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(54) **OPTICAL ELEMENT DRIVING DEVICE, CAMERA DEVICE, AND ELECTRONIC APPARATUS**

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H02K 11/215	(2016.01)
H02K 41/035	(2006.01)
H04M 1/02	(2006.01)
G03B 30/00	(2021.01)

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CPC ***G02B 7/02*** (2013.01); ***G01D 5/145*** (2013.01); ***G02B 3/12*** (2013.01); ***H02K 11/215*** (2016.01); ***H02K 41/0354*** (2013.01); ***H04M 1/0264*** (2013.01); *G03B 30/00* (2021.01)

(58) **Field of Classification Search**

CPC ... G02B 7/02; G02B 3/12; G02B 7/08; G02B 26/004; G02B 3/14; G02B 6/3538; G02B 26/005; G01D 5/145; H02K 11/215; H02K 41/0354; H04M 1/0264; G03B 30/00; G03B 3/10; G03B 5/00

See application file for complete search history.

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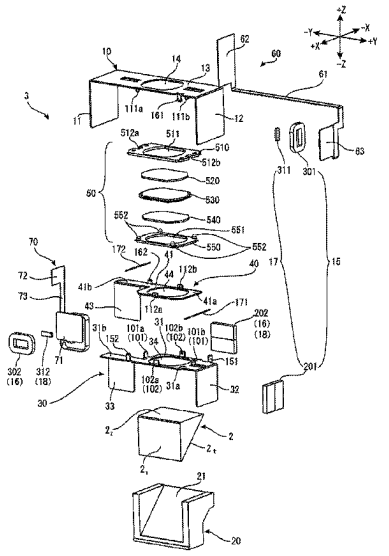
(57) **ABSTRACT**

An optical element driving device includes: a fixed portion; an optical element in which liquid is encapsulated between a first end surface and a second end surface opposite to each other and the first end surface is fixed to the fixed portion; a first movable portion supported by the fixed portion and rotatable around an axis of a first rotation shaft; and a second movable portion supported by the first movable portion, rotatable around an axis of a second rotation shaft orthogonal to the first rotation shaft, and fixing the second end surface.

12 Claims, 4 Drawing Sheets



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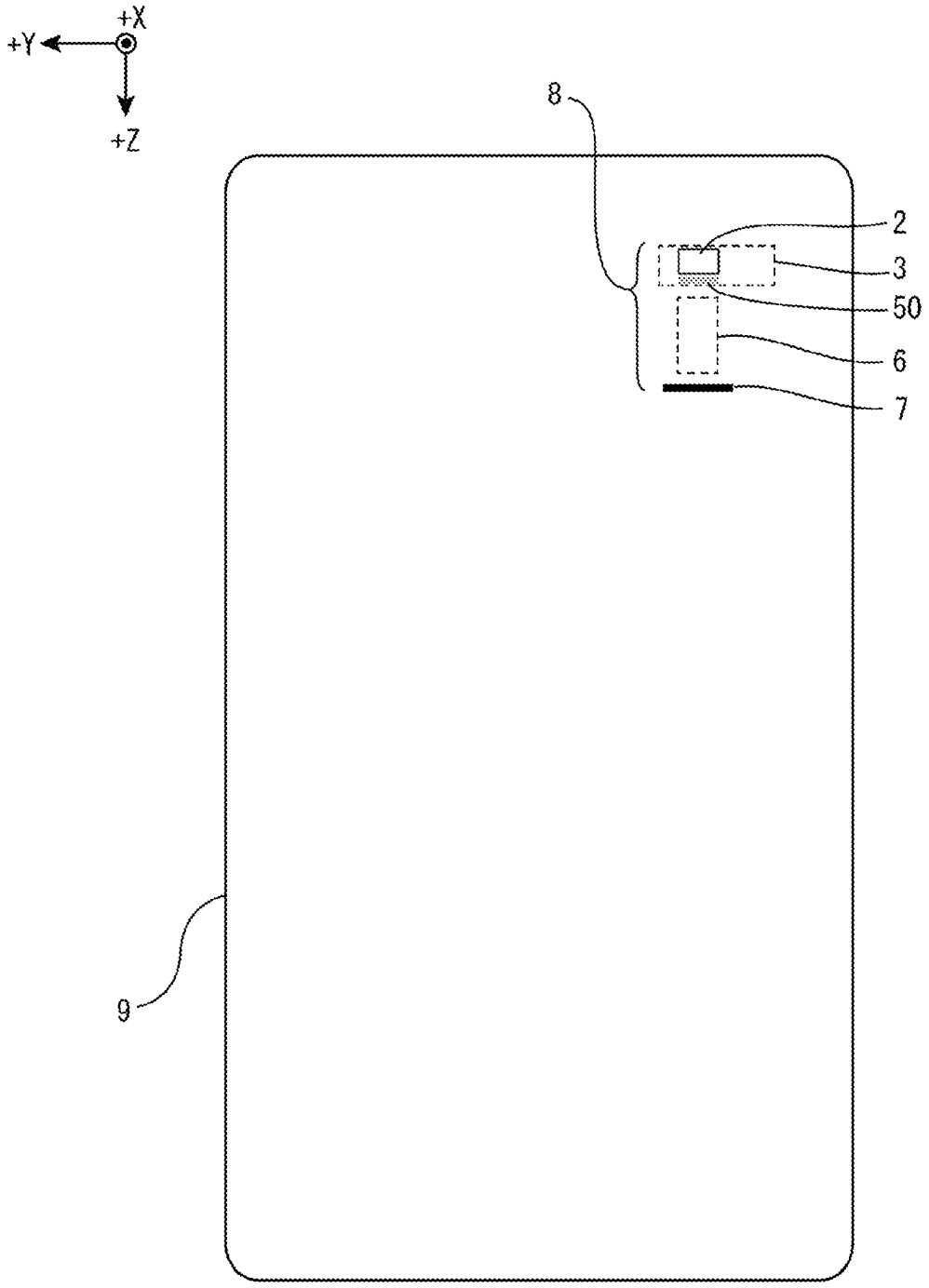

