. 4B to 4D with energizing of the coils 51a to 51d in the reverse direction. Thereby, the revolver 20 further rotates counterclockwise.

[0076] As shown in Fig. 4A, when the revolver 20 returns to the reference position (0 degrees), the cores 23a to 23d on the revolver 20 are aligned with the boundaries of the magnetic poles of the magnets 52a to 52d, respectively, so that the revolver 20 is positioned at the reference position without application of a holding force and the lens 12 is accordingly positioned on the optical axis L. The AF-rotation control unit 71 specifies the lens state as the standard lens state by sensing that both of the magnetic sensors 32a, 32b detect the reference magnets 22a, 22b to be activated and finishes the lens exchange operation.

[0077] Since the coils 51a, 51c and the coils 51b, 51d are arranged with a shift of the relative phase of 90 degrees with respect to the arrangement of the magnets 52a to 52d, the two sides of the coils 51a, 51c and the two sides of the coils 51b, 51d are alternately aligned with the magnetic poles of the magnets 52a to 52d, every time the revolver 20 rotates by the unit rotation angle. Therefore, the revolver 20 can be rotationally driven without losing control.

[0078] As described above, the lens exchange apparatus 100 according to the

present embodiment comprises a revolver 20 to hold a plurality of lenses 11 to 13 apart from each other around a rotation center, a holder 30 to rotatably support the revolver 20, and a motor 50 including a mover 51 attached to the revolver 20 and a stator 52 attached to the holder 30 so as to face the mover 51, wherein the motor 50 rotationally drives the revolver 20 with respect to the holder 30. By rotationally driving the revolver 20 with respect to the holder 30 using the motor 50, it is possible to exchange the plurality of lenses 11 to 13, select one of the lenses and position it on the optical axis L of the image sensor 99. A camera module of a lens exchange type in which one module is constructed from the lens on the optical axis L and the image sensor 99 can be provided.

[0079] In the lens exchange apparatus 100 according to the present embodiment, the two magnetic sensors 32a, 32b are provided on the holder 30, the two reference magnets 22a, 22b are provided on the revolver 20, the rotational position of the revolver 20 is detected by specifying the magnetic sensors 32a, 32b aligned with the reference magnets 22a, 22b to detect magnetic fields generated by them and be activated, but any numbers of magnetic sensors and reference magnets may be used. The rotational position of the revolver 20 may be detected by specifying magnetic sensors aligning with at least one reference magnet on the revolver 20 and reacting to the magnetic fields of the reference magnets, where at least one reference magnet may be provided on the revolver 20, a plurality of magnetic sensors may be arranged around the revolver 20 on the holder 30 so as to face at least one reference magnet.

[0080] In such a case, the plurality of magnetic sensors are arranged corresponding to positions of the revolver 20 where the plurality of lenses 11 to 13 are positioned on the optical axis L of the image sensor 99. Thereby, by specifying at least one of the

plurality of magnetic sensors which detects at least one reference magnet and is thus activated, it is possible to specify a lens positioned on the optical axis L of the image sensor 99.

[0081] In the lens exchange apparatus 100 according to the present embodiment, a moving coil-type motor is employed in which the plurality of coils 51a to 51d arranged on the side surface of the revolver 20 is used as the mover 51 and the plurality of magnets 52a to 52d arranged on the holder 30 around the revolver 20 are used as the stator 52, but the motor is not limited to this type, a moving magnet-type motor may be employed in which a plurality of magnets are arranged on the side surface of the revolver 20 as the mover 51 and a plurality of magnets are arranged on the holder 30 around the revolver 20 as the stator 52. Furthermore, the mover 51 may not be limited to being provided on the side surface and be provided near the periphery of the upper surface or the lower surface of the revolver 20, and the stator 52 may be provided on the holder so as to face the mover 51, thereby a planar-facing type motor may be configured.

[0082] Figs. 5A to 5E show a configuration of a lens exchange apparatus 110 according to a variation, where Fig. 5A shows a configuration of the lens exchange apparatus 110 in a top view. Fig. 5B shows a configuration of the lens exchange apparatus 110 in a cross section along the reference line II-II of Fig. 5A. Fig. 5C shows a configuration of a revolver 120 in a top view. Fig. 5D shows a configuration of a holder 130 in a top view. Fig. 5E shows a configuration of a base 140 in a top view. In these figures, with respect to the optical axis L located at a light receiving center of an image sensor 99, the direction parallel to the optical axis L is defined as the Z-axis direction, the direction of the straight line connecting the optical axis L and the rotation center of the revolver 120 (the center of the shaft 33 on the holder 130) in a plane perpendicular to the Z-axis

direction is defined as the Y-axis direction, and the direction orthogonal to the Z- and Y-axis directions is defined as the X-axis direction.

[0083] The lens exchange apparatus 110 comprises a revolver 120, a holder 130, a base 140, a motor 150, and a control unit 170.

[0084] The revolver 120 is for holding the lenses 11 to 13, and is configured similarly to the revolver 20 described above except for following features. The reference magnets 22a, 22b are respectively provided on the back of the first side 51a1 of the coil 51a and between the coil 51d and the vibrationproof member 26. Furthermore, the plurality of cores 23a to 23c are disposed on the side surface of the revolver 20 in proximity to the lenses 13 to 11, respectively.

[0085] The holder 130 is a casing for rotatably supporting the revolver 120, and is configured similarly to the holder 30 described above, except for following features. The four grooves 31a to 31d are located, respectively, on the +X side, +Y side, -X side, and -Y side in the recess 31 and accommodate, respectively, the magnets 52a to 52d therein. In other words, the magnets 52b, 52d are located on opposite sides in the direction of the straight line connecting the optical axis L and the center of the shaft 33. The magnetic sensors 32a, 32b are buried in the inner surface on the +X, -Y and the -X, -Y side in the recess 31, respectively.

[0086] The base 140 is for swingably supporting the holder 130, and configured similarly to the base 40 described above except for following features. The coils 61b, 61d are for constructing a stator 61 of the actuator 160, and provided in the FPC 40b so as to be aligned, respectively, with the magnets 52b, 52d provided in the holder 130 in the Z-axis direction. The magnetic sensors 42a, 42b are for detecting, respectively, magnetic fields generated by the magnets 52a, 52b to detect the position of the holder

130 with respect to the base 140 in the X- and Y-directions. The magnetic sensor 42a is disposed on the FPC 40b so as to be aligned with the magnet 52a on the holder 130 in the Z-axis direction. The magnetic sensor 42b is provided on the FPC 40b and overlaps with the coil 61b so as to be aligned with the magnet 52b on the holder 130 in the Z-axis direction.

[0087] Each of the coils 61b, 61d includes a pair of sub-coils, where one sub-coil is aligned with the first magnetic pole 52b1, 52d1 included in the magnet 52b, 52d and a magnetic pole of the opposite polarity located on its back surface, and the other sub-coil is aligned with the second magnetic pole 52b2, 52d2 and a magnetic pole of the opposite polarity located on its back surface. The magnets 52b, 52d and the coils 61b, 61d aligned therewith construct the actuator 160 (one example of a swing apparatus and also referred to as an OIS-actuator) to swing the holder 130 in the Y-axis direction on the base 140.

[0088] The motor 150 is constructed similarly to the motor 50 described above except for that the magnets 52a to 52d are arranged differently.

[0089] Fig. 6 shows a configuration of a control system of the lens exchange apparatus 110 according to the variation. The control system is constructed to include a control unit 170. A computer apparatus executes a control program to realize the control unit 170 having functions of a AF-rotation control unit 71 and a OIS control unit 72.

[0090] The AF-rotation control unit 71 is to rotationally control the revolver 120 and AF-control a lens on the optical axis L based on output signals of the magnetic sensors 32a, 32b on the holder 130. The principles of rotational driving and AF-driving of the revolver 120 are as described above.

[0091] The OIS control unit 72 can correct in the X- and Y-directions the position of a

lens located on the optical axis L of the image sensor 99 from among the plurality of lenses 11 to 13 held by the revolver 120, i.e. perform image stabilization, by calculating the position of the holder 130 in the X- and Y-directions with respect to the base 140 based on detection signals of the magnetic sensors 42a, 42b and controlling the actuator 160 such that the coils 61b, 61d are excited to swing the holder 130 in the Y-axis direction on the base 140, and controlling the motor 150 such that the revolver 120 is minutely rotated with respect to the holder 130 based on the calculated results.

[0092] The control unit 170 having such a configuration rotationally drives the revolver 120 that holds the plurality of lenses 11 to 13 using the motor 150 to exchange the lenses 11 to 13 and position one of the lenses on the optical axis L, AF-controls the lens on the optical axis L by driving the revolver 120 in the Z-axis direction using the actuator 34, and OIS-controls the lens on the optical axis L by swinging the revolver 120 in the Y-axis direction using the actuator 160 and minutely rotating the revolver 120 using the motor 150. Thereby, it is possible to precisely control positions of the plurality of lenses 11 to 13 by the common control system.

[0093] Fig. 7 shows one example of a configuration of a portable terminal 200. The portable terminal 200 may be, for example, a smartphone, a tablet computer, etc. and comprises the plurality of lenses 11 to 13, the image sensor 99, and the lens exchange apparatus 100 according to the present embodiment or the lens exchange apparatus 110 according to the variation. The plurality of lenses 11 to 13 are held by the revolver 20 (120) comprised by the lens exchange apparatus 100 (110), and the image sensor 99 is disposed in the lens exchange apparatus 100 (110) such that its optical axis L aligns with the centers of the opening 30a of the holder 30 (130) and the opening 40a of the base 40 (140). The portable terminal 200 having such a configuration provides a

portable terminal comprising a camera module that uses a single image sensor 99, a single AF-actuator 34, and a single OIS-actuator 60 (160) for the lenses 11 to 13 by employing a lens exchange method to exchange the plurality of lenses 11 to 13 and position one of the lenses on the optical axis L of the image sensor 99 by the lens exchange apparatus 100 (110).

[0094] While the embodiments of the present invention have been described, the technical scope of the invention is not limited to the above described embodiments. It will be apparent to persons skilled in the art that various alterations and improvements can be added to the above-described embodiments. It will also be apparent from the scope of the claims that the embodiments added with such alterations or improvements can be included in the technical scope of the invention.

[0095] The operations, procedures, steps, and stages of each process performed by an apparatus, system, program, and method shown in the claims, embodiments, or diagrams can be performed in any order as long as the order is not indicated by "prior to," "before," or the like and as long as the output from a previous process is not used in a later process. Even if the process flow is described using phrases such as "first" or "next" in the claims, embodiments, or diagrams, it does not necessarily mean that the process must be performed in this order.

WHAT IS CLAIMED IS:

1. A lens exchange apparatus for exchanging a plurality of lenses to dispose any one on an optical axis of an image sensor, comprising:
 - a revolver to hold a plurality of lenses apart from each other around a rotation center;
 - a holder to rotatably support the revolver; and
 - a motor including a mover attached to the revolver and a stator attached to the holder so as to face the mover, wherein the motor rotationally drives the revolver with respect to the holder.
2. The lens exchange apparatus according to claim 1, wherein the mover has a plurality of coils arranged on a side surface of the revolver and the stator has a plurality of magnets arranged around the revolver, such that the plurality of magnets interact with the plurality of coils.
3. The lens exchange apparatus according to claim 2, wherein each of the plurality of magnets has a first magnetic pole and a second magnetic pole, and the plurality of magnets are arranged such that the magnetic poles are alternated around the revolver,
 - wherein each of the plurality of coils has a first side and a second side apart from each other along the circumference of the revolver,
 - wherein the relative size and arrangement of the plurality of magnets and the plurality of coils is such that, for a rotational position of the revolver, the first

side of a first coil of the plurality of coils is aligned with the first magnetic pole of a first magnet of the plurality of magnets and the second side of the first coil is aligned with the second magnetic pole of the first magnet, and the first side of a second coil of the plurality of coils is aligned with the second magnetic pole of a second magnet of the plurality of magnets and the second side of the second coil is aligned with the first magnetic pole of a third magnet of the plurality of magnets, the second magnet and the third magnet being adjacent.

4. The lens exchange apparatus according to claim 3, wherein a third coil of the plurality of coils is positioned such that the first side of the third coil is aligned between the first and second magnets and the second side of the third coil is aligned with a boundary of the first and second magnetic poles of the second magnet, and a fourth coil of the plurality of coils is positioned such that the first side of the fourth coil is aligned with a boundary of the first and second magnetic poles of the fourth magnet and the second side of the fourth coil is aligned between the first magnet and a fourth magnet.

5. The lens exchange apparatus according to any one of claims 2-4, wherein each of the plurality of magnets has a first magnetic pole and a second magnetic pole, and the plurality of magnets are arranged such that the magnetic poles are alternated around the revolver,

wherein each of the plurality of coils has a first and a second side apart from each other along the circumference of the revolver,

wherein an array pitch of the plurality of coils is $3/2$ times a separation

distance between the first side and the second side of each of the plurality of coils, and an array pitch of the plurality of magnets is 2 times the separation distance between the first side and the second side of each of the plurality of coils.