FIG. 1

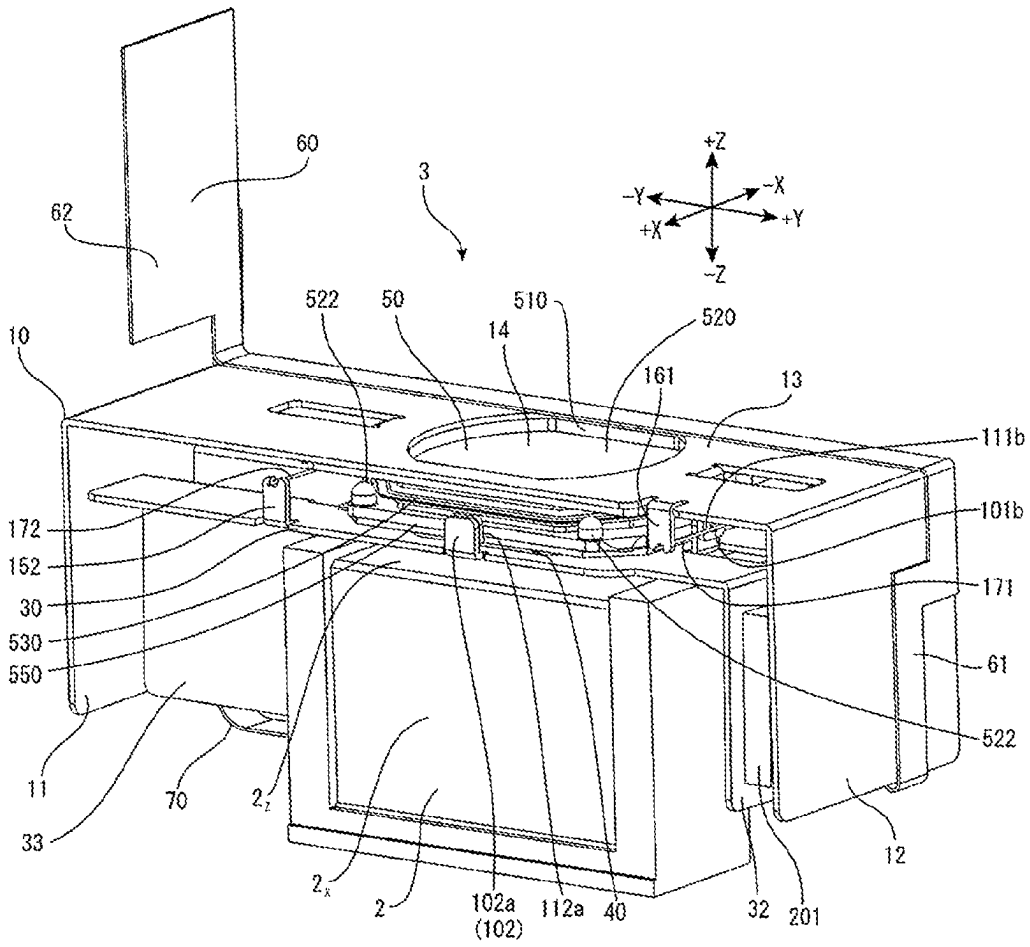
60
62
3
+Z
-Y
-X
+X
+Y
-Z
522
50
510
14
520
161
13
10
111b
172
101b
152
30
171
530
61
550
522
11
70
2_z
33
2_x
2
102a
(102)
112a
40
32
201
12

FIG. 2

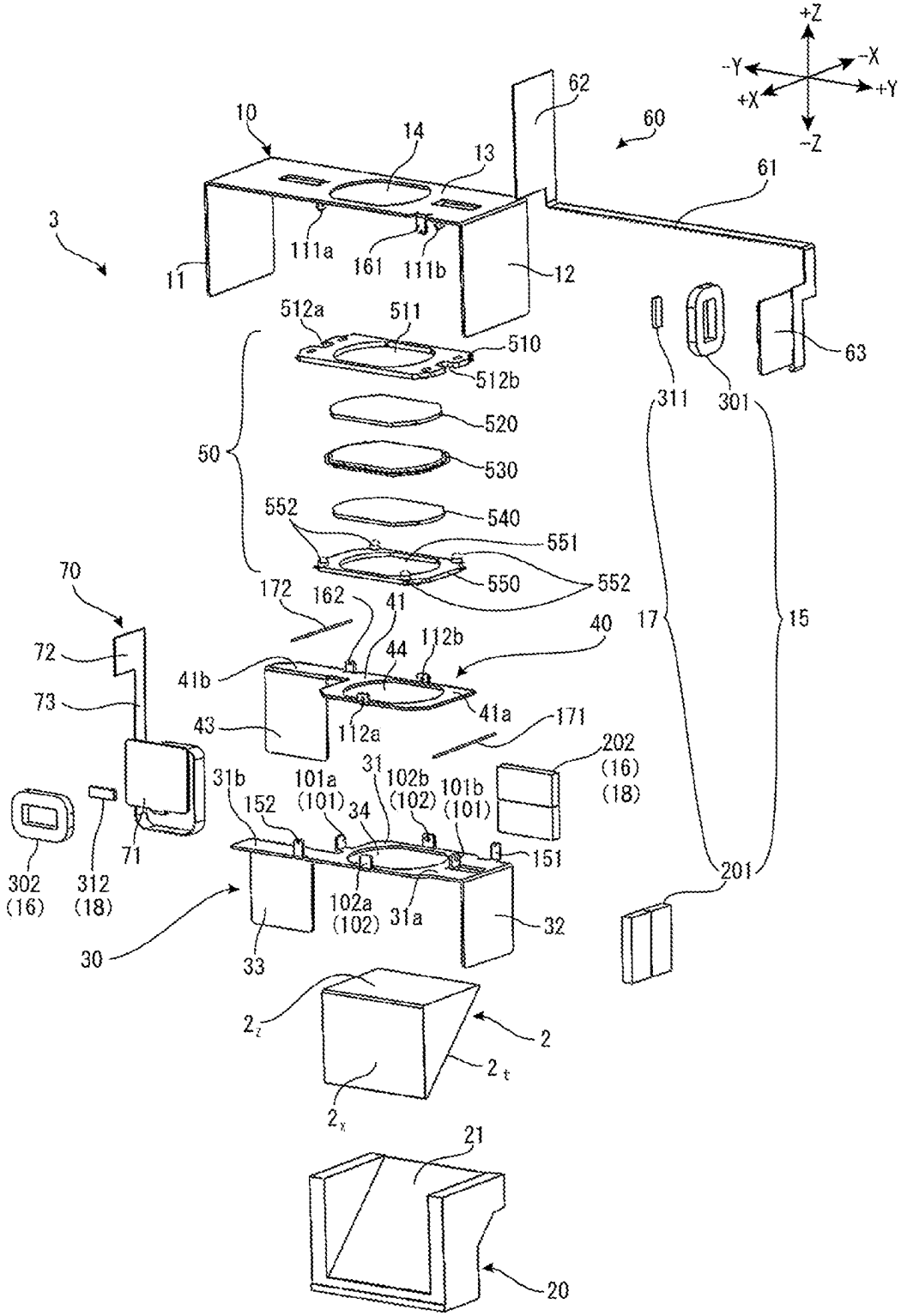
+Z
-Y
-X
+X
+Y
-Z
3
10
14
13
62
60
61
11
111a
161
111b
12
63
512a
511
510
512b
311
301
520
50
530
552
540
551
550
552
70
172
162
41
40
17
15
72
41b
44
112b
73
43
112a
41a
171
202
(16)
(18)
31
31b
101a
(101)
102b
(102)
101b
(101)
152
34
151
302
(16)
312
(18)
71
201
102a
(102)
31a
32
30
33
2z
2
2t
2x
21
20

FIG. 3

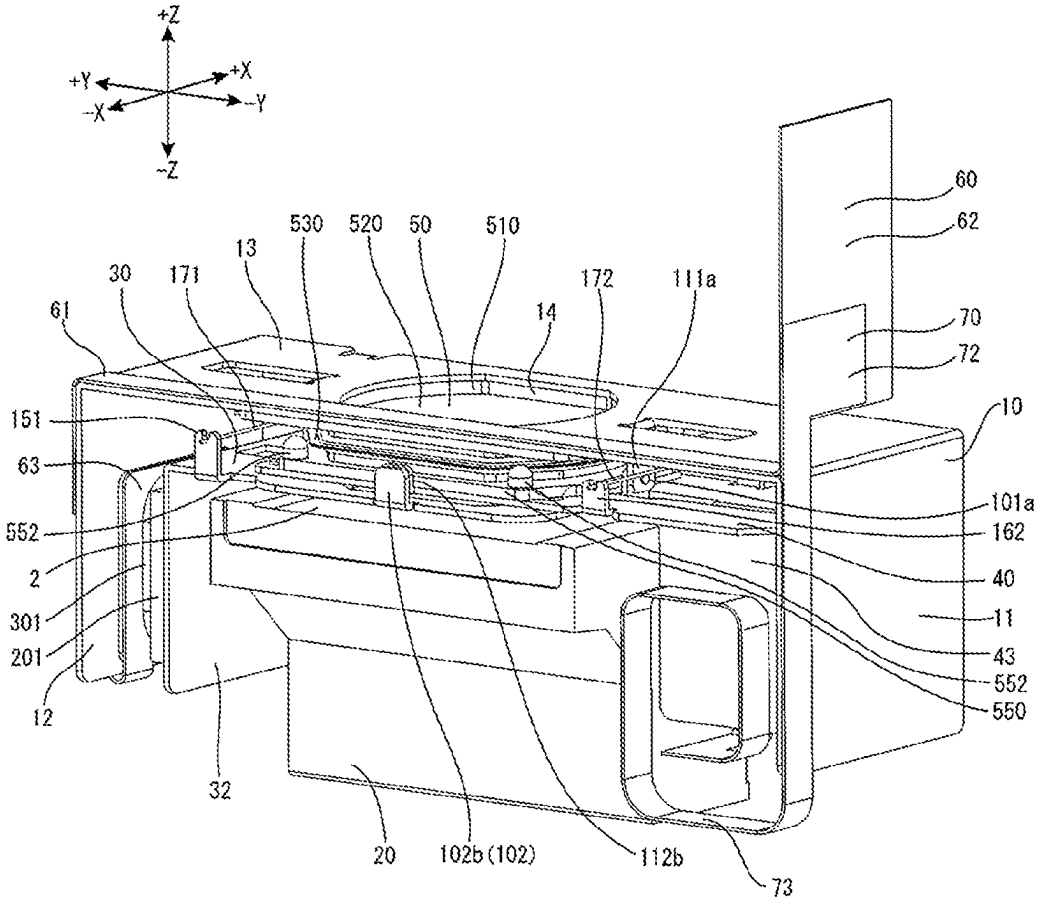
+Z
+Y
+X
-X
-Y
-Z
530
520
50
510
13
30
171
172
111a
14
61
60
62
70
72
10
151
63
552
2
301
201
12
32
20
102b(102)
112b
73
101a
162
40
11
43
552
550

FIG.4

OPTICAL ELEMENT DRIVING DEVICE, CAMERA DEVICE, AND ELECTRONIC APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of Chinese Patent Application No. 202111354743.5 filed Nov. 16, 2021, which is hereby incorporated by reference herein in its entirety.