6. The lens exchange apparatus according to any one of claims 3-5, wherein the revolver has at least one core which is aligned with a boundary of the first magnetic pole and the second magnetic pole of one of the plurality of magnets when the revolver is rotatably positioned such that one of the plurality of lenses is located on the optical axis.

7. The lens exchange apparatus according to any one of claims 2-6, further comprising a base to swingably support the holder, wherein the base has a plurality of different coils provided to respectively face the plurality of magnets.

8. The lens exchange apparatus according to claim 7, further comprising a control unit to excite the plurality of different coils based on output signals of a magnetic sensor disposed on the base to face at least one of the plurality of magnets.

9. The lens exchange apparatus according to claim 7 or 8, wherein the plurality of magnets include two pairs of magnets, each pair of magnets located on opposite sides of the rotation center of the revolver.

10. The lens exchange apparatus according to claim 7 or 8, wherein the plurality of magnets include two magnets located on opposite sides of the rotation

center of the revolver such that the optical axis is directly between the two magnets.

11. The lens exchange apparatus according to any one of claims 1-10, wherein the revolver has at least one reference magnet, and wherein the holder has a plurality of magnetic sensors disposed around the revolver to detect the at least one reference magnet.

12. The lens exchange apparatus according to claim 11, wherein the plurality of magnetic sensors on the holder are positioned such that at least one magnetic sensor detects at least one reference magnet at each rotational position of the revolver in which one of the plurality of lenses is positioned on the optical axis of the image sensor.

13. The lens exchange apparatus according to claim 11, wherein the plurality of lenses include three lenses disposed at a constant angular interval around the rotation center of the revolver, wherein the at least one reference magnet includes two reference magnets disposed at an angular interval equal to the constant angular interval, and wherein the plurality of magnetic sensors on the holder include two magnetic sensors disposed at an angular interval equal to the constant angular interval.

14. The lens exchange apparatus according to any one of claims 11-13, further comprising a control unit to correct a position of the revolver along the optical axis based on detection results of a magnetic sensor detecting the reference magnet

among the plurality of magnetic sensors on the holder.

15. The lens exchange apparatus according to any one of claims 1-14, wherein the holder has a shaft to rotatably support the revolver and an actuator to drive the shaft along the optical axis.

16. The lens exchange apparatus according to claim 15, wherein the shaft supports the revolver at the center of mass of the revolver.

17. A portable terminal comprising:
a plurality of lenses;
an image sensor; and
a lens exchange apparatus according to any one of claims 1-16 for
exchanging the plurality of lenses to dispose any one on an optical axis of the image
sensor.

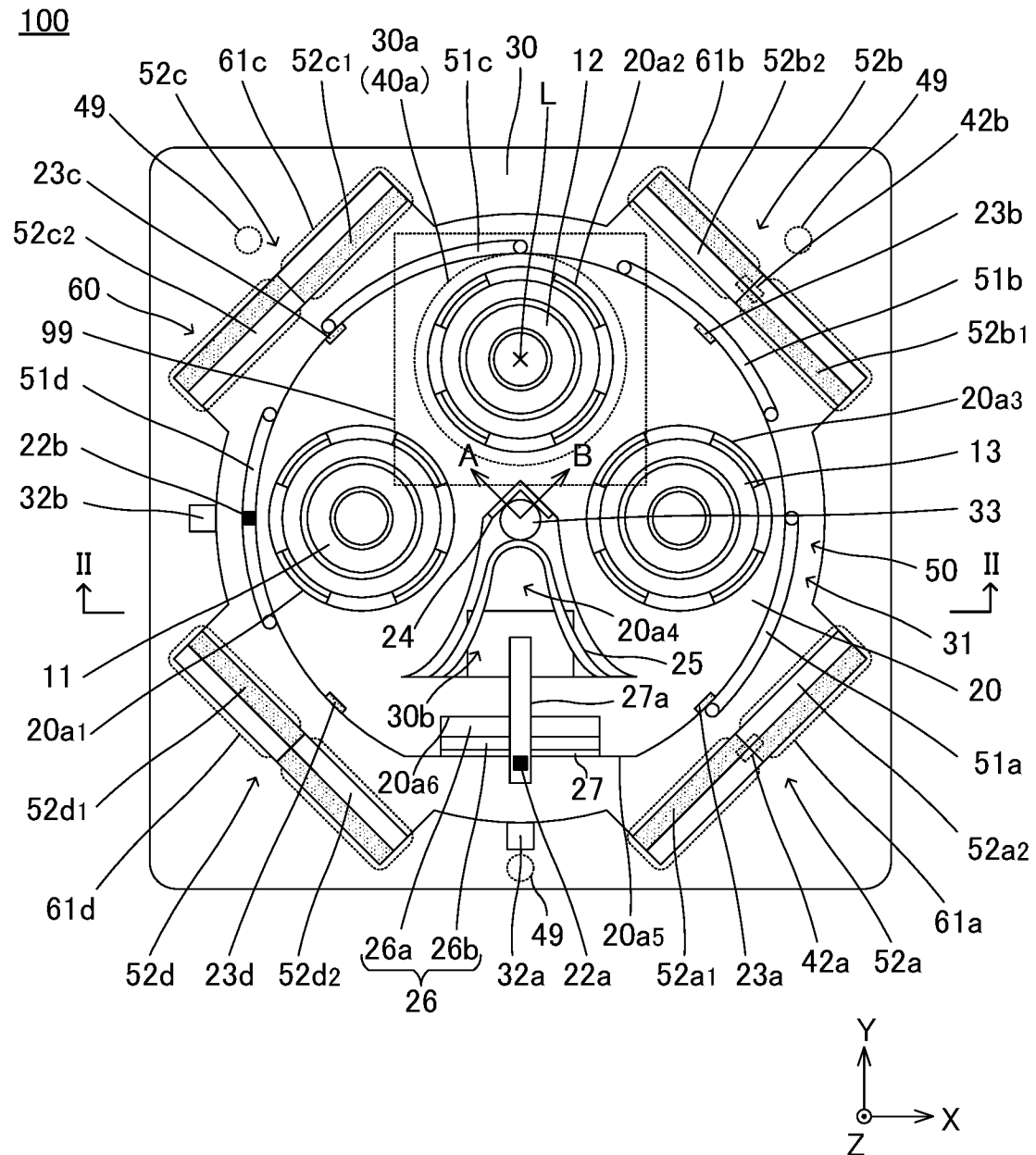


Fig. 1A

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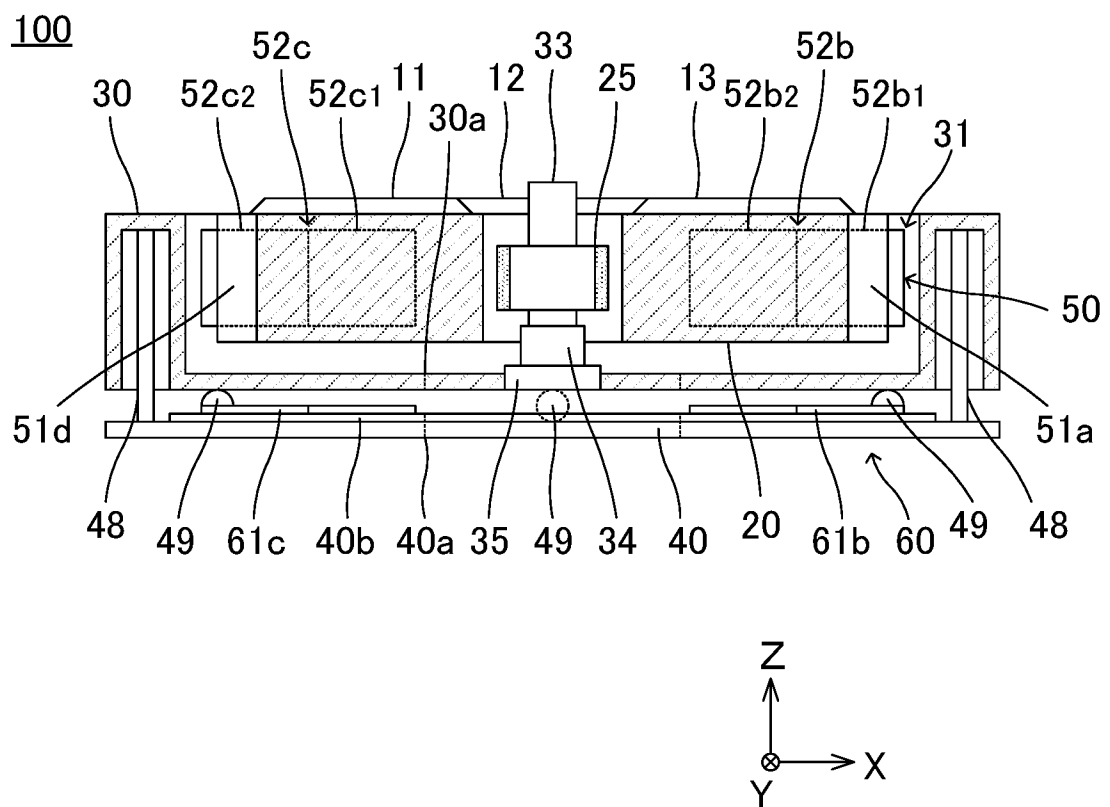