TECHNICAL FIELD

The present disclosure relates to an optical element driving device, a camera device and an electronic apparatus used in electronic apparatus such as smartphones.

BACKGROUND

Some camera devices used in electronic apparatus such as smartphones use a liquid lens unit or the like as an optical element to control the direction of travel of light from a subject. For example, in the imaging system disclosed in Japanese Patent Application Laid-Open No. 2021-505951 (Patent Document 1), an optical element filled with liquid in a container having a transparent bottom portion and a transparent window opposite to the transparent bottom portion is used. In this imaging system, the optical element is deformed by tilting the transparent window around the first axis and tilting the transparent window around the second axis orthogonal to the first axis to control the traveling direction of light passing through the optical element.

SUMMARY

However, in the technique of Patent Document 1, the transparent window is tilted around the first axis by applying different forces from each other to both ends of the transparent window in the second axis direction of the transparent window, and the transparent window is tilted around the second axis by applying different forces from each other to both ends in the first axis direction of the transparent window. Hereby, the position of the first axis is shifted due to the balance of the forces applied to both ends of the transparent window in the second axis direction of the transparent window and the position of the second axis is shifted due to the balance of the forces applied to both ends of the transparent window in the first axis direction of the transparent window, and as a consequence, there was a problem that the accuracy of controlling the traveling direction of the passing light is deteriorated. In addition, the imaging system disclosed in Patent Document 1 require a complex control system for controlling the forces applied to both ends of the transparent window in the second axis direction of the transparent window and forces applied to both ends of the transparent window in the first axis direction, and as a consequence, there was a problem that it lacks reliability.

The present disclosure has been made in view of such problems, and the present disclosure aims to provide an optical element driving device, a camera device and an electronic apparatus. The optical element driving device, a camera device and an electronic apparatus can control with high accuracy in the traveling direction of the passing light of the optical element without performing complex control.

To achieve the above-described object, in accordance with a first aspect of the present disclosure, there is provided

an optical element driving device including: a fixed portion; an optical element in which liquid is encapsulated between a first end surface and a second end surface opposite to each other and the first end surface is fixed to the fixed portion; a first movable portion supported by the fixed portion and rotatable around an axis of a first rotation shaft; and a second movable portion supported by the first movable portion, rotatable around an axis of a second rotation shaft orthogonal to the first rotation shaft, and fixing the second end surface.

In accordance with a second aspect of the present disclosure, there is provided a camera device including the optical element driving device described above.

In accordance with a third aspect of the present disclosure, there is provided an electronic apparatus including the camera device described above.

Further features of the present invention will become apparent from the following description of exemplary embodiments (with reference to the attached drawings).

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a front view of a smartphone **9** which is an electronic apparatus on which a camera device **8** including an optical element driving device **3** of one embodiment of the present disclosure is mounted.

FIG. **2** is a perspective view of the optical element driving device **3** shown in FIG. **1**;

FIG. **3** is an exploded perspective view of the optical element driving device **3** shown in FIG. **2**; and

FIG. **4** is a perspective view of the optical element driving device **3** shown in FIG. **2** as viewed from another angle.

DETAILED DESCRIPTION OF THE DRAWINGS

Hereinafter, embodiments of the present disclosure are explained with reference to drawings.

As shown in FIG. **1**, in the present embodiment, a camera device **8** is mounted on, for example, an electronic apparatus such as a smartphone **9**. The camera device **8** includes: a prism **2** that bends incident light from a subject at a right angle; an optical element driving device **3** that supports a liquid lens unit **50** passing the passing light of the prism **2** and drives to change the inclination of the incident surface of the light; a lens body **6** that passes the passing light of the liquid lens unit **50**; and an image sensor **7** that photoelectrically converts the passing light of the lens body **6**.

In the following, as shown in FIG. **2** to FIG. **4**, a rectangular coordinate system consisting of an X axis, a Y axis and a Z axis orthogonal to each other is assumed, and the configuration of the present embodiment is explained. The Z axis is an axis passing through an optical axis of a lens body **6**. Light from the subject is incident on the prism **2** from the X axis direction, is bent at a right angle by the prism **2**, advances in the Z axis direction and passes through the liquid lens unit **50** and lens body **6**. Hereinafter, in the Z axis direction, a side where the prism **2** is located when viewed from the lens body **6** is referred to as a −Z side, and a side where the image sensor **7** on the opposite side is located is referred to as a +Z side. In addition, in the X axis direction, a side of the subject when viewed from the prism **2** is referred to as a +X side, and its opposite side is referred to as a −X side.

As shown in FIG. **2** to FIG. **4**, the optical element driving device **3** has an approximate configuration as follows. The optical element driving device **3** includes a fixed portion comprising a case **10**, a liquid lens unit **50** as an optical

element, a first movable portion **30**, and a second movable portion **40**. In the liquid lens unit **50**, liquid is encapsulated between a first end surface (a first glass **520**) and a second end surface (a second glass **540**) opposite to each other, and the first end surface is fixed to the fixed portion. The first movable portion **30** is supported by the fixed portion so as to be rotatable around the axis of the first rotation shaft **101**. The second movable portion **40** is supported by the first movable portion **30** so as to be rotatable around the axis of the second rotation shaft **102**, and further fixes the second end surface of the liquid lens unit **50**.