Fig. 1B

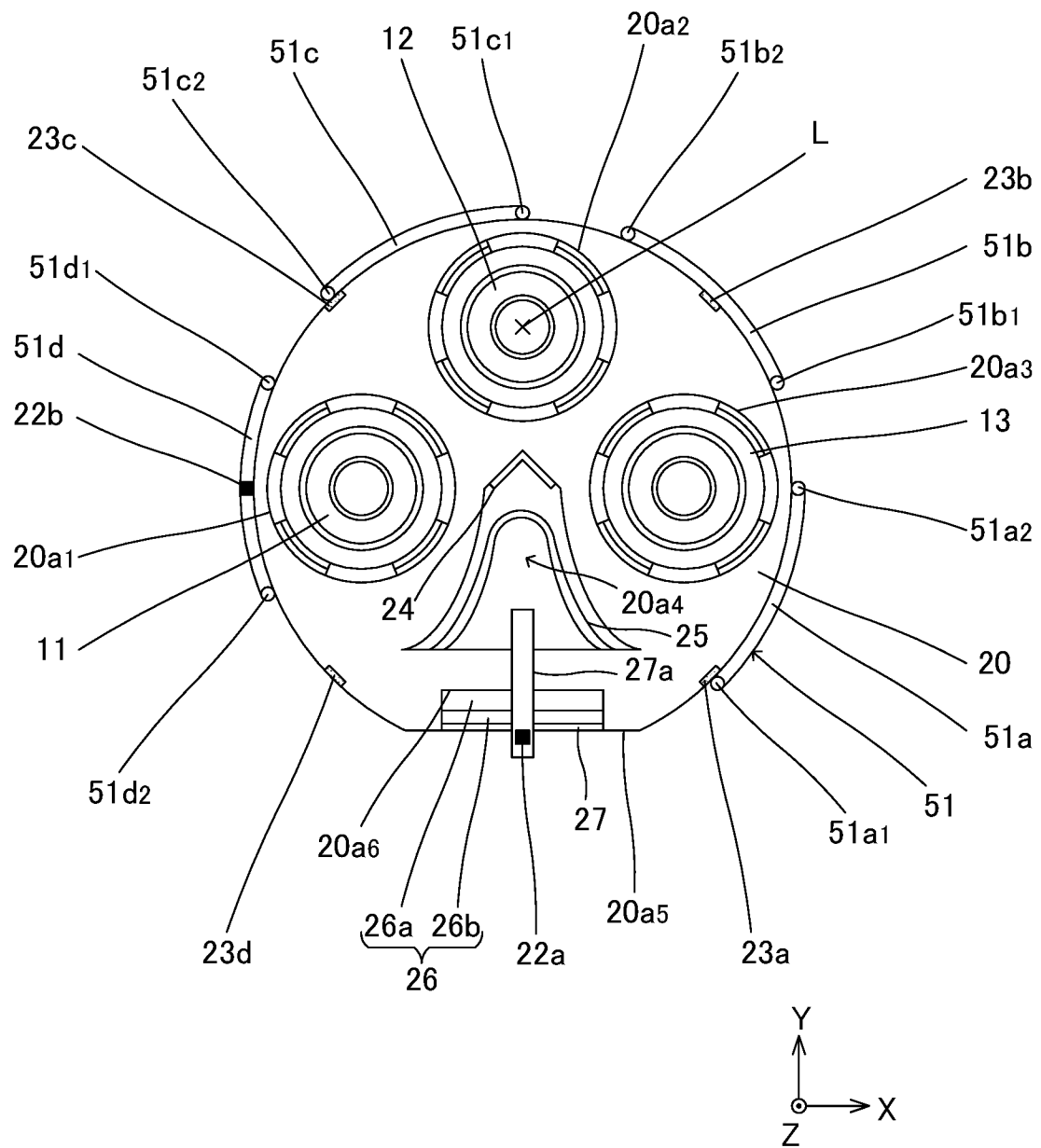


Fig. 1C

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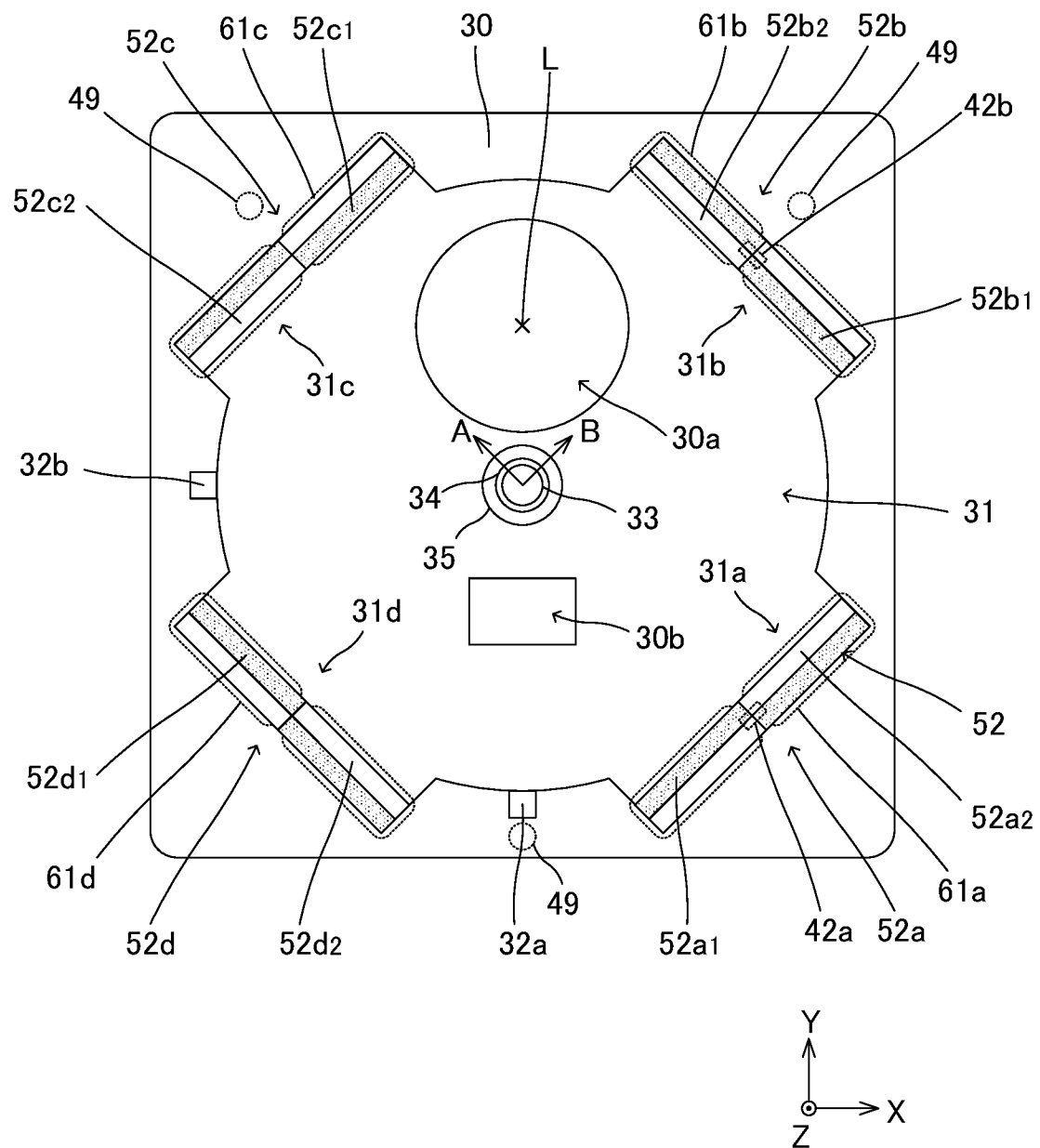


Fig. 1D

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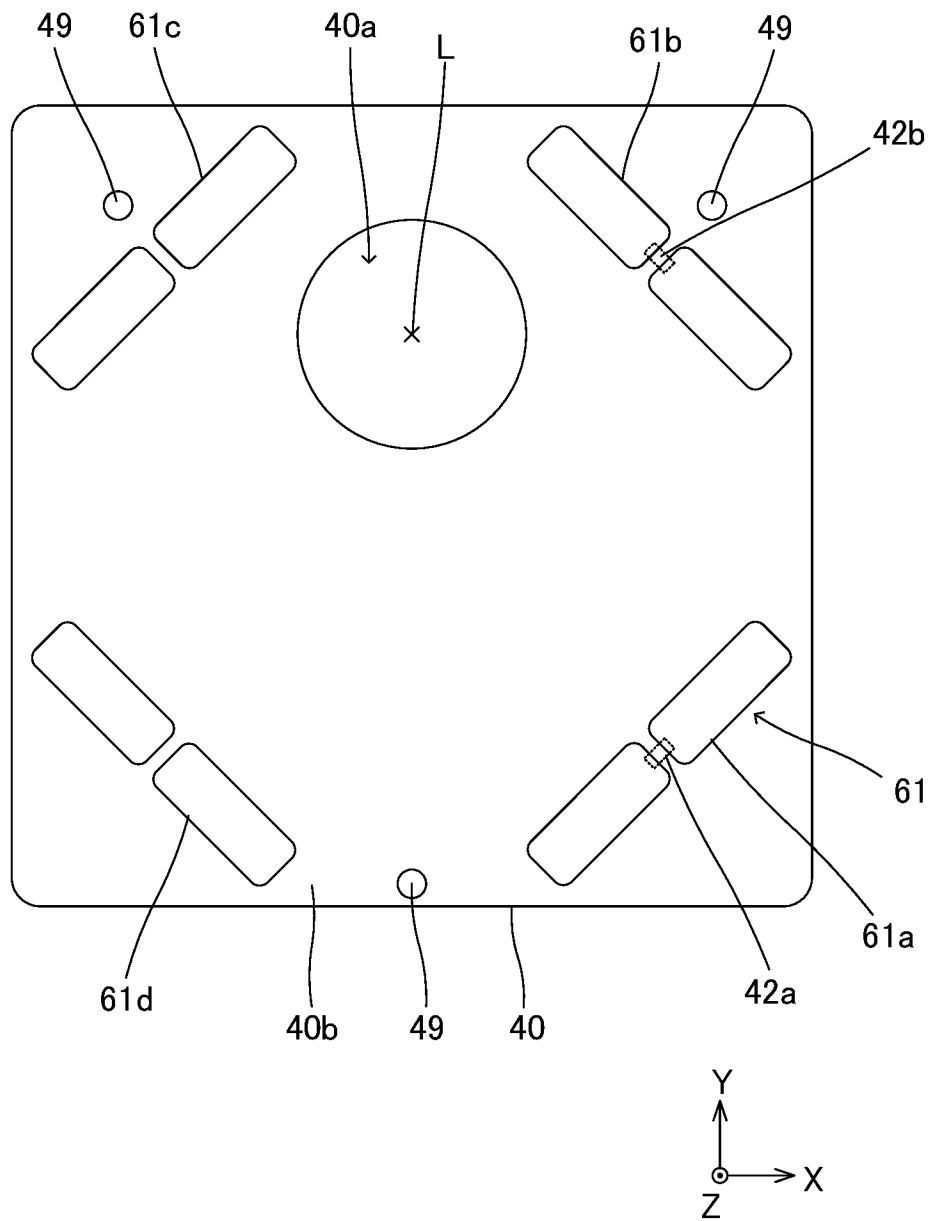
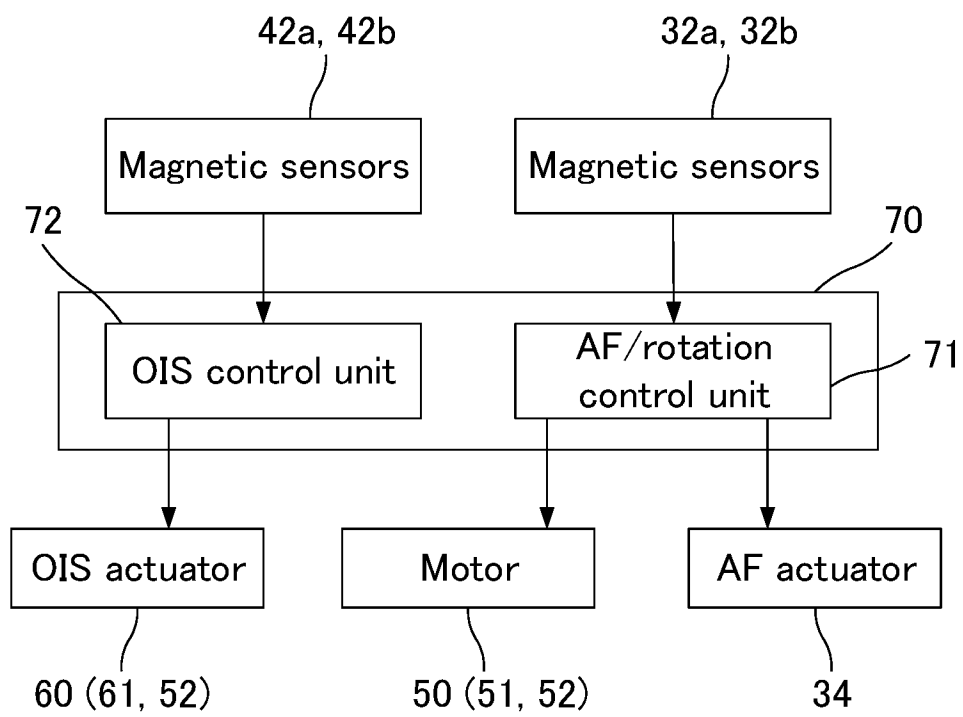