Further, as shown in FIG. **3**, the optical element driving device **3** has a first driving portion **15** and a second driving portion **16**, a first detecting portion **17** and a second detecting portion **18**, and a first wire spring **171** and a second wire spring **172**. The first wire spring **171** returns the first movable portion **30** to its point of origin and the second wire spring **172** returns the second movable portion **40** to its point of origin.

Before explaining the configuration of the optical element driving device **3**, the prism **2** and a mount portion **20** are explained. The mount portion **20** is a member that supports the prism **2**. As shown in FIG. **3**, the prism **2** has a cross-sectional shape of a right-angled isosceles triangle surrounded by an incidence surface **2***x* and an emission surface **2***z* orthogonal to each other and a reflection surface **2***t* connecting the incidence surface **2***x* and the emission surface **2***z*. The mount portion **20** has a placing portion **21** with an inclined portion and two side wall portions, and supports the reflection surface **2***t* of the prism **2** by the placing portion **21**. The mount portion **20** supporting the prism **2** is accommodated in the case **10** of the optical element driving device **3** and is fixed to the main body portion of the camera device **8**. Light from the subject is incident from the +X side on the incidence surface **2***x* of the prism **2** supported by the mount portion **20**. This light is bent at a right angle by the reflection surface **2***t* of the prism **2** and is emitted from the emission surface **2***z* to the +Z side. The emitted light from the prism **2** passes through a liquid lens unit **50** and a through hole **14** of the case **10** to be described later and is directed to the lens body **6** and image sensor **7** shown in FIG. **1**.

Next, the configuration of the optical element driving device **3** is explained in detail. In the optical element driving device **3**, the case **10**, which is a fixed portion, is formed by bending a plate-like member, and has a main body portion **13** and two approximately rectangular side plate portions **11** and **12** extending in the −Z axis direction from both ends in the Y axis direction of the main body portion **13**. The through hole **14** is provided in the center of the main body portion **13**. Both sides in the Y axis direction adjacent to the through hole **14** are notched and bent to the −Z axis side to form upright portions, and the respective upright portions are provided with through holes as bearings **111***a*, **111***b*. The bearings **111***a* and **111***b* are aligned across the through hole **14** in the Y axis direction. Further, at an edge on the +X side of the main body portion **13**, a portion of the +Y side portion thereof is bent to the −Z axis direction to form an upright portion, and the upright portion is provided with a wire support portion **161**. The optical element driving device **3** is fixed to the main body portion of the camera device **8** by the side plate portions **11** and **12** of the case **10**. In the present embodiment, a portion which is substantially fixed to the main body portion of the camera device **8** and does not move is treated as a fixed portion.

As shown in FIG. **3**, the first movable portion **30**, the second movable portion **40** and the liquid lens unit **50** are arranged between the mount portion **20** and the main body portion **13** of the case **10**.

The first movable portion **30** is formed by bending a plate-like member and has a flat plate portion **31**. This flat plate portion **31** has a main body portion **31***a* provided with a through hole **34** that passes emitted light from the emission surface **2***z* of the prism **2**, and an extension portion **31***b* extending from the +X side portion of an edge on the −Y side of the main body portion **31***a* to the −Y axis direction. A side plate portion **32** extends in the −Z axis direction from an edge on the +Y side of the main body portion **31***a*. A first magnet **201** is fixed to the surface on the +Y side of the side plate portion **32**. The first magnet **201** is magnetized in the Y axis direction and the magnetization directions of the +X side portion and the −X side portion are opposite. Further, a side plate portion **33** extends in the −Z axis direction from an edge on the −X side of the extension portion **31***b*. A second magnet **202** is fixed to the surface on the −X side of the side plate portion **33**. The second magnet **202** is magnetized in the X axis direction and the magnetization directions of the +Z side portion and the −Z side portion are opposite.

The main body portion **31***a* of the first movable portion **30** has an upright portion protruding in the +Z axis direction and formed with first rotation shafts **101***a* and **101***b* constituting the first rotating shaft **101**. The upright portion formed with the first rotation shaft **101***a* is formed by bending a portion of an edge of the main body portion **31***a* on the −Y side to the +Z side. The first rotation shaft **101***a* is formed as a cylinder protruding from the surface on the −Y side of the upright portion. The upright portion formed with the first rotation shaft **101***b* is formed by notching and bending the main body portion **31***a* to the +Z side. The first rotation shaft **101***b* is formed as a cylinder protruding from the surface on the +Y side of the upright portion. The first rotation shafts **101***a* and **101***b* and the bearings **111***a* and **111***b* in the main body portion **13** of the case **10** are aligned across the through hole **34** in the Y axis direction. The first rotation shafts **101***a* and **101***b* are inserted into the bearings **111***a* and **111***b* of the case **10** and rotatably supported. Therefore, the first movable portion **30** is rotatable around the axes of the first rotation shafts **101***a* and **101***b* parallel to the Y axis direction with respect to the case **10** which is the fixed portion. The axis of rotation formed by the first rotation shaft **101***a* and the first rotation shaft **101***b* is the axis of the first rotation shaft **101**.

In the main body portion **31***a* of the first movable portion **30**, an upright portion provided with a wire support portion **151** is formed by bending in the vicinity of the +Y side end portion of the edge on the −X side. Further, in the extension portion **31***b* of the first movable portion **30**, an upright portion provided with a wire support portion **152** is formed by bending at the edge on the −X side. The first wire spring **171** is supported at one end by the wire support portion **151** of the first movable portion **30**, and is supported at the other end by the wire support portion **161** of the case **10**. The first wire spring **171** generates drag force against the rotation driving force around the axis of the first rotation shaft **101** generated in the first movable portion **30**.