Fig. 1E

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*Fig. 2*

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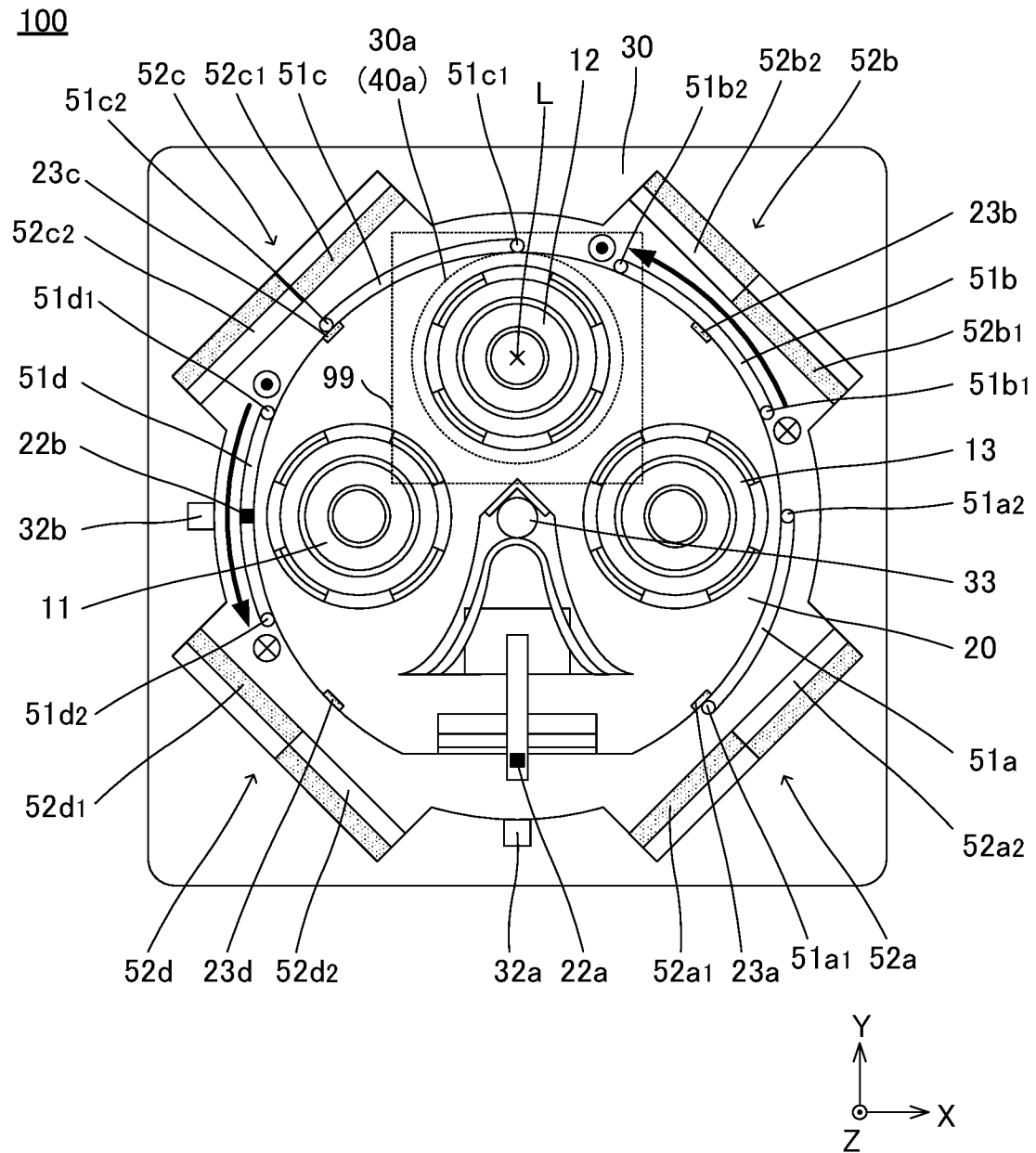
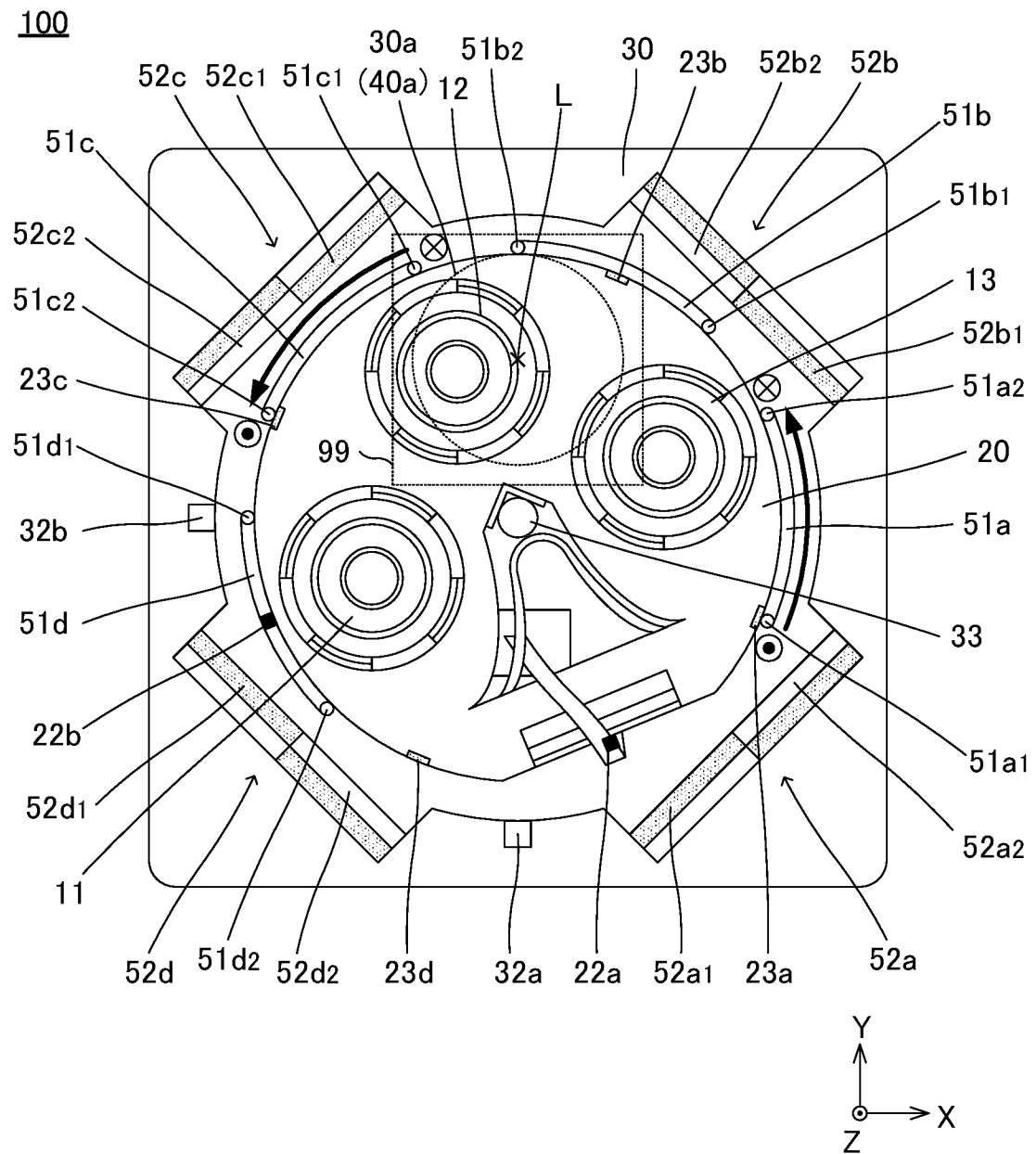
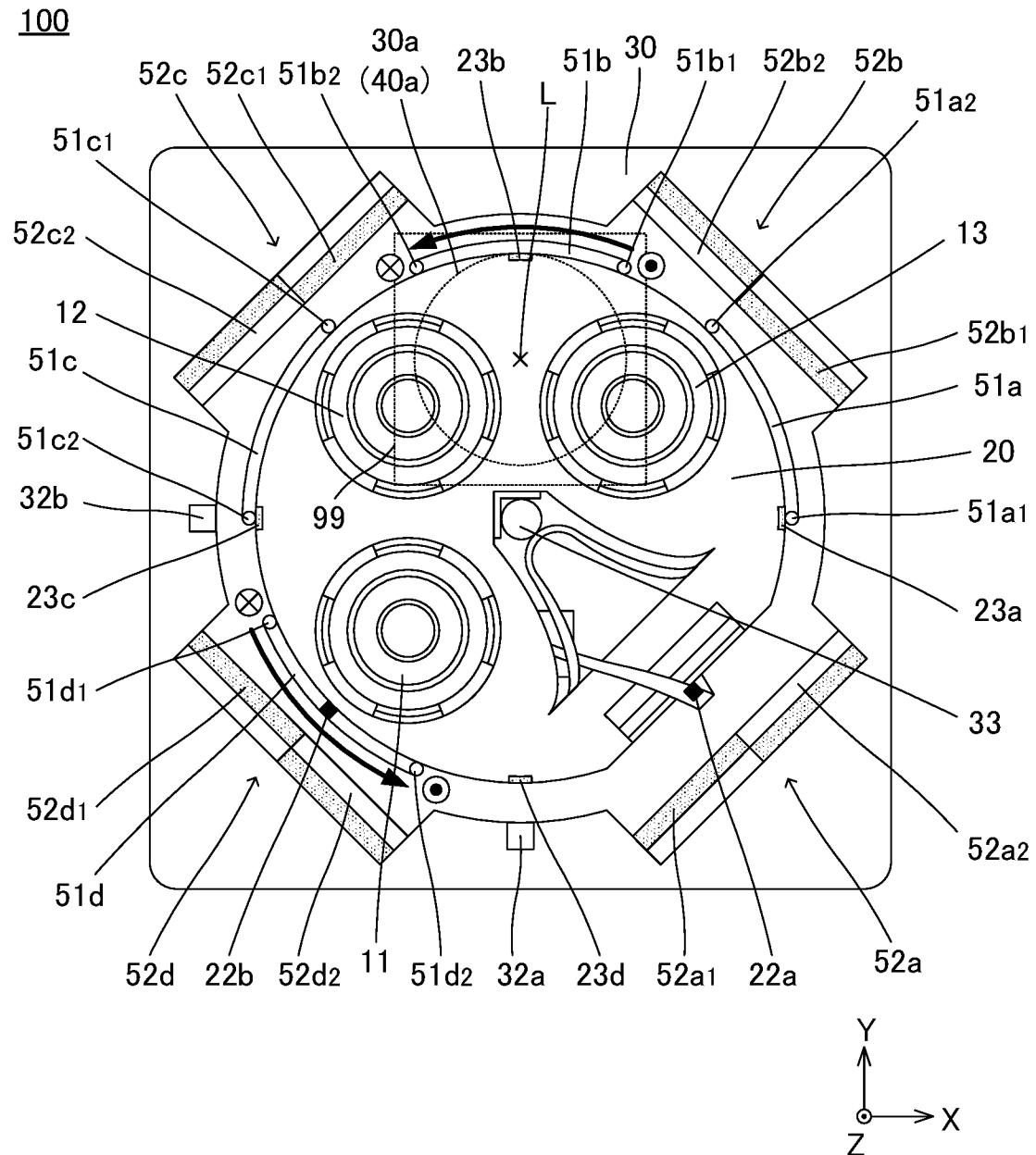


Fig. 3A

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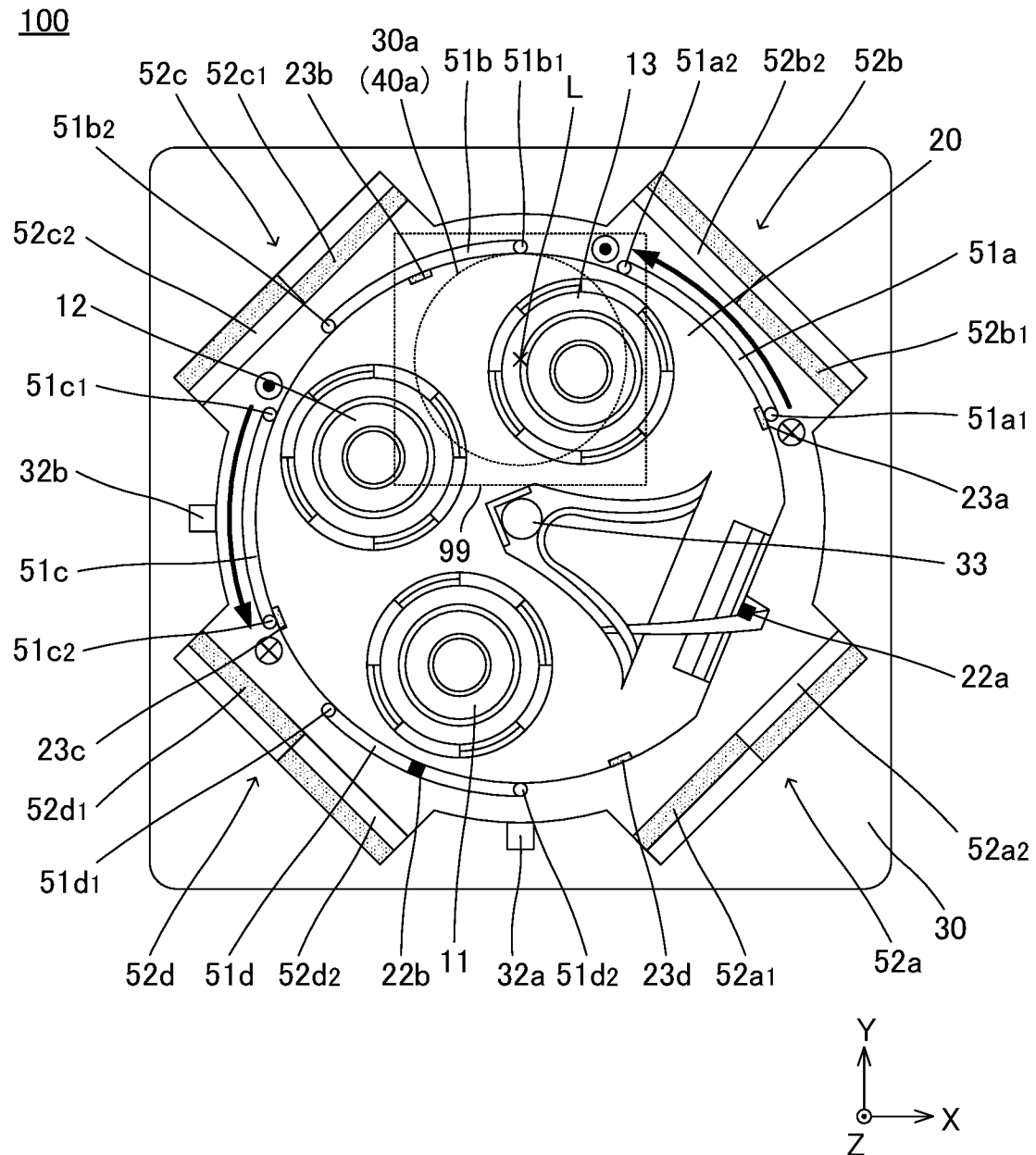


Fig. 3D

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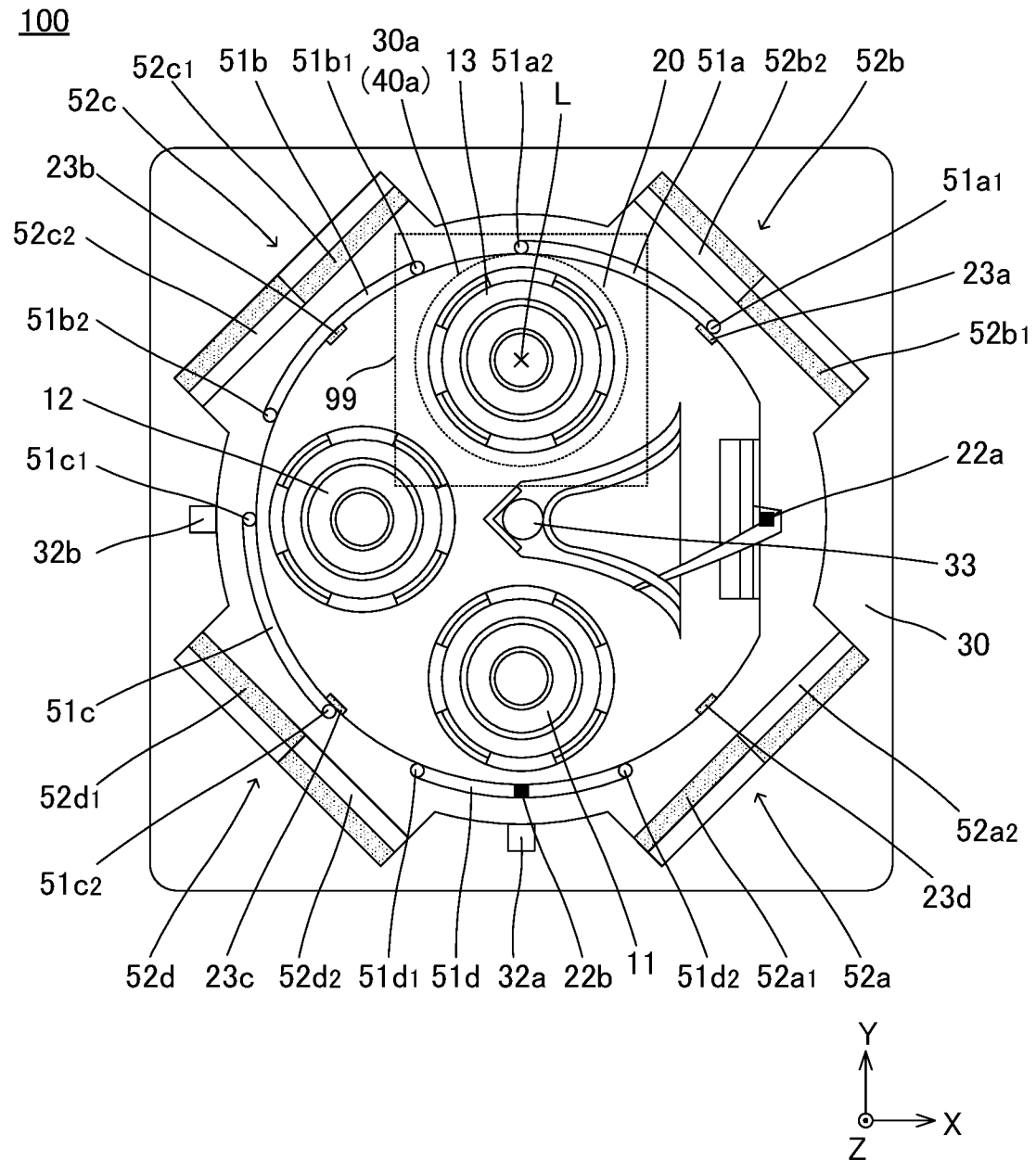


Fig. 3E

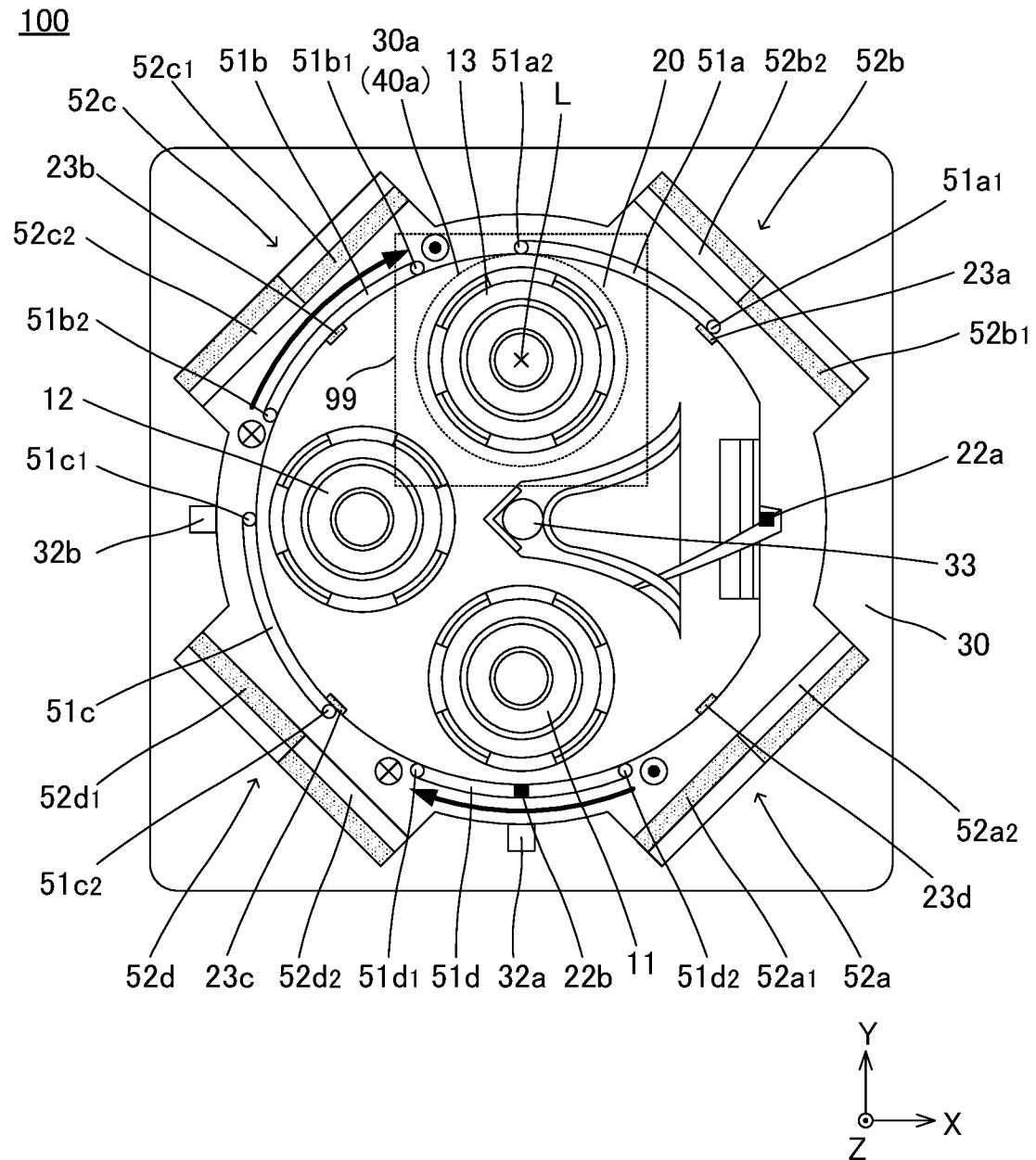


Fig. 3F

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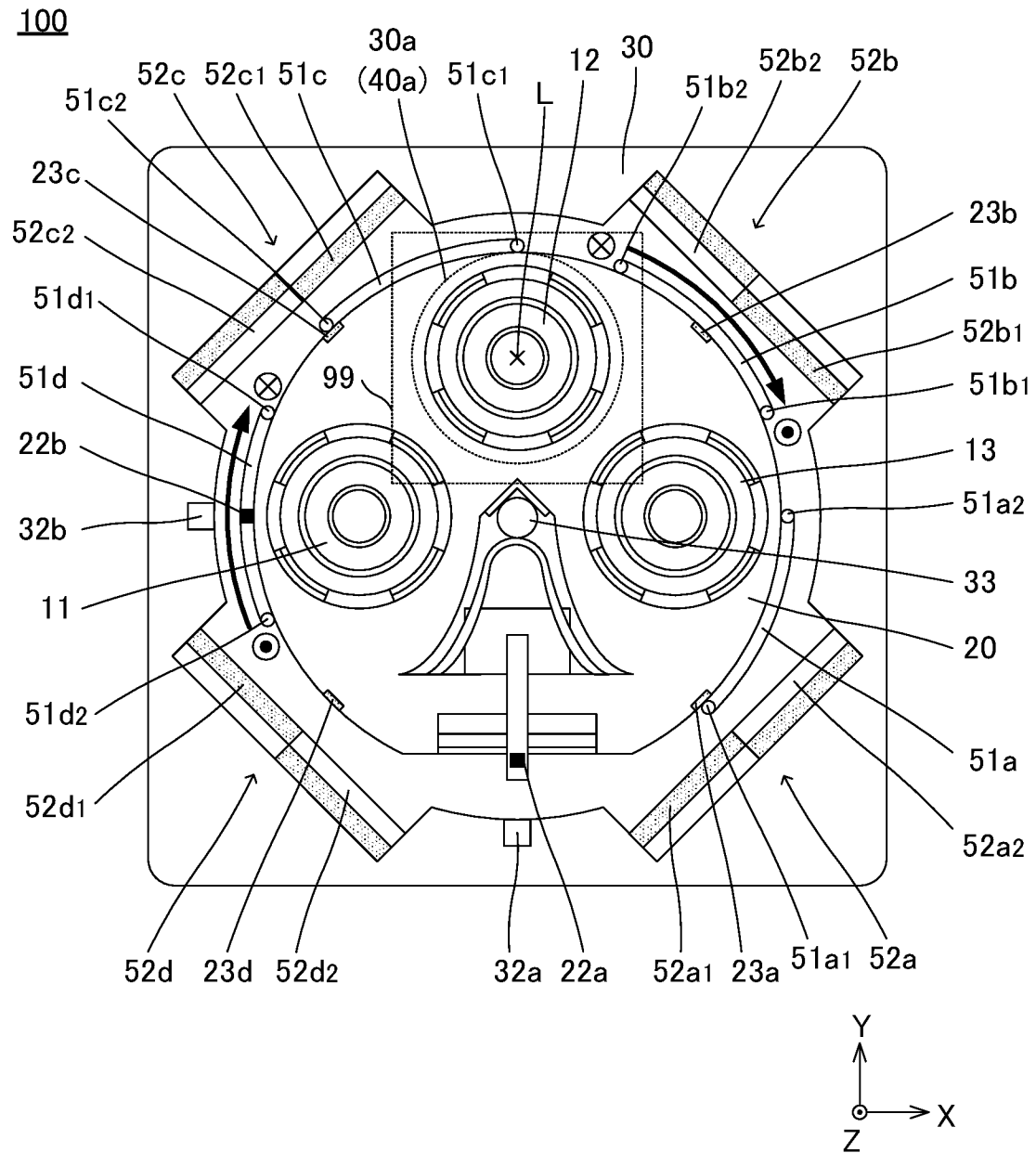


Fig. 4A

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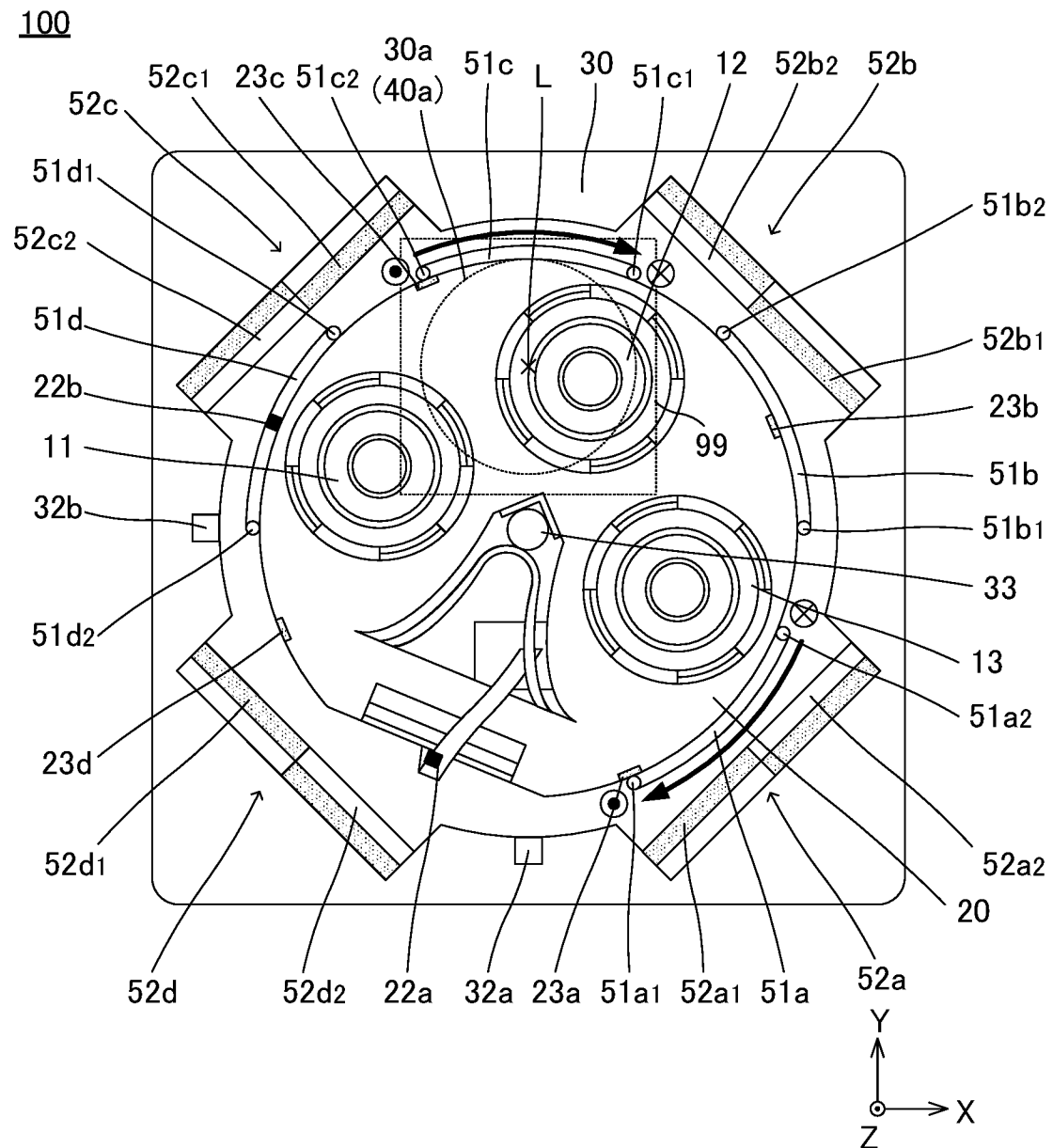