The second movable portion **40** is formed by bending a plate-like member and has a flat plate portion **41**. The flat plate portion **41** has a main body portion **41***a* provided with a through hole **44** that passes emitted light from the emission surface **2***z* of the prism **2**, and an extension portion **41***b* extending from an edge on the −Y side of the main body

portion **41***a*. A side plate portion **43** extends in the −Z axis direction from an edge on the +X side of the extension portion **41***b*.

Upright portions formed with through holes as bearings **112***a* and **112***b* are bent and protrude in the +Z axis direction from edges on the ±X sides of the main body portion **41***a* of the second movable portion **40**. The bearings **112***a* and **112***b* are aligned across the through hole **44** in the X axis direction. Further, the second rotation shafts **102***a* and **102***b* constituting the second rotating shaft **102** of the first movable portion **30** are also aligned across the through hole **34** in the X axis direction. The second movable portion **40** is arranged on the +Z side of the first movable portion **30** with the side plate portion **43** adjacent to the −X side portion of the side plate portion **33**. The second rotation shafts **102***a* and **102***b* of the first movable portion **30** are inserted into the bearings **112***a* and **112***b* of the second movable portion **40** and rotatably supported. Therefore, the second movable portion **40** is rotatable around the axes of the second rotation shafts **102***a* and **102***b* of the first movable portion **30** parallel to the X axis direction with respect to the first movable portion **30**. The axis of rotation formed by the second rotation shaft **102***a* and **102***b* is the axis of the second rotation shaft **102**.

Further, in the extension portion **41***b* of the second movable portion **40**, an upright portion provided with a wire support portion **162** is formed by bending at the edge on the −X side. The second wire spring **172** is supported at one end by the wire support portion **152** of the first movable portion **30**, and is supported at the other end by the wire support portion **162** of the second movable portion **40**. The second wire spring **172** generates drag force against the rotation driving force around the axis of the second rotation shaft **102** generated in the second movable portion **40**.

Thus, in the present embodiment, the fixed portion comprising the case **10**, the first movable portion **30**, and the second movable portion **40** supported by the first movable portion **30** constitute a gimbal mechanism rotating the first movable portion **30** around the axis of the first rotation shaft (**101**) parallel to the Y axis direction and rotating the second movable portion **40** around the axis of the second rotation shaft (**102**) parallel to the X axis direction.

The liquid lens unit **50** is an optical element formed by arranging a first plate **510**, a first glass **520**, a liquid lens **530**, a second glass **540** and a second plate **550** in the −Z axis direction. The first plate **510** and the second plate **550** are provided with through holes **511** and **551** that pass the emitted light from the emission surface **2***z* of the prism **2**, respectively. Further, notch portions **512***a* and **512***b* are provided at the edges on both sides in the Y axis direction of the first plate **510** to pass through the upright portions provided with the bearings **111***a* and **111***b* of the case **10**. The upright portions provided with the bearings **111***a* and **111***b* reach the positions of the upright portions provided with the first rotation shafts **101***a* and **101***b* of the first movable portion **30** via the notch portions **512***a* and **512***b*.

The liquid lens **530** is formed by filling a transparent flexible container with liquid. The first plate **510** is fixed to the surface on the −Z side of the main body portion **13** of the case **10**. The second plate **550** is fixed to the surface on the +Z side of the main body portion **41***a* of the second movable portion **40**. The first glass **520** is fixed to the first plate **510** and the liquid lens **530** and maintains the flatness the surface of the liquid lens **530** on the +Z side. The second glass **540** is fixed to the second plate **550** and the liquid lens **530** and maintains the flatness of the surface of the liquid lens **530** on the −Z side. Further, stoppers **552** protruding to the +Z side are provided at four corners of the second plate **550**. Therefore, when the second movable portion **40** is inclined around the axis of the first rotation shaft **101** and/or around the axis of the second rotation shaft **102**, the second plate **550** is also inclined according to the inclination of the second movable portion **40**, and according to the inclination of the second plate **550**, the surface on the −Z side of the liquid lens **530** is inclined while remaining flat. In the liquid lens unit **50** according to the present embodiment, the first glass **520** serves as a first end surface supported by the fixed portion and the second glass **540** serves as a second end surface supported by the second movable portion **40**. Thereby, the emitted light of the prism **2** advances in a direction inclined to the optical axis of the lens body **6**, so that the position of incidence on the image sensor **7** is changed. Conversely, when the direction of the light incident on the camera device **8** is changed due to hand shake or the like, the position of incidence on the image sensor **7** can be maintained constant.

It is desirable that the centers of the through holes **14**, **34**, **44**, **511**, and **551** coincide when viewed from the Z axis direction, and the center of the through hole **511** is the center of the first end surface, i.e. the center of the first glass **520**, and the first end surface is orthogonal to the Z axis. In addition, when viewed form the Z axis direction, it is desirable that the first rotation shaft **101** and the second rotation shaft **102** pass through the center of the through hole **511**. In addition, when viewed from a direction orthogonal to the Z axis, it is desirable that the first rotation shaft **101** and the second rotation shaft **102** overlap with the second end surface, i.e. the center of the second glass **540**, that is, are at the same height. In addition, when viewed form the Z axis direction, when the first wire spring **171** is support on the axis line of the first rotation shaft **101** of the first movable portion **30**, there is no change in height, so that the wire support portion **151** is provided at a place that is not on the axis line of the first rotation shaft **101**. Similarly, when viewed from the Z axis direction, when the second wire spring **172** is supported on the axis line of the second rotation shaft **102** of the second movable portion **40**, there is no changed in height, so that the wire support portion **162** is provided at a place that is not on the axis line of the second rotation shaft **102**.