Fig. 4B

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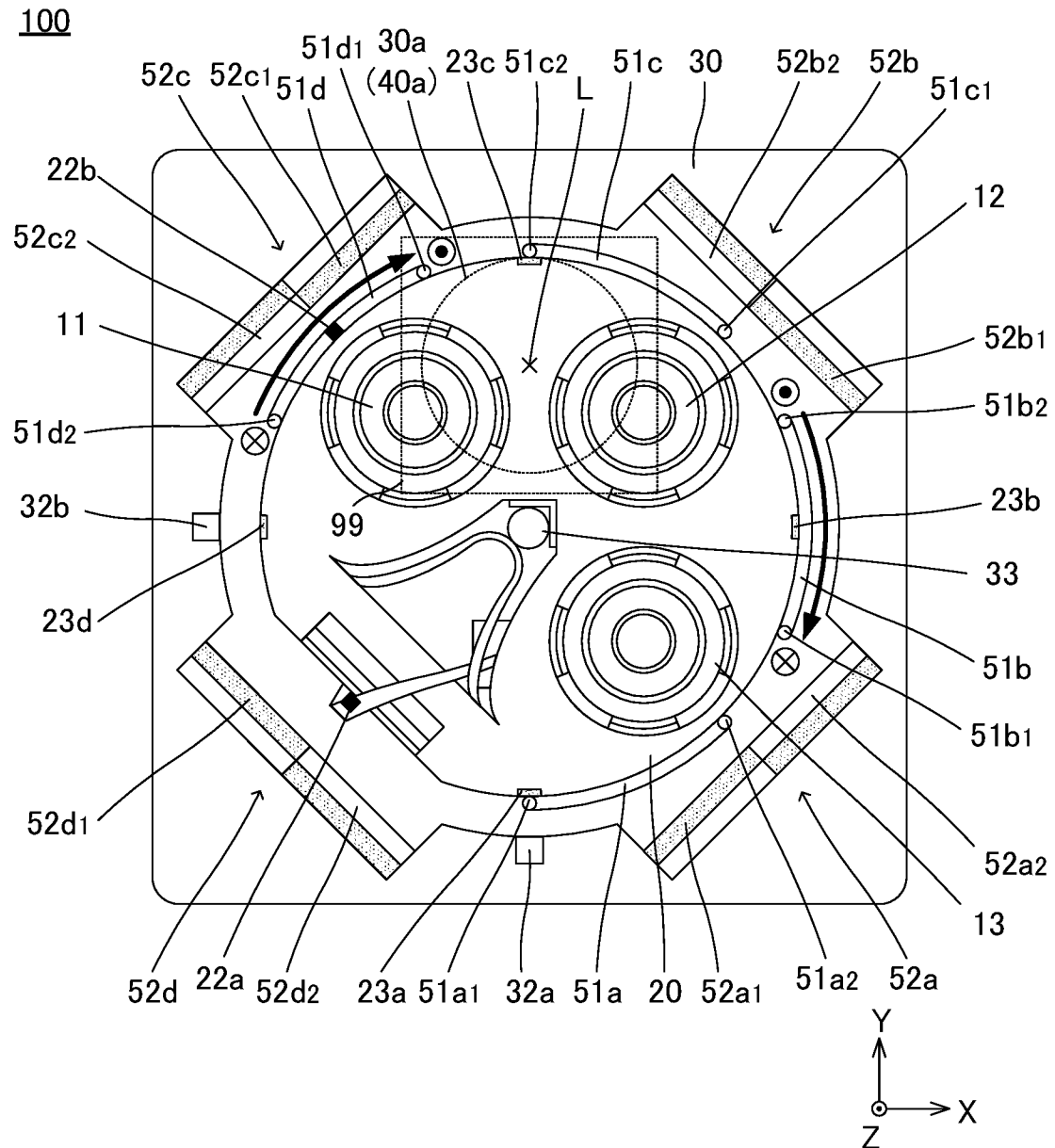


Fig. 4C

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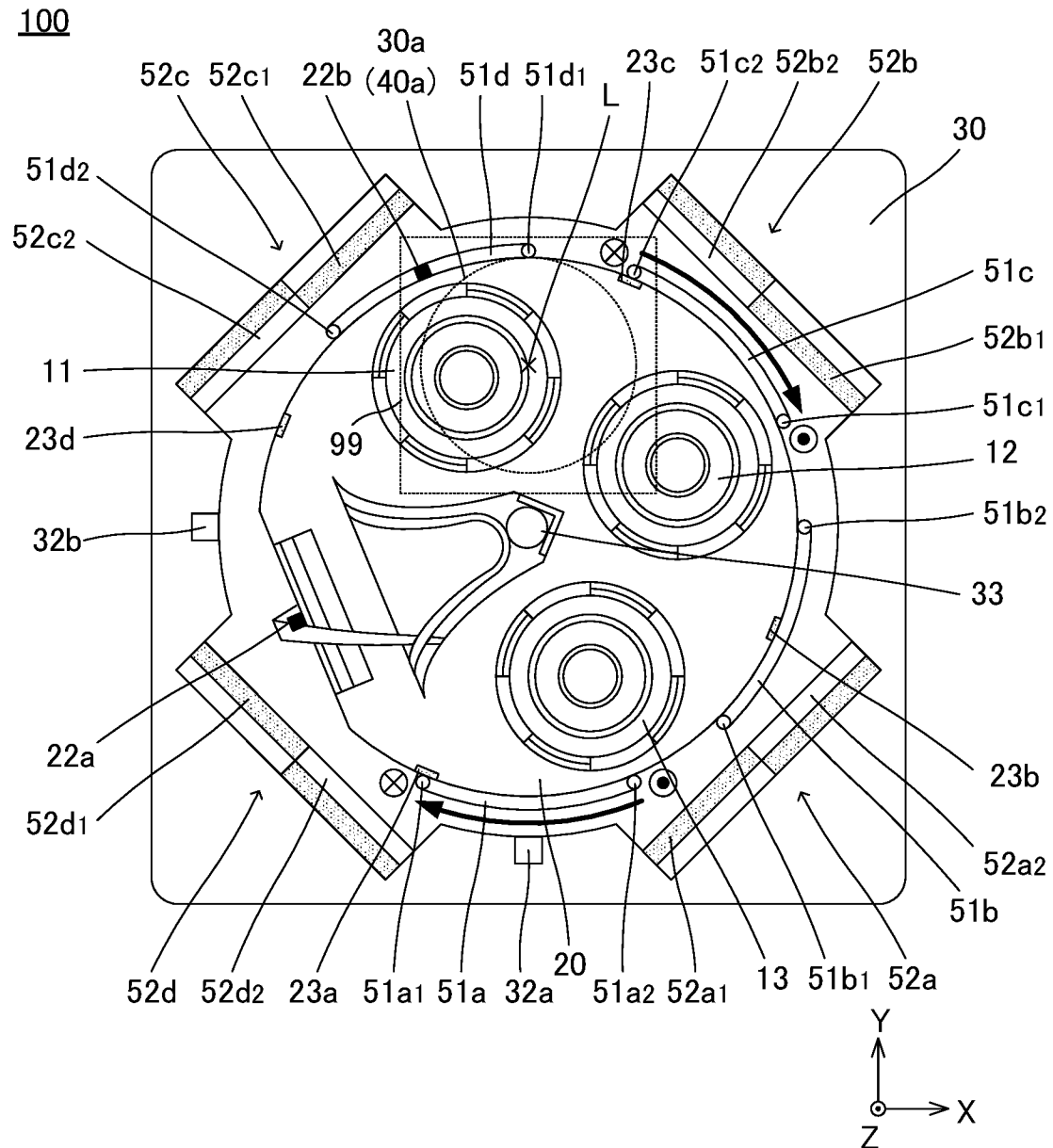


Fig. 4D

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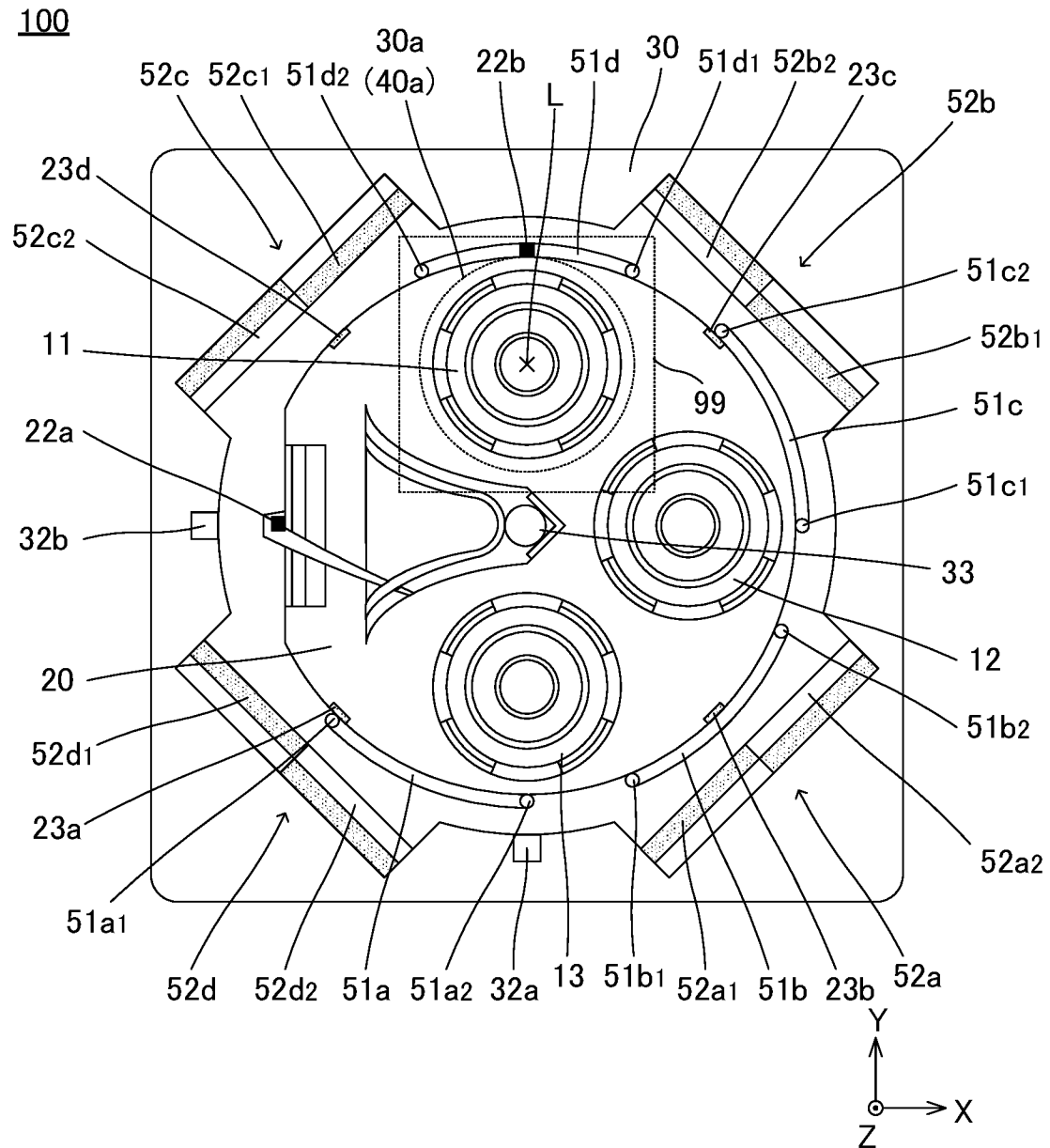


Fig. 4E

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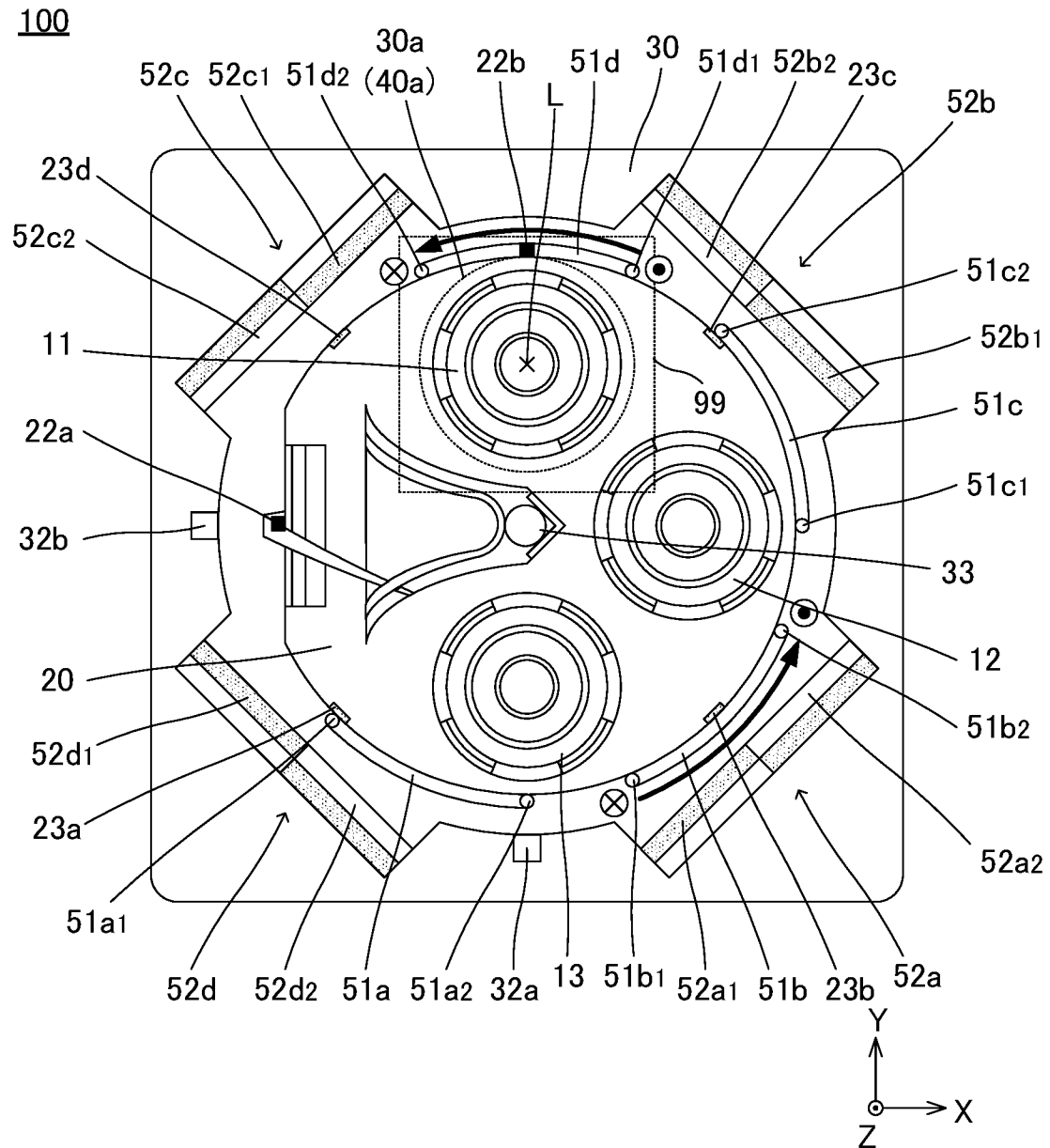


Fig. 4F

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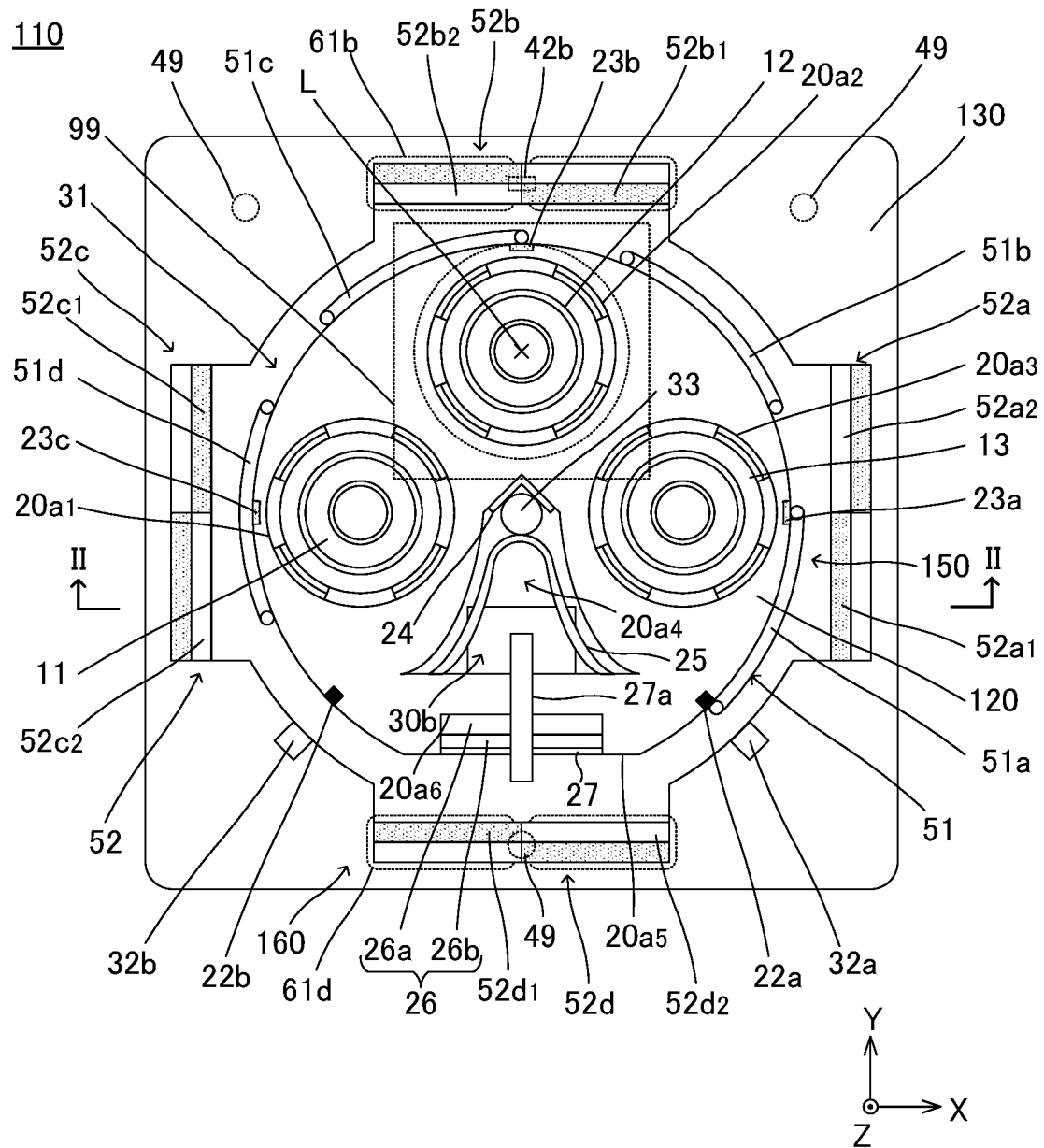


Fig. 5A

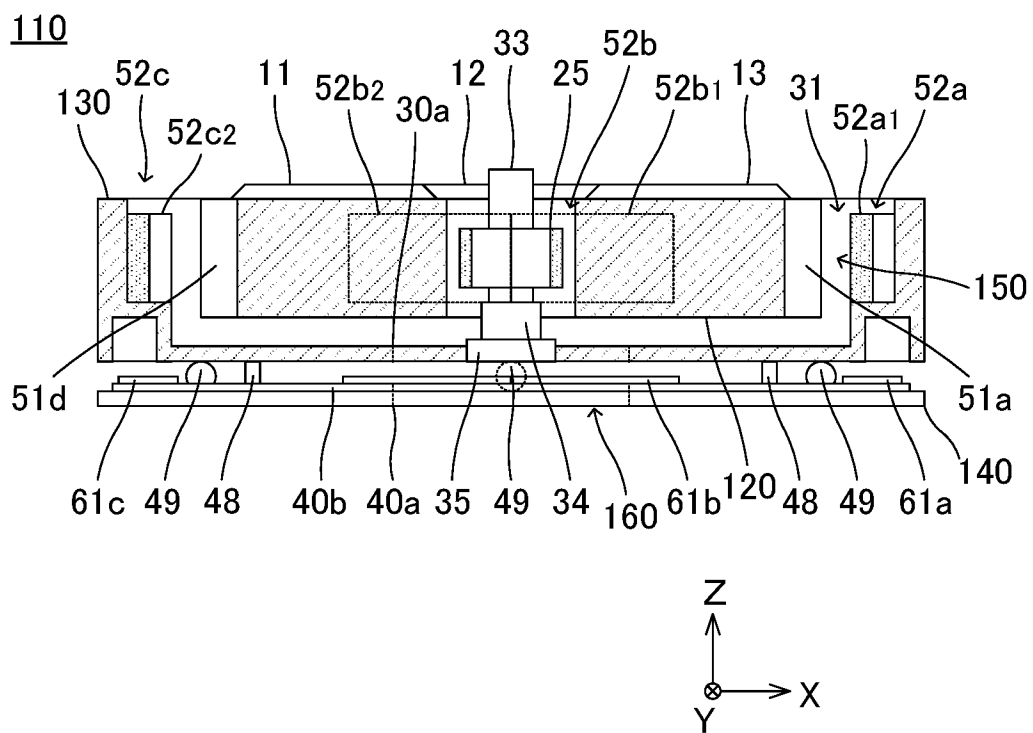


Fig. 5B

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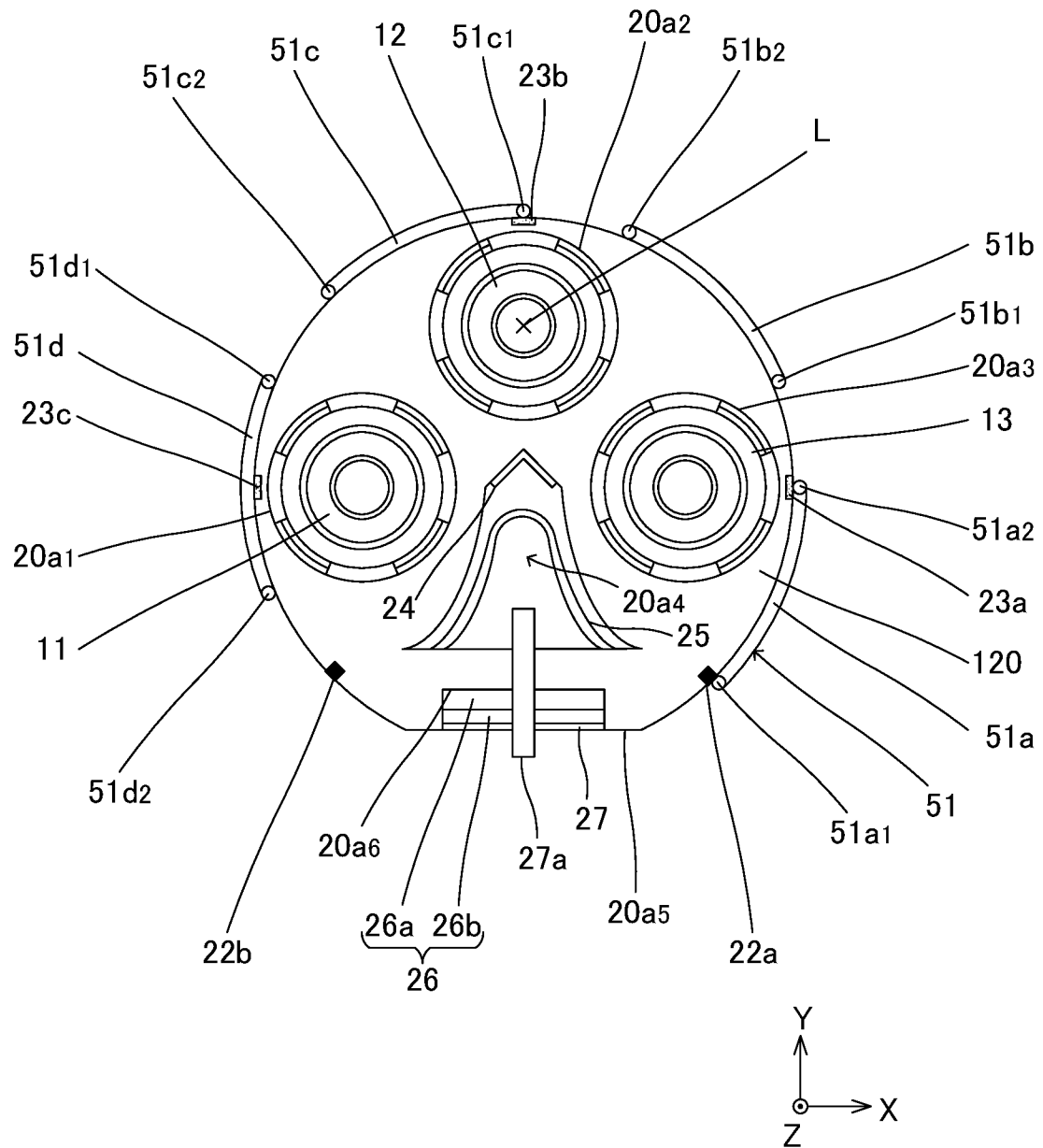