As shown in FIG. **3**, the FPC (Flexible Printed Circuit board) **60** has a strip-like portion **61** extending in the Y axis direction and a side surface portion **62** bent and projecting in the +Z axis direction from the −Y side end portion of the strip-like portion **61**. A +Y side end portion of the strip-like portion **61** is bent and projects in the −Z axis direction, and is further folded back to the −Y axis direction, and a side surface portion **63** is provided at the end portion. A first coil **301** long in the Z axis direction is disposed on the surface on the −Y side of the side surface portion **63**. An electric current flows in the first coil **301** via the strip-like portion **61**. Further, a Hall element **311**, which is the first magnetic sensor, is disposed inside the winding of the first coil **301** on the surface of the −Y side of the side surface portion **63**. In the FPC **60**, the side surface portion **63** is fixed on the −Y side (inside) portion of the side plate portion **12** of the case **10**, and the strip-like portion **61** is fixed along the edge on the −X side of the outside of the side plate portion **12** and main body portion **13**. The first coil **301** and the Hall element **311** disposed at the side surface portion **63** of the FPC **60** are opposed to the first magnet **201** disposed at the side plate portion **32** of the first movable portion **30**. The first magnet **201** and the first coil **301** constitute the first driving portion **15** rotationally driving the first movable portion **30** around

the axis of the first rotation shaft **101** with respect to the case **10** which is the fixed portion. Further, the first magnet **201** and the Hall element **311** which is the first magnetic sensor constitute the first detecting portion **17** detecting the rotation displacement of the first movable portion **30** around the axis of the first rotation shaft **101**. The side surface portion **62** is electrically connected to the main body of the camera device **8**.

As shown in FIG. **3**, the FPC (Flexible Printed Circuit board) **70** has a side surface portion **71** orthogonal to the X axis direction, a side surface portion **72** fixed to the side surface portion **62** of the FPC **60**, and a strip-like portion **73** connecting the side surface portion **71** and the side surface portion **72**. A second coil **302** long in the Y axis direction is disposed on the surface on the +X side of the side surface portion **71**. An electric current flows in the second coil **302** via the strip-like portion **73**. Further, a Hall element **312**, which is the second magnetic sensor, is disposed inside the winding of the second coil **302** on the surface on the +X side of the side surface portion **71**. In the FPC **70**, the side surface portion **71** is fixed to the surface on the +X side of the side plate portion **43** of the second movable portion **40**. The second coil **302** and Hall element **312** disposed at the side surface portion **71** of the FPC **70** are opposed to the second magnet **202** disposed on the surface on the −X side of the side plate portion **33** of the first movable portion **30**. The second magnet **202** and the second coil **302** constitute the second driving portion **16** rotationally driving the second movable portion **40** around the axis of the second rotation shaft **102** with respect to the first movable portion **30**.

Further, the second magnet **202** and the Hall element **312** which is the second magnetic sensor constitute the second detecting portion **18** detecting the rotation displacement of the second movable portion **40** around the axis of the second rotation shaft **102**.

As shown in FIG. **4**, the strip-like portion **73** first extends from the side surface portion **72** in the −Z axis direction, thereafter is curved to change the orientation to the +Y axis direction, and end portion of the strip-like portion **73** enters inside the case **10** from the outside. Then, a portion of the strip-like portion **73** which enters inside the case **10** and opposes to the −X axis side portion of the side plate portion **43** extends in the +Y axis direction, thereafter, bends and extends in the +Z axis direction, then an end portion in the direction of travel bends and extends in the −Y axis direction, bends and extends in the −Z axis direction, then bends and extends in the +Y axis direction.

Finally, an end portion in the direction of travel is changed in orientation to the +X axis direction, reaches the +X axis side portion of the side plate portion **43**, and is connected to the side surface portion **71**. Thus, the strip-like portion **73** is provided in a swirl shape, and thereby, the second movable portion **40** can rotate without being affected by the tension of the FPC **70**.

In the present embodiment, when inclining the second glass **540** which is the second end surface of the liquid lens unit **50** which is the optical element around the axis of the first rotation shaft **101** and/or around the axis of the second rotation shaft **102**, a predetermined electric current is applied to the first coil **301** and/or the second coil **302**. The predetermined electric current is an electric current having a polarity corresponding to a desired inclination direction around the axis of the first rotation shaft **101** and a magnitude corresponding to a desired inclination angle, and/or an electric current having a polarity corresponding to a desired inclination direction around the axis of the second rotation shaft **102** and a magnitude corresponding a desired inclination angle. The electric current is supplied to the first coil **301** via the FPC **60** and is supplied to the second coil **302** via the FPC **70**. As a result, the first movable portion **30** is driven by the electromagnetic force in the X axis direction acting between the first magnet **201** and the first coil **301**, and rotates around the axis of the first rotation shaft **101**. Further, the second movable portion **40** is driven by the electromagnetic force in the Z axis direction acting between the second magnet **202** and the second coil **302**, and rotates around the axis of the second rotation shaft **102**. Thereby, the second movable portion **40** is inclined with respect to the case **10** which is the fixed portion, and the second glass **540** which is the second end surface of the liquid lens unit **50** is inclined according to the inclination of the second movable portion **40**. The Hall element **311** detects the rotation displacement of the first movable portion **30** around the axis of the first rotation shaft **101** based on the magnetic field received from the first magnet **201**, and the Hall element **312** detects the rotation displacement of the second movable portion **40** around the axis of the second rotation shaft **102** based on the magnetic field received from the second magnet **202**. The electric current flowing in the first coil **301** and/or the second coil **302** is adjusted based on the detected value of the rotation displacement.