Fig. 5C

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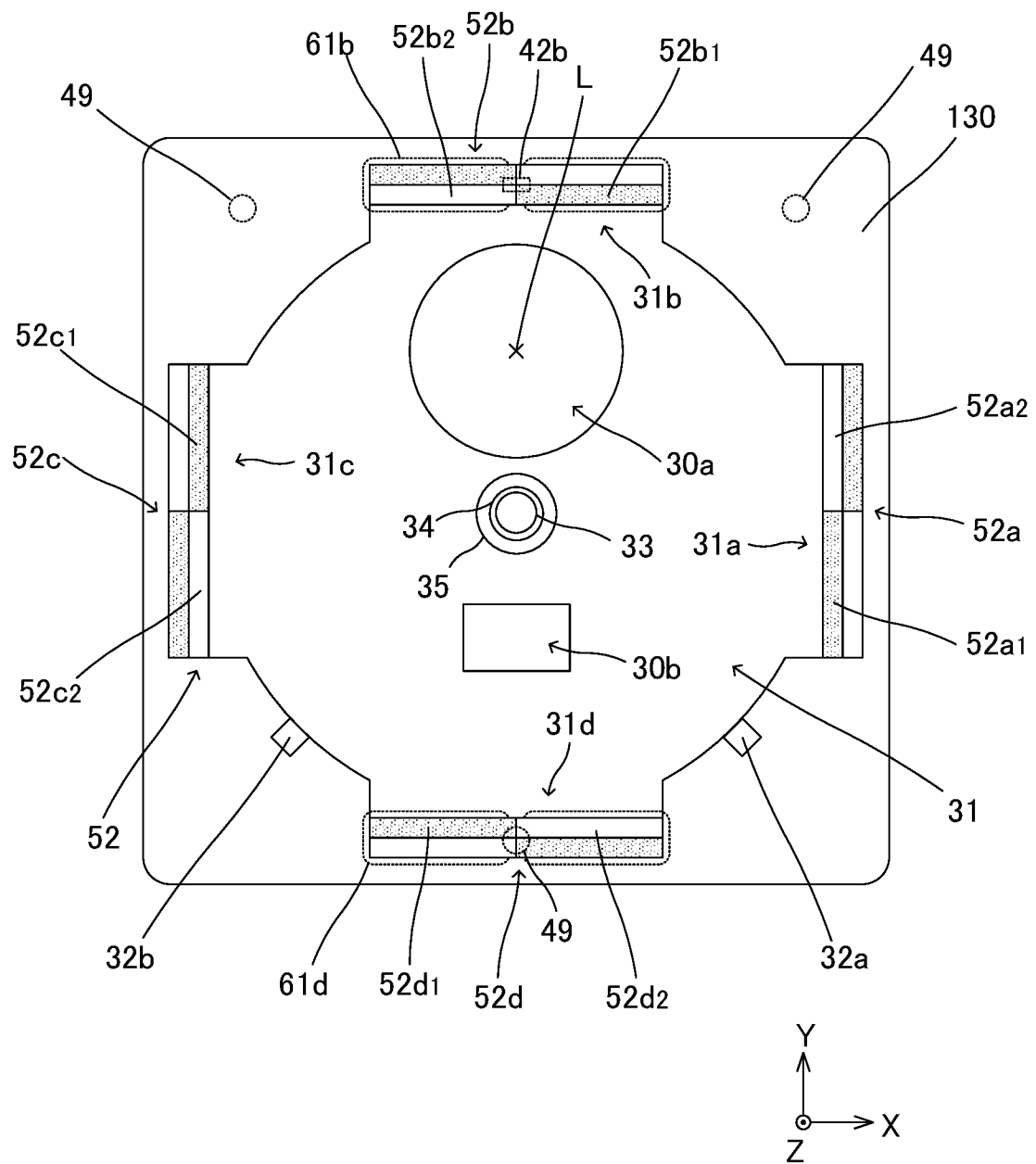


Fig. 5D

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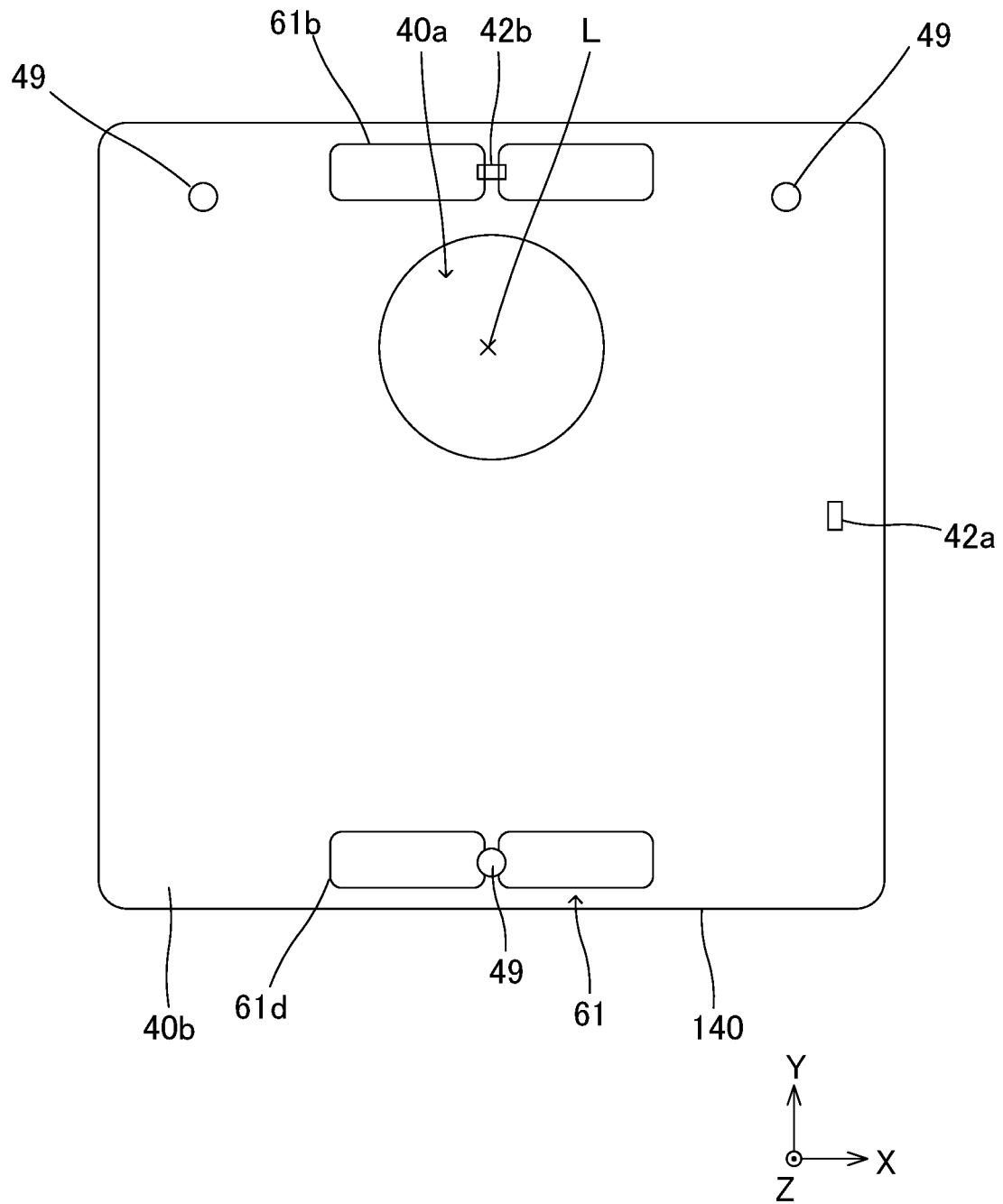
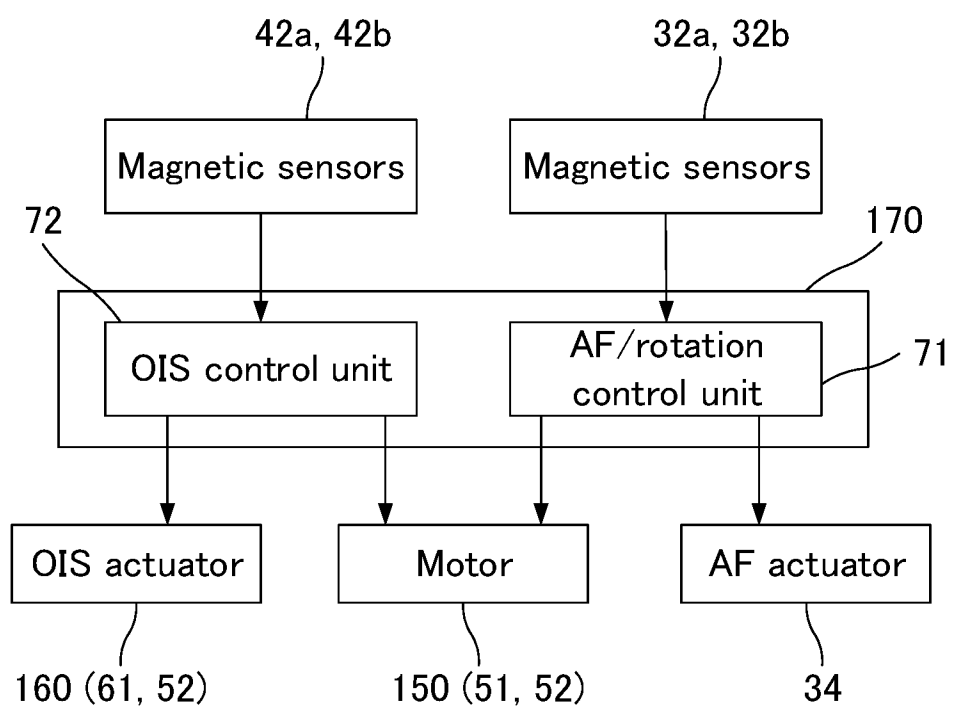
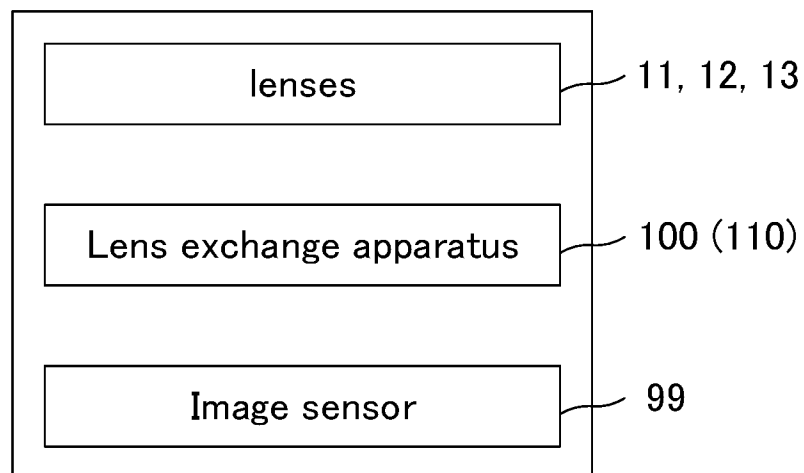


Fig. 5E

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*Fig. 6*

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200*Fig. 7*

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2018/123770

A. CLASSIFICATION OF SUBJECT MATTER

H04N 5/225(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04N

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

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

CNPAT, CNKI, WPI, EPODOC: lens, exchange, plurality, axis, image, sensor, camera, revolver, rotate, hold, base, center, stator, rotor, mover, coil, magnet, motor, switch, change

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CN 106820519 A (HUIZHOU TCL MOBILE COMMUNICATION CO., LTD.) 13 June 2017 (2017-06-13) description, paragraphs [0029]-[0039] and figures 1-4	1-2, 15-17
Y	US 2014077649 A1 (ROBERT BOSCH GMBH) 20 March 2014 (2014-03-20) description, paragraphs [0018]-[0022] and figure 1	1-2, 15-17
A	CN 207053634 U (TRULY OPTO-ELECTRONICS LTD.) 27 February 2018 (2018-02-27) the whole document	1-17
A	CN 107800942 A (TRULY OPTO-ELECTRONICS LTD.) 13 March 2018 (2018-03-13) the whole document	1-17
A	US 2005169618 A1 (AKADA, HIROSHI) 04 August 2005 (2005-08-04) the whole document	1-17

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

* Special categories of cited documents:

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“E” earlier application or patent but published on or after the international filing date

“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

“O” document referring to an oral disclosure, use, exhibition or other means

“P” document published prior to the international filing date but later than the priority date claimed

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&” document member of the same patent family

Date of the actual completion of the international search

09 September 2019

Date of mailing of the international search report

26 September 2019

Name and mailing address of the ISA/CN

National Intellectual Property Administration, PRC
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Telephone No. 86-(10)-53961700

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2018/123770

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	106820519	A	13 June 2017	None			
US	2014077649	A1	20 March 2014	WO	2012150114	A2	08 November 2012
				CN	103620927	A	05 March 2014
				CN	103620927	B	20 June 2017
				DE	102011075195	A1	08 November 2012
				WO	2012150114	A3	22 August 2013
CN	207053634	U	27 February 2018	None			
CN	107800942	A	13 March 2018	None			
US	2005169618	A1	04 August 2005	US	7149419	B2	12 December 2006
				JP	2005215564	A	11 August 2005
				JP	4566570	B2	20 October 2010