The above are the details of the configuration of the embodiment of the present disclosure. The optical element driving device **3** according to the present embodiment includes: a case **10** which is a fixed portion; a liquid lens unit **50** which is an optical element in which liquid is encapsulated between a first end surface and a second end surface opposite to each other and the first end surface is fixed to the case **10**; a first movable portion **30** supported by the case **10** and rotatable around an axis of the first rotation shaft **101**; and a second movable portion **40** supported by the first movable portion **30**, rotatable around an axis of a second rotation shaft **102** orthogonal to the first rotation shaft **101**, and fixing the second end surface. Therefore, since the positions of the first rotation shaft **101** and the second rotation shaft **102** do not shift, even if complicated control is no performed, the accuracy of controlling the inclination around the axis of the first rotation shaft **101** and the inclination around the axis of the second rotation shaft **102** for the second end surface of the liquid lens unit **50** can be improved. That is, the accuracy of controlling the traveling direction of transmitted light of the liquid lens unit **50** is high.

It is to be noted that, the first driving portion **15** only needs to be arranged so that the driving force acts in the tangential direction of the circle centered on the first rotation shaft **101**. Further, the second driving portion **16** only needs to be arranged so that the driving force acts in the tangential direction of the circle centered on the second rotation shaft **102**.

While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

What is claimed is:

1. An optical element driving device, comprising:

a fixed portion having a main body portion provided with a pair of bearings aligned across a through hole;

an optical element in which liquid is encapsulated between a first end surface and a second end surface opposite to each other and the first end surface is fixed to the fixed portion;

a first movable portion having a main body portion provided with a through hole corresponding to the through hole of the fixed portion and a pair of first rotation shafts aligned across the through hole, and a pair of second rotation shafts arranged to orthogonal to the pair of first rotation shafts, wherein the first movable portion is rotatable supported by the pair of bearings of the fixed portion and rotatable around an axis of the first rotation shaft; and

a second movable portion having a main body portion provided with a through hole corresponding to the through hole of the first movable portion and a pair of bearings supporting rotatable the pair of second rotation shafts of the first movable portion, and fixing the second end surface of the optical element by the main body portion;

a first driving portion having a first magnet fixed to a first side plate portion connected to the main body portion of the first movable portion and a first coil arranged at a first FPC (Flexible Printed Circuit board) fixed to the fixed portion, the first coil arranged opposite the first magnet, the first driving portion rotationally driving the first movable portion around the axis of the first rotation shaft; and

a second driving portion having a second magnet fixed to a second side plate portion connected to the main body portion of the first movable portion, the second side plate portion arranged to orthogonal to the first side plate portion and a second coil arranged at one end of a second FPC (Flexible Printed Circuit board) having the one end fixed to the second movable portion and the other end fixed to the first FPC, the second coil arranged opposite the second magnet, the second FPC provided with a strip-like portion in a swirl shape, the second driving portion rotationally driving the second movable portion around the axis of the second rotation shaft.

2. The optical element driving device according to claim **1**, comprising:

a first detecting portion fixed to the fixed portion and detecting rotation displacement of the first movable portion around the axis of the first rotation shaft by detecting a magnetic field generated by the first magnet; and

a second detecting portion fixed to the second movable portion and detecting rotation displacement of the second movable portion around the axis of the second rotation shaft by detecting a magnetic field generated by the second magnet.

3. The optical element driving device according to claim **2**, wherein

when the second end surface of the optical element is inclined around the axis of the first rotation shaft and/or around the axis of the second rotation shaft, an adjusted electric current based on the rotation displacement detected from the first detecting portion and the second detecting portion is applied to the first coil and/or the second coil through the first FPC and the second FPC.

4. The optical element driving device according to claim **1**, comprising:

a first wire spring connected between the fixed portion and the first movable portion; and

a second wire spring connected between the first movable portion and the second movable portion, and

wherein a wire support portion of the first wire spring is provided at a place away from an axis line of the first rotation shaft of the first movable portion and a wire support portion of the second wire spring is provided at a place away from an axis line of the second rotation shaft of the second movable portion,

wherein the first wire spring generates drag against the rotation driving force around the axis of the first rotation shaft of the first movable portion to return the first movable portion to its point of origin and the second wire spring generates drag against the rotation driving force around the axis of the second rotation shaft of the second movable portion to return the second movable portion to its point of origin.

5. The optical element driving device according to claim **1**, wherein the first rotation shaft and the second rotation shaft pass through a center of the first end surface and are orthogonal to an axis perpendicular to the first end surface.

6. The optical element driving device according to claim **1**, wherein the first rotation shaft and the second rotation shaft are at the same height as the second end surface.

7. A camera device comprising the optical element driving device according to claim **1**.

8. An electronic apparatus comprising the camera device according to claim **7**.

9. The optical element driving device according to claim **1**, wherein

a center position of the through hole of the main body portion of the fixed portion, a center position of the through hole of the first movable portion and a center position of the through hole of the second movable portion coincide with each other.

10. The optical element driving device according to claim **1**, wherein

the optical element is a liquid lens unit formed by arranging a first plate, a first glass, a liquid lens, a second glass and a second plate in the optical axis direction of the liquid lens.

11. The optical element driving device according to claim **1**, wherein

the fixed portion, the first movable portion, and the second movable portion supported by the first movable portion constitute a gimbal mechanism rotating the first movable portion around the axis of the first rotation shaft and rotating the second movable portion around the axis of the second rotation shaft.

12. The optical element driving device according to claim **1**, wherein

the second FPC provided with a strip-like portion in a swirl shape connects a side surface portion fixed to a side surface portion of the first FPC to a side surface portion which the second coil is arranged.

